

COMPOSITIONS, METHODS AND SYSTEMS FOR PROTEIN CORONA ANALYSIS AND USES THEREOF

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] The present application claims priority to and benefit from U.S. Provisional Application Nos. 62/756,960 filed November 7, 2018; 62/824,278 filed March 26, 2019; and 62/874,862 filed July 16, 2019, the entire contents of each of which are herein incorporated by reference.

BACKGROUND

[0002] Broad scale implementation of proteomic information in science and medicine has lagged behind genomics in large part because of complexities inherent in protein molecules themselves, necessitating complex workflows that limit the scalability of such analyses. Disclosed herein are compositions and methods for rapid processing of proteomic data and identification of key biomarkers associated with disease.

SUMMARY

[0003] The present invention provides a panel of nanoparticles for the detection of a wide range of diseases and disorders and determination of disease states in a subject.

[0004] Creating and characterizing protein coronas has also been performed in the field; however, most of the experimentation has been done on non-magnetic particles, such as liposomes and polymeric nanoparticles, or other particle types that may be used for targeted drug delivery.

[0005] The problem with the current (typically academic) assays for protein corona formation and characterization is that they are not amenable to high-throughput and/or automated formats, as the particles used in the assay need to be isolated for corona collection. The advantage of SPMNPs used for protein coronas is their quick magnetic response that can be easily separated from the suspension mixture by applying an external magnetic field. This type of magnetic particle is a good platform for further chemical modification with different functional groups which can help fine tune the interaction between particles and plasma proteins.

[0006] In some aspects, the present disclosure provides a method of identifying proteins in a sample, the method comprising: incubating a particle panel with the sample to form a plurality of distinct biomolecule coronas corresponding to distinct particle types of the particle panel;

magnetically isolating the particle panel from unbound protein in the sample to enrich proteins in the plurality of distinct biomolecule coronas; and assaying the plurality of distinct biomolecule coronas to identify the enriched proteins.

[0007] In some aspects, the assaying is capable of identifying from 1 to 20,000 protein groups. In further aspects, the assaying is capable of identifying from 1000 to 10,000 protein groups. In further aspects, the assaying is capable of identifying from 1,000 to 5,000 protein groups. In still further aspects, the assaying is capable of identifying from 1,200 to 2,200 protein groups. In some aspects, the protein group comprises a peptide sequence having a minimum length of 7 amino acid residues. In some further, the assaying is capable of identifying from 1,000 to 10,000 proteins. In some still further, the assaying is capable of identifying from 1,800 to 5,000 proteins.

[0008] In some embodiments, the sample comprises a plurality of samples. In some embodiments, the plurality of samples comprises at least two or more spatially isolated samples. In further embodiments, the incubating comprises contacting the at least two or more spatially isolated samples with the particle panel at the same time. In further embodiments, the magnetically isolating comprises magnetically isolating the particle panel from unbound protein in the at least two or more spatially isolated samples of the plurality of samples at the same time. In further embodiments, the assaying comprises assaying the plurality of distinct biomolecule coronas to identify proteins in the at least two or more spatially isolated samples at the same time.

[0009] In some embodiments, the method further comprises repeating the methods described herein, wherein, when repeated, the incubating, isolating, and assaying yields a percent quantile normalized coefficient (QNCV) of variation of 20% or less, as determined by comparing a peptide mass spectrometry feature from at least three full-assay replicates for each particle type in the particle panel. In some embodiments, when repeated, the incubating, isolating, and assaying yields a percent quantile normalized coefficient (QNCV) of variation of 10% or less, as determined by comparing a peptide mass spectrometry feature from at least three full-assay replicates for each particle type in the particle panel. In some embodiments, the assaying is capable of identifying proteins over a dynamic range of at least 7, at least 8, at least 9, or at least 10.

[0010] In some embodiments, the method further comprises washing the particle panel at least one time or at least two times after magnetically isolating the particle panel from the unbound protein. In some embodiments, after the assaying the method further comprises lysing the proteins in the plurality of distinct biomolecule coronas.

[0011] In some embodiments, the method further comprises digesting the proteins in the plurality of distinct biomolecule coronas to generate digested peptides.

[0012] In some embodiments, the method further comprises purifying the digested peptides.

[0013] In some embodiments, the assaying comprises using mass spectrometry to identify proteins in the sample. In some embodiments, the assaying is performed in about 2 to about 4 hours. In some embodiments, the method is performed in about 1 to about 20 hours. In some embodiments, the method is performed in about 2 to about 10 hours. In some embodiments, the method is performed in about 4 to about 6 hours. In some embodiments, the isolating takes no more than about 30 minutes, no more than about 15 minutes, no more than about 10 minutes, no more than about 5 minutes, or no more than about 2 minutes. In some embodiments, the plurality of samples comprises at least 10 spatially isolated samples, at least 50 spatially isolated samples, at least 100 spatially isolated samples, at least 150 spatially isolated samples, at least 200 spatially isolated samples, at least 250 spatially isolated samples, or at least 300 spatially isolated samples. In further embodiments, the plurality of samples comprises at least 96 samples.

[0014] In some embodiments, the particle panel comprises at least 2 distinct particle types, at least 3 distinct particle types, at least 4 distinct particle types, at least 5 distinct particle types, at least 6 distinct particle types, at least 7 distinct particle types, at least 8 distinct particle types, at least 9 distinct particle types, at least 10 distinct particle types, at least 11 distinct particle types, at least 12 distinct particle types, at least 13 distinct particle types, at least 14 distinct particle types, at least 15 distinct particle types, at least 20 distinct particle types, at least 25 particle types, or at least 30 distinct particle types. In further embodiments, the particle panel comprises at least 10 distinct particle types. In further embodiments, the at least two spatially isolated samples differ by at least one physicochemical property.

[0015] In some embodiments, the particle panel comprises a first distinct particle type and a second distinct particle type, wherein the first distinct particle type and the second distinct particle type share at least one physicochemical property and differ by at least one physicochemical property, such that the first distinct particle type and the second distinct particle type are different. In some embodiments, the particle panel comprises a first distinct particle type and a second distinct particle type, wherein the first distinct particle type and the second distinct particle type share at least two physicochemical properties and differ by at least two physicochemical properties, such that the first distinct particle type and the second distinct particle type are different. In some embodiments, the particle panel comprises a first distinct particle type and a second distinct particle type, wherein the first distinct particle type and the second distinct particle type share at least one physicochemical property and differ by at least two physicochemical properties, such that the first distinct particle type and the second distinct particle type are different.

[0016] In some embodiments, the particle panel comprises a first distinct particle type and a second distinct particle type, wherein the first distinct particle type and the second distinct particle type share at least two physicochemical properties and differ by at least one physicochemical property, such that the first distinct particle type and the second distinct particle type are different. In further embodiments, the physicochemical property comprises size, charge, core material, shell material, porosity, or surface hydrophobicity. In further embodiments, size is diameter or radius, as measured by dynamic light scattering, SEM, TEM, or any combination thereof.

[0017] In some embodiments, the particle panel comprises a first distinct particle type and a second distinct particle type, wherein the first distinct particle type and the second distinct particle type comprise a carboxylate material, wherein the first distinct particle is a microparticle, and wherein the second distinct particle type is a nanoparticle. In some embodiments, the particle panel comprises a first distinct particle type and a second distinct particle type, wherein the first distinct particle type and the second distinct particle type comprise a surface charge of from 0 mV and -50 mV, wherein the first distinct particle type has a diameter of less than 200 nm, and wherein the second distinct particle type has a diameter of greater than 200 nm.

[0018] In some embodiments, the particle panel comprises a first distinct particle type and a second distinct particle type, wherein the first distinct particle type and the second distinct particle type comprise a diameter of 100 to 400 nm, wherein the first distinct particle type has a positive surface charge, and wherein the second distinct particle type has a neutral surface charge. In some embodiments, the particle panel comprises a first distinct particle type and a second distinct particle type, wherein the first distinct particle type and the second distinct particle type are nanoparticles, wherein the first distinct particle type has a surface charge less than -20 mV and the second distinct particle type has a surface charge greater than -20 mV.

[0019] In some embodiments, the particle panel comprises a first distinct particle type and a second distinct particle type, wherein the first distinct particle type and the second distinct particle type are microparticles, wherein the first distinct particle type has a negative surface charge, and wherein the second distinct particle type has a positive surface charge. In some embodiments, the particle panel comprises a subset of negatively charged nanoparticles, wherein each particle of the subset differ by at least one surface chemical group. In some embodiments, the particle panel comprises a first distinct particle type, a second particle, and a third distinct particle type, wherein the first distinct particle type, the second distinct particle type, and the third distinct particle type comprise iron oxide cores, polymer shells, and are less than about 500 nm in diameter and wherein the first distinct particle type comprises a negative charge, the

second distinct particle type comprises a positive charge, and the third distinct particle type comprises a neutral charge, wherein the diameter is a mean diameter as measured by dynamic light scattering. In further embodiments, the first distinct particle type comprises a silica coating, the second distinct particle type comprises a poly(N-(3-(dimethylamino)propyl) methacrylamide) (PDMAEMA), and the third distinct particle type comprises a poly(oligo(ethylene glycol) methyl ether methacrylate) (POEGMA) coating.

[0020] In some embodiments, at least one distinct particle type of the particle panel is a nanoparticle. In some embodiments, at least one distinct particle type of the particle panel is a microparticle. In some embodiments, at least one distinct particle type of the particle panel is a superparamagnetic iron oxide particle. In some embodiments, each particle of the particle panel comprises an iron oxide material. In some embodiments, at least one distinct particle type of the particle panel has an iron oxide core. In some embodiments, at least one distinct particle type of the particle panel has iron oxide crystals embedded in a polystyrene core. In some embodiments, each distinct particle type of the particle panel is a superparamagnetic iron oxide particle. In some embodiments, each distinct particle type of the particle panel comprises an iron oxide core. In some embodiments, each one distinct particle type of the particle panel has iron oxide crystals embedded in a polystyrene core. In some embodiments, at least one distinct particle type of particle panel comprises a carboxylated polymer, an aminated polymer, a zwitterionic polymer, or any combination thereof. In some embodiments, at least one particle type of the particle panel comprises an iron oxide core with a silica shell coating. In some embodiments, at least one particle type of the particle panel comprises an iron oxide core with a poly(N-(3-(dimethylamino)propyl) methacrylamide) (PDMAEMA) coating. In some embodiments, at least one particle type of the particle panel comprises an iron oxide core with a poly(oligo(ethylene glycol) methyl ether methacrylate) (POEGMA) coating.

[0021] In some embodiments, at least one distinct particle type of the particle panel comprises a negative surface charge. In some embodiments, at least one distinct particle type of the particle panel comprises a positive surface charge. In some embodiments, at least one distinct particle type of the particle panel comprises a neutral surface charge. In some embodiments, the particle panel comprises one or more distinct particle types selected from TABLE 10. In some embodiments, the particle panel comprises two or more distinct particle types, three or more distinct particle types, four or more distinct particle types, five or more distinct particle types, six or more distinct particle types, seven or more distinct particle types, eight or more distinct particle types, nine or more distinct particle types, or all ten distinct particle types selected from TABLE 10. In some embodiments, the particle panel comprises one or more distinct particle

types selected from TABLE 12. In some embodiments, the particle panel comprises two or more distinct particle types, three or more distinct particle types, four or more distinct particle types, five or more distinct particle types, six or more distinct particle types, seven or more distinct particle types, eight or more distinct particle types, nine or more distinct particle types, or all ten distinct particle types selected from TABLE 12.

[0022] In various aspects, the present disclosure provides a composition comprising three or more distinct magnetic particle types that differ by two or more physicochemical properties, wherein a subset of the three or more distinct magnetic particle types share a physicochemical property of the two or more physicochemical properties and wherein such particle types of the subset bind different proteins.

[0023] In some embodiments, the three or more distinct magnetic particle types adsorb proteins from a biological sample over a dynamic range of at least 7, at least 8, at least 9, or at least 10. In some embodiments, the three or more distinct magnetic particle types are capable of adsorbing from 1 to 20,000 proteins groups from a biological sample. In some aspects, the three or more distinct magnetic particle types are capable of adsorbing from 1,000 to 10,000 protein groups from a biological sample. In further aspects, the three or more distinct magnetic particle types are capable of adsorbing from 1,000 to 5,000 protein groups from a biological sample. In further aspects, the three or more distinct magnetic particle types are capable of adsorbing from 1,200 to 2,200 protein groups from a biological sample. In still further aspects, wherein the protein group comprises a peptide sequence having a minimum length of 7 amino acid residues. In some aspects, the three or more distinct magnetic particle types are capable of adsorbing from 1 to 20,000 proteins from a biological sample. In further aspects, the three or more distinct magnetic particle types are capable of adsorbing from 1,000 to 10,000 proteins from a biological sample. In still further aspects, the three or more distinct magnetic particle types are capable of adsorbing from 1,800 to 5,000 proteins from a biological sample.

[0024] In some embodiments, the composition comprises at least 4 distinct magnetic particle types, at least 5 distinct magnetic particle types, at least 6 distinct magnetic particle types, at least 7 distinct magnetic particle types, at least 8 distinct magnetic particle types, at least 9 distinct magnetic particle types, at least 10 distinct magnetic particle types, at least 11 distinct magnetic particle types, at least 12 distinct magnetic particle types, at least 13 distinct magnetic particle types, at least 14 distinct magnetic particle types, at least 15 distinct magnetic particle types, at least 20 distinct magnetic particle types, or at least 30 distinct magnetic particle types. In some embodiments, the composition comprises at least 10 distinct magnetic particle types. In some embodiments, the composition comprises a first distinct particle type and a second distinct

particle type, wherein the first distinct particle type and the second distinct particle type share at least two physicochemical properties and differ by at least two physicochemical properties, such that the first distinct particle type and the second distinct particle type are different.

[0025] In some embodiments, the composition comprises a first distinct particle type and a second distinct particle type, wherein the first distinct particle type and the second distinct particle type share at least two physicochemical properties and differ by at least one physicochemical property, such that the first distinct particle type and the second distinct particle type are different. In some embodiments, the physicochemical property comprises size, charge, core material, shell material, porosity, or surface hydrophobicity. In further embodiments, the size is diameter or radius, as measured by dynamic light scattering, SEM, TEM, or any combination thereof.

[0026] In some embodiments, the composition comprises a first distinct particle type and a second distinct particle type, wherein the first distinct particle type and the second distinct particle type comprise a carboxylate material, wherein the first distinct particle is a microparticle, and wherein the second distinct particle type is a nanoparticle. In some embodiments, the particle panel comprises a first distinct particle type and a second distinct particle type, wherein the first distinct particle type and the second distinct particle type comprise a surface charge of from 0 mV and -50 mV, wherein the first distinct particle type has a diameter of less than 200 nm, and wherein the second distinct particle type has a diameter of greater than 200 nm. In some embodiments, the particle panel comprises a first distinct particle type and a second distinct particle type, wherein the first distinct particle type and the second distinct particle type comprise a diameter of 100 to 400 nm, wherein the first distinct particle type has a positive surface charge, and wherein the second distinct particle type has a neutral surface charge.

[0027] In some embodiments, the particle panel comprises a first distinct particle type and a second distinct particle type, wherein the first distinct particle type and the second distinct particle type are nanoparticles, wherein the first distinct particle type has a surface charge less than -20 mV and the second distinct particle type has a surface charge greater than -20 mV. In some embodiments, the particle panel comprises a first distinct particle type and a second distinct particle type, wherein the first distinct particle type and the second distinct particle type are microparticles, wherein the first distinct particle type has a negative surface charge, and wherein the second distinct particle type has a positive surface charge. In some embodiments, the composition comprises a subset of negatively charged nanoparticles, wherein each particle type of the subset differ by at least one surface chemical group. In some embodiments, the composition comprises a first distinct particle type, a second distinct particle type, and a third

distinct particle type, wherein the first distinct particle type, the second distinct particle type, and the third distinct particle type comprise iron oxide cores, polymer shells, and are less than about 500 nm in diameter and wherein the first distinct particle type comprises a negative charge, the second distinct particle type comprises a positive charge, and the third distinct particle type comprises a neutral charge, wherein the diameter is a mean diameter as measured by dynamic light scattering. In further embodiments, the first distinct particle type comprises a silica coating, the second distinct particle type comprises a poly(N-(3-(dimethylamino)propyl) methacrylamide) (PDMAEMA), and the third distinct particle type comprises a poly(oligo(ethylene glycol) methyl ether methacrylate) (POEGMA) coating.

[0028] In some embodiments, the three or more distinct magnetic particle types comprise a nanoparticle. In some embodiments, the three or more distinct magnetic particle types comprises a microparticle. In some embodiments, at least one distinct particle type of the three or more distinct magnetic particle types is a superparamagnetic iron oxide particle. In some embodiments, at least one distinct particle type of the three or more distinct magnetic particle types comprise an iron oxide material. In some embodiments, at least one distinct particle type of the three or more distinct magnetic particle types has an iron oxide core. In some embodiments, at least one distinct particle type of the three or more distinct magnetic particle types has iron oxide crystals embedded in a polystyrene core.

[0029] In some embodiments, each distinct particle type of the three or more distinct magnetic particle types is a superparamagnetic iron oxide particle. In some embodiments, each distinct particle type of the three or more distinct magnetic particle types comprise an iron oxide core. In some embodiments, each one distinct particle type of the three or more distinct magnetic particle types has iron oxide crystals embedded in a polystyrene core. In some embodiments, at least one particle type of the three or more distinct magnetic particle types comprises a polymer coating.

[0030] In some embodiments, the three or more distinct magnetic particle types comprise a carboxylated polymer, an aminated polymer, a zwitterionic polymer, or any combination thereof. In some embodiments, at least one particle type of the three or more distinct magnetic particle types comprises an iron oxide core with a silica shell coating. In some embodiments, at least one particle type of the three or more distinct magnetic particle types comprises an iron oxide core with a poly(N-(3-(dimethylamino)propyl) methacrylamide) (PDMAEMA) coating. In some embodiments, at least one particle type of the three or more distinct magnetic particle types comprises an iron oxide core with a poly(oligo(ethylene glycol) methyl ether methacrylate) (POEGMA) coating.

[0031] In some embodiments, at least one particle type of the three or more distinct magnetic particle types comprises a negative surface charge. In some embodiments, at least one particle type of the three or more distinct magnetic particle types comprises a positive surface charge. In some embodiments, at least one particle type of the three or more distinct magnetic particle types comprises a neutral surface charge.

[0032] In some embodiments, the three or more distinct magnetic particle types comprise one or more particle types of TABLE 10. In some embodiments, the particle panel comprises two or more distinct particle types, three or more distinct particle types, four or more distinct particle types, five or more distinct particle types, six or more distinct particle types, seven or more distinct particle types, eight or more distinct particle types, nine or more distinct particle types, or all ten distinct particle types selected from TABLE 10. In some embodiments, the three or more distinct magnetic particle types comprise one or more particle types of TABLE 12. In some embodiments, the particle panel comprises two or more distinct particle types, three or more distinct particle types, four or more distinct particle types, five or more distinct particle types, six or more distinct particle types, seven or more distinct particle types, eight or more distinct particle types, nine or more distinct particle types, or all ten distinct particle types selected from TABLE 12.

[0033] In some aspects, the present disclosure provides a method of determining the biological state of a sample from a subject, comprising: exposing a biological sample to a panel comprising a plurality of nanoparticles, thereby generating a plurality of protein coronas; generating proteomic data from the plurality of protein coronas; determining a protein profile of the plurality of protein coronas; and associating the protein profile to a biological state, wherein the panel comprises at least two different nanoparticles.

[0034] In some embodiments, the panel comprises at least three different nanoparticles. In some embodiments, the method associates the protein profile to the biological state with at least 90% accuracy. In some embodiments, the plurality of nanoparticles comprises at least one iron oxide nanoparticle.

[0035] In some aspects, the present disclosure provides, a method of selecting a panel for protein corona analysis, comprising selecting a plurality of nanoparticles with at least three different physicochemical properties.

[0036] In some embodiments, the different physicochemical properties is selected from a group consisting of surface charge, surface chemistry, size, and morphology. In some embodiments, the different physicochemical properties comprise surface charge.

[0037] In various embodiments, the present disclosure provides a method of identifying proteins in a sample, the method comprising: incubating a panel comprising a plurality of particle types with the sample to form a plurality of protein corona; digesting the plurality of protein coronas to generate proteomic data; and identifying proteins in the sample by quantifying the proteomic data. In some embodiments, the sample is from a subject.

[0038] In some embodiments, the method further comprises determining a protein profile of the sample from the identifying step and associating the protein profile with a biological state of the subject. In some embodiments, the method further comprises determining a biological state of the sample from the subject by: generating proteomic data by digesting the plurality of protein coronas; determining a protein profile of the plurality of protein coronas; and associating the protein profile with the biological state, wherein the panel comprises at least two different nanoparticles. In some embodiments, the associating is performed by a trained classifier.

[0039] In some embodiments, the panel comprises at least three different particle types, at least four different particle types, at least five different particle types, at least six different particle types, at least seven different particle types, at least eight different particle types, at least nine different particle types, at least 10 different particle types, at least 11 different particle types, at least 12 different particle types, at least 13 different particle types, at least 14 different particle types, at least 15 different particles, or at least 20 different particle types. In some embodiments, the panel comprises at least four different particle types. In some embodiments, at least one particle type of the panel comprises a physical feature that is different from a second particle type of the panel. In some embodiments, the physical feature is size, polydispersity index, surface charge, or morphology. In some embodiments, the size of at least one particle type of the plurality of particle types in the panel is from 10 nm to 500 nm.

[0040] In some embodiments, the polydispersity index of at least one particle type of the plurality of particle types in the panel is from 0.01 to 0.25. In some embodiments, the morphology of at least one particle type of the plurality of particle types comprises spherical, colloidal, square shaped, rods, wires, cones, pyramids, or oblong. In some embodiments, the surface charge of at least one particle type of the plurality of particle types comprises a positive surface charge. In some embodiments, the surface charge of at least one particle type of the plurality of particle types comprises a negative surface charge.

[0041] In some embodiments, the surface charge of at least one particle type of the plurality of particle types comprises a neutral surface charge. In some embodiments, at least one particle type of the plurality of particle types comprises a chemical feature that is different from a second particle type of the panel. In some embodiments, the chemical feature is a surface functional

chemical group. In some embodiments, the functional chemical group is an amine or a carboxylate. In some embodiments, at least one particle type of the plurality of particle types is made of a material comprising a polymer, a lipid, or a metal.

[0042] In further embodiments, the polymer comprises polyethylenes, polycarbonates, polyanhydrides, polyhydroxyacids, polypropylfumerates, polycaprolactones, polyamides, polyacetals, polyethers, polyesters, poly(orthoesters), polycyanoacrylates, polyvinyl alcohols, polyurethanes, polyphosphazenes, polyacrylates, polymethacrylates, polycyanoacrylates, polyureas, polystyrenes, or polyamines, a polyalkylene glycol (e.g., polyethylene glycol (PEG)), a polyester (e.g., poly(lactide-co-glycolide) (PLGA), polylactic acid, or polycaprolactone), or a copolymer of two or more polymers.

[0043] In further embodiments, the lipid comprises dioleoylphosphatidylglycerol (DOPG), diacylphosphatidylcholine, diacylphosphatidylethanolamine, ceramide, sphingomyelin, cephalin, cholesterol, cerebroside and diacylglycerols, dioleoylphosphatidylcholine (DOPC), dimyristoylphosphatidylcholine (DMPC), and dioleoylphosphatidylserine (DOPS), phosphatidylglycerol, cardiolipin, diacylphosphatidylserine, diacylphosphatidic acid, N-dodecanoyl phosphatidylethanolamines, N-succinyl phosphatidylethanolamines, N-glutarylphosphatidylethanolamines, lysylphosphatidylglycerols, palmitoyloleyolphosphatidylglycerol (POPG), lecithin, lysolecithin, phosphatidylethanolamine, lysophosphatidylethanolamine, dioleoylphosphatidylethanolamine (DOPE), dipalmitoyl phosphatidyl ethanolamine (DPPE), dimyristoylphosphoethanolamine (DMPE), distearoyl-phosphatidyl-ethanolamine (DSPE), palmitoyloleyolphosphatidylethanolamine (POPE) palmitoyloleyolphosphatidylcholine (POPC), egg phosphatidylcholine (EPC), distearoylphosphatidylcholine (DSPC), dioleoylphosphatidylcholine (DOPC), dipalmitoylphosphatidylcholine (DPPC), dioleoylphosphatidylglycerol (DOPG), dipalmitoylphosphatidylglycerol (DPPG), palmitoyloleyolphosphatidylglycerol (POPG), 16-O-monomethyl PE, 16-O-dimethyl PE, 18-1-trans PE, palmitoyloleyolphosphatidylethanolamine (POPE), 1-stearoyl-2-oleyolphosphatidylethanolamine (SOPE), phosphatidylserine, phosphatidylinositol, sphingomyelin, cephalin, cardiolipin, phosphatidic acid, cerebroside, dicetylphosphate, or cholesterol.

[0044] In some embodiments, the metal comprises gold, silver, copper, nickel, cobalt, palladium, platinum, iridium, osmium, rhodium, ruthenium, rhenium, vanadium, chromium, manganese, niobium, molybdenum, tungsten, tantalum, iron, or cadmium. In some embodiments, at least one particle type of the plurality of particle types is surface functionalized with polyethylene glycol. In some embodiments, the method associates the protein profile to the biological state with at

least 70% accuracy, at least 75% accuracy, at least 80% accuracy, at least 85% accuracy, at least 90% accuracy, at least 92% accuracy, at least 95% accuracy, at least 96% accuracy, at least 97% accuracy, at least 98% accuracy, at least 99% accuracy, or 100 % accuracy. In some embodiments, the method associates the protein profile to the biological state with at least 70% sensitivity, at least 75% sensitivity, at least 80% sensitivity, at least 85% sensitivity, at least 90% sensitivity, at least 92% sensitivity, at least 95% sensitivity, at least 96% sensitivity, at least 97% sensitivity, at least 98% sensitivity, at least 99% sensitivity, or 100 % sensitivity.

[0045] In some embodiments, the method associates the protein profile to the biological state with at least 70% specificity, at least 75% specificity, at least 80% specificity, at least 85% specificity, at least 90% specificity, at least 92% specificity, at least 95% specificity, at least 96% specificity, at least 97% specificity, at least 98% specificity, at least 99% specificity, or 100 % specificity. In some embodiments, wherein the method identifies at least 100 unique proteins, at least 200 unique proteins, at least 300 unique proteins, at least 400 unique proteins, at least 500 unique proteins, at least 600 unique proteins, at least 700 unique proteins, at least 800 unique proteins, at least 900 unique proteins, at least 1000 unique proteins, at least 1100 unique proteins, at least 1200 unique proteins, at least 1300 unique proteins, at least 1400 unique proteins, at least 1500 unique proteins, at least 1600 unique proteins, at least 1700 unique proteins, at least 1800 unique proteins, at least 1900 unique proteins, or at least 2000 unique proteins. In some embodiments, at least one particle type of the plurality of particle types comprises an iron oxide nanoparticle. In further embodiments, the sample is a biofluid. In still further embodiments, the biofluid comprises plasma, serum, CSF, urine, tear, or saliva

[0046] In various embodiments, the present disclosure provides a method of selecting a panel for protein corona analysis, comprising selecting a plurality of particle types with at least three different physicochemical properties. In some embodiments, the different physicochemical properties is selected from a group consisting of surface charge, surface chemistry, size, and morphology. In further embodiments, the different physicochemical properties comprises surface charge.

[0047] In various embodiments, the present disclosure provides a composition comprising a panel of particles, wherein the panel comprises a plurality of particle types and wherein the plurality of particle types comprises at least three different physicochemical properties. In some embodiments, the different physicochemical properties is selected from a group consisting of surface charge, surface chemistry, size, and morphology. In further embodiments, the different physicochemical properties comprises surface charge.

[0048] In various embodiments, the present disclosure provides a system of comprising any one of the above described panels.

[0049] In various embodiments, the present disclosure provides a system comprising a panel, wherein the panel comprises a plurality of particle types. In some embodiments, the plurality of particle types comprises at least three different physicochemical properties. In some embodiments, the panel comprises at least 3, at least 4, at least 5, at least 6, at least 7, at least 8, at least 9, at least 10, at least 11, or at least 12 different particle types. In some embodiments, the plurality of particle types are capable of adsorbing a plurality of proteins from a sample to form a plurality of protein coronas. In some embodiments, the plurality of protein coronas are digested to determine a protein profile. In some embodiments, the protein profile is associated with a biological state using a trained classifier.

[0050] In some aspects, wherein the sample is a biological sample. In further aspects, the biological sample is plasma, serum, CSF, urine, tear, cell lysates, tissue lysates, cell homogenates, tissue homogenates, nipple aspirates, fecal samples, synovial fluid and whole blood, or saliva. In some aspects, wherein the sample is a non-biological sample. In further aspects, the non-biological sample is water, milk, solvents, or a homogenized sample.

INCORPORATION BY REFERENCE

[0051] All publications, patents, and patent applications mentioned in this specification are herein incorporated by reference to the same extent as if each individual publication, patent, or patent application was specifically and individually indicated to be incorporated by reference.

BRIEF DESCRIPTION OF THE DRAWINGS

[0052] The novel features of the invention are set forth with particularity in the appended claims. The patent or application file contains at least one drawing executed in color. Copies of this patent or patent application publication with color drawing(s) will be provided by the Office upon request and payment of the necessary fee. A better understanding of the features and advantages of the present invention will be obtained by reference to the following detailed description that sets forth illustrative embodiments, in which the principles of the invention are utilized, and the accompanying drawings of which:

[0053] **FIG. 1** shows examples of surface chemistries for magnetic particles (MPs). In some cases, the magnetic particles may be magnetic core nanoparticles (MNP).

[0054] **FIG. 2A** shows the formation of protein corona on a particle. The profile of the protein corona depends on protein-particle, protein-protein, and protein concentration factors. **FIG. 2B**

shows the formation of protein corona on three different particles. In some cases, the particles may be nanoparticles. The properties of the particles result in different protein corona profiles.

[0055] **FIG. 3** shows several examples of particle types and several ways the particle surfaces can be functionalized. In some cases, the particles may be nanoparticles.

[0056] **FIG. 4** shows the separation of superparamagnetic iron oxide nanoparticles (SPIONs) from the remaining solution. As illustrated in the left photo, the SPIONs are dispersed in solution, seen as a dark, opaque solution in a glass vial, prior to or concurrent with application of a magnet to the side of the vial. Within 30 seconds of applying a magnet to the side of the vial, the SPIONs are separated from the solution, as illustrated by accumulation of dark particles next to the magnet and an increase in solution transparency in the photo on the right. Upon shaking the separated solution shown in the right image, the particles return to the dispersed state shown in the left image within 5 seconds. The SPIONs have a fast response.

[0057] **FIG. 5** provides an example of a process for generating proteomic data and a process for panel selection.

[0058] **FIG. 6** shows several examples of different attributes of particles and methods of characterizing the particles.

[0059] **FIG. 7** is an example of size distribution of nanoparticles as characterized by dynamic light scattering. **FIG. 7** shows a dynamic light scattering overlay of two particle types: SP-002 (phenol-formaldehyde coated particles) and SP-010 (carboxylate, PAA coated particles), both of which have iron oxide cores. Dynamic light scattering can also be used to measure a size distribution of particles of larger sizes, including microparticles.

[0060] **FIG. 8A** and **FIG. 8B** show the characterization of nanoparticles with different functionalization prior to corona formation. **FIG. 8A** shows the transmission electron microscopy (TEM) of SP-002 (phenol-formaldehyde coated particles). **FIG. 8B** shows the TEM of SP-339 (polystyrene carboxyl particles). TEM can also be used to characterize particles of larger sizes, including microparticles.

[0061] **FIG. 9** shows the Fe 2p/3 spectrum for various nanoparticles including SP-333 (carboxylate), SP-339 (polystyrene carboxylate), SP-356 (silica amino), SP-374 (silica silanol), HX-20 (SP-003) (silica coated), HX-42 (SP-006) (silica coated, amine), and HX-74 (SP-007) (PDMPAPMA coated (dimethylamine)). The spectrum was obtained from XPS (x-ray photoelectron spectroscopy), which provides the chemical fingerprint of the particle surfaces (measures % of various elements on the surface). XPS can also be used to measure spectra of particles of larger sizes, including microparticles.

[0062] **FIG. 10** shows an example of a process of the present disclosure for proteomic analysis. The process illustrated is optimized for high-throughput and automation that can be run in hours and across multiple samples in parallel. The process includes particle-matrix association, particle wash (x3), formation of the protein corona, in-plate digestion, and mass spectrometry. Using the process, it may take only 4 to 6 hours per batch of 96 samples. Typically, one particle type at a time is incubated with a sample.

[0063] **FIG. 11** shows the protein counts (number of proteins identified from corona analysis) for panel sizes ranging from 1 particle type to 12 particle types. Each particle in a panel may be unique in base material, surface functionalization, and/or physical property (e.g., size or shape). Single pooled plasma representing a pool of healthy subjects was used. Counts are the numbers of unique proteins observed across the panel of 12 particle types in about 2 hour mass spectrometry (MS) runs. 1318 proteins were identified with a panel size of 12 particle types. As used herein, a “feature” identified by mass spectrometry includes a signal at a specific combination of retention time and m/z (mass-to-charge ratio), where each feature has an associated intensity. Some features are further fragmented in a second mass spectrometry analysis (MS2) for identification.

[0064] **FIG. 12** represents gel electrophoresis analyses of multiple particle types after incubation in plasma across multiple days. Each individual assay typically ran for about 1 hour, but triplicate measurements were made on three different days, and by different operators, to demonstrate assay precision. From left to right, the gel shows a ladder, three consecutive columns of SP-339 (polystyrene carboxyl), three consecutive columns of SP-374 (silica silanol), a DNA ladder, and three consecutive columns of HX56 (SP-007) (silica amino).

[0065] **FIG. 13** shows mass spectrometry analyses for protein identification across three separate assays for one particle type (SP-339, polystyrene carboxyl). Across the three separate assays, 180 proteins were commonly identified.

[0066] **FIG. 14A** and **FIG. 14B** show the concentration responses for spiked proteins as compared to the controls. The spikes change with concentration. Endogenous protein controls did not change with concentration. **FIG. 14A** shows data from spike recovery experiments of CRP. The protein was spiked at 4 levels: 2X, 5X, 10X, and 100X. HX-42 (SP-006) (left) and HX-97 (right, same as SP-007) were used. **FIG. 14B** shows the response slopes for spikes and controls. The slopes from the regression models fit to MS ~ enzyme-linked immunosorbent assay (ELISA) data.

[0067] **FIG. 15** shows a comparative study for evaluating particle types for panel selection. 56 serum samples were obtained from 28 diseased subjects and 28 control subjects. The diseased

subjects had confirmed Stage IV non-small-cell lung carcinoma (NSCLC), comorbidities, and treatments, such as diabetes, cardiovascular disease, hypertension, and etc. The control subjects were age- and gender-matched to the diseased subjects to reduce bias. The study was used to evaluate particle types between groups with large differences, and shows they are age and gender matched. Seven particles were used for the study, as shown in **FIG. 16A**.

[0068] **FIG. 16A** shows a comparison of samples (28 diseased vs. 28 controls) using a panel of seven particle types, including SP-339, HX74 (SP-007), SP-356, SP-333, HX20 (SP-003), SP-364, and HX42 (SP-006). 14,481 filtered MS features were compared and 120 (0.8%) were different. **FIG. 16B** shows the top hits from SP-339 of **FIG. 16A**. The detected differences confirm the ability of the coronas to differentiate between sample types and ultimately build classifiers to define disease vs. healthy.

[0069] **FIG. 17A** shows a schematic of a process of the present application including collection of samples from healthy and cancer patients, isolation of plasma from the samples, incubation with uncoated liposomes to form protein coronas, and enrichment of select plasma proteins. Proteins in a sample were assayed using a particle-type panel with distinct particle types to enrich proteins in distinct biomolecule coronas formed on the distinct particle types. Protein corona formation is specific to the physicochemical properties of particles. **FIG. 17B** shows corona analysis with an embodiment of the present disclosure, a Proteograph, for a three-particle type panel. Plasma was collected from 45 subjects (8 from each of 5 cancers, including glioblastoma, lung cancer, meningioma, myeloma, and pancreatic cancer, and 5 healthy controls). The output of the corona analysis, Proteographs, were created for each particle in the 3-particle type panel. Random forest models were built in each of 1000 rounds of cross-validation. This provided strong evidence for robust corona analysis signal. Initial exploratory analysis was done via principal component analysis (PCA) on the proteins detected from the combination of the three particles.

[0070] **FIG. 18A** and **FIG. 18B** show that early stage cancers can be separated up to 8 years before symptoms develop. The Golestan Cohort enrolled 50,000 healthy subjects between 2004 and 2008. As shown in **FIG. 18A**, banked plasma from enrollment was tested. 8 years after enrollment, approximately 1000 patients developed cancers. **FIG. 18B** shows the classification of the banked plasma from **FIG. 18A**. Corona analysis of banked plasma from enrollment date accurately classified cancers for 15 out of 15 subjects examined (5 patients each for 3 cancers).

[0071] **FIG. 19** shows the robust classification of five cancers using a three-particle corona analysis with Proteograph with an overall accuracy of 95%. The data shows that adding particle

type diversity increases performance. Three different liposomes with negative, neutral, and positive net charge on the surfaces (at pH 7.4) were used.

[0072] FIG. 20 shows an example of scaling of particle biosensor production. The platform can be used across multiple assays and samples.

[0073] FIG. 21 illustrates an example of particle types of the present disclosure. The particle types may include nanoparticles (NPs) and microparticles.

[0074] FIG. 22A-B illustrate a schematic of the formation of particle protein corona (FIG. 22A), and an embodiment of the present disclosure, the Proteograph platform workflow, based on multi-particle type protein corona approach and mass spectrometry for plasma proteome analysis (FIG. 22B). FIG. 22A show three distinct particle types (depicted in the center of the figure, with the top, middle, and bottom spheres representing the three distinct particle types), each different from the other by at least one physicochemical property, which leads to the formation of different protein corona compositions on the particle surfaces. FIG. 22B shows the corona analysis workflow with Proteograph, which includes: (1) particle-plasma incubation and protein corona formation; (2) particle protein corona purification by a magnet; (3) digestion of corona proteins; and (4) mass spectrometry analysis.

[0075] FIG. 23 illustrates characterization of the three superparamagnetic iron oxide nanoparticles (SPIONs) shown in the left-most first column, which from top to bottom, are: silica-coated SPION (SP-003), poly(N-(3-(dimethylamino)propyl) methacrylamide) (PDMA-PMA)-coated SPION (SP-007), and poly(oligo(ethylene glycol) methyl ether methacrylate) (POEGMA)-coated SPION (SP-011), by the following methods: scanning electron microscopy (SEM, second columns of images), dynamic light scattering (DLS, third column of graphs), transmission electron microscopy (TEM, fourth column of images), high-resolution transmission electron microscopy (HRTEM, fifth column), and X-ray photoelectron spectroscopy (XPS, sixth column), respectively. DLS shows three replicates of each particle type. The HRTEM pictures were recorded at the surface of individual SP-003, SP-007, and SP-011 particle types, respectively, and the arrow points to the region of amorphous SiO₂ (top HRTEM image) coating and amorphous SiO₂/polymer coatings (middle and bottom HRTEM images) on the particle surface.

[0076] FIG. 24 shows the dynamic range for proteins observed on neat plasma vs. SP-003, SP-007, and SP-011 particles by comparison to a compiled database from Keshishian et al. (Mol Cell Proteomics. 2015 Sep;14(9):2375-93. doi: 10.1074/mcp.M114.046813. Epub 2015 Feb 27.)(top panel).

[0077] **FIG. 25** shows a correlation of the maximum intensities of particle corona proteins vs. plasma proteins to the published concentration of the same proteins

[0078] **FIG. 26** shows the reproducibility of particle corona intensities for each particle type (SP-003, SP-007, and SP-011) as demonstrated by three replicates using the same plasma sample.

[0079] **FIG. 27** shows changed features in a non-small cell lung cancer (NSCLC) pilot study using the SP-007 particles. Seven MS features were identified as statistically, significantly different between 28 subjects with Stage IV NSCLC (with associated co-morbidities and treatment effects) and 28 age- and gender-matched, apparently healthy subjects. The table at bottom is a list of the seven proteins that were significantly different, including 5 known proteins and 2 unknown proteins. If a peptide-spectrum match was made for MS2 data associated with the feature, that peptide sequence (and charge) as well as the potential parent protein are indicated; if an MS2 match was not associated with the feature, both the peptide and the protein are marked as "Unknown".

[0080] **FIG. 28A** shows a schematic for synthesis of SPION core.

[0081] **FIG. 28B** shows a schematic for synthesis of silica-coated SPION (SP-003).

[0082] **FIG. 28C** shows a schematic for synthesis of vinyl group functionalized SPION.

[0083] **FIG. 28D** shows a schematic for synthesis of poly(N-(3-(dimethylamino)propyl) methacrylamide) (PDMAPMA)-coated SPION (SP-007).

[0084] **FIG. 28E** shows a schematic for synthesis of poly(oligo(ethylene glycol) methyl ether methacrylate) (POEGMA)-coated SPION (SP-011).

[0085] **FIG. 29** shows the distribution of the presence-filtered, cluster quality-filtered, median-normalized MS feature intensities for the 56-sample NSCLC comparative study. Each line represents the density of the $\log_2$ feature intensity for either a diseased sample or a control sample. Density is plotted from 0.00 to 0.15 on the y-axis, and $\log_2$ feature intensity is plotted from 15 to 35 on the x-axis. At the highest peak located near a $\log_2$ feature intensity of about 28, with densities ranging from about 0.13 to about 0.17, the two highest traces correspond to control samples, while the lowest trace corresponds to a diseased sample. The remaining control and diseased traces are distributed between the highest and lowest traces. At the two shoulder peaks, occurring at about 20 $\log_2$ feature intensity and about 23 $\log_2$ feature intensity, the highest two traces are control traces and the lowest two traces are control traces at the 20 $\log_2$ feature intensity peak, and the highest traces is a diseased trace at the 23 $\log_2$ feature intensity.

[0086] **FIG. 30** shows the accuracy of measurements for C-reactive proteins (CRP) on the SP-007 nanoparticles in a spike-recovery experiment for four different peptides.

[0087] FIG. 31 shows the accuracy of measurement for peptide features of Angiogenin in a spike-recovery experiment.

[0088] FIG. 32 shows the accuracy of measurement for peptide features of S10A8 in a spike-recovery experiment.

[0089] FIG. 33 shows the accuracy of measurement for peptide features of S10A9 in a spike-recovery experiment.

[0090] FIG. 34 shows the accuracy of measurement for peptide features of C-reactive protein (CRP) in a spike-recovery experiment.

[0091] FIG. 35 shows the accuracy of measurement for protein features in a spike-recovery experiment.

[0092] FIG. 36 shows matching and coverage of a particle panel of the 10 distinct particle types to a 5,304-plasma protein database of MS intensities. The ranked intensities for the database proteins are shown in the top panel ("Database"), the intensities for proteins from simple plasma MS evaluation are shown in the second panel ("Plasma") and the intensities for the optimal 10-particle type panel are shown in the remaining panels. The plasma protein intensities database is from Keshishian et al. (2015). Multiplexed, Quantitative Workflow for Sensitive Biomarker Discovery in Plasma Yields Novel Candidates for Early Myocardial Injury. *Molecular & Cellular Proteomics*, 14(9), 2375–2393.

[0093] FIG. 37 shows various particle types that may be included in panels disclosed herein.

[0094] FIG. 37A shows a schematic of a hollow magnetic particle.

[0095] FIG. 37B shows a schematic of a particle with hydrophobic pockets.

[0096] FIG. 37C shows a schematic of a shell-yolk SPION microgel hybrid particle.

[0097] FIG. 38 shows a schematic of particle surfaces engineered to capture proteins and/or peptides, adapted from *Mol. Cells* 2019, 42(5), 386-396.

DETAILED DESCRIPTION

[0098] Disclosed herein are compositions and methods of use thereof for assaying peptides and proteins in a sample in a simple and high throughput manner. The present disclosure provides particle panels of multiple distinct particle types, which enrich proteins from a sample onto distinct biomolecule coronas formed on the surface of the distinct particle types. The particle panels disclosed herein can be used in methods of corona analysis to detect thousands of proteins across a wide dynamic range in the span of hours.

[0099] Currently, there are a small number of protein-based biomarkers in use today for clinical diagnosis, and in spite of extensive efforts to analyze the plasma proteome for the expansion of markers, relatively few new candidates have been accepted as clinically useful tests. The plasma

proteome contains >10,000 proteins and potentially an order of magnitude more protein isoforms with a concentration range spanning over 10 orders of magnitude (from mg/mL to pg/mL). These attributes, combined with a lack of convenient molecular tools for protein analytical work (such as copy- or amplification-mechanisms), make comprehensive studies of the plasma proteome exceptionally challenging. Approaches to overcome the broad dynamic range of proteins in biological samples are still for robust identification and quantification against a background of thousands of unique proteins and even more protein variants. However, there are no existing technologies that are capable of simultaneous measurement of proteins across the entire plasma concentration range in a format with a sufficient throughput and with a practical cost profile to allow for appropriately-sized studies with robust prospects for validation and replication. These challenges not only limit the discovery of protein-based biomarkers of disease but have been a bottleneck for the faster adoption of proteogenomics and protein annotation of genomic variants. Advances in mass spectrometry (MS) approaches along with development of improved data analytics have offered tools for deep and broad proteomic analysis. Several attempts have been made to substantially improve the detection of low abundance proteins, such as depletion of highly abundant proteins, plasma fractionation, peptide fractionation, and isobaric labeling. However, current approaches are fairly complex and time-consuming (days to weeks), and thus require a tradeoff between depth of protein coverage and sample throughput. Consequently, a simple and robust strategy for comprehensive and rapid analysis of the available body of information in the proteome remains an unmet need.

[0100] Additionally, the earlier a disease is diagnosed, the more likely that the disease can be cured or successfully managed leading to a better prognosis for the patient. When a disease is treated early, it may be possible to prevent or delay problems from the disease and may improve the outcomes for the patient, including extending the patient's life and/or quality of life. Early diagnosis of cancer is crucial, as many types of cancers can be successfully treated in their early stages. For example, five-year survival after early diagnosis and treatment of breast, ovarian, and lung cancers is 90%, 90%, and 70%, respectively, compared to 15%, 5%, and 10% for patients diagnosed at the most advanced stage of disease. Once cancer cells leave their tissue of origin, successful treatment using available established therapeutics becomes very unlikely. Although recognizing the warning signs of cancers and taking prompt action may lead to early diagnosis, the majority of cancers (e.g., lung) show symptoms only after cancer cells have already invaded the surrounding tissues and metastasized throughout the body. For example, more than 60% of patients with breast, lung, colon, and ovarian cancer have concealed or even metastatic colonies by the time their cancers are detected. Therefore, there is an urgent need for development of an

effective approach for early detection of cancer. Such an approach should have the sensitivity to identify a cancer at various stages and the specificity to give a negative result when the person being tested is free of the cancer. There have been extensive efforts to develop methods for early detection of cancers; although huge numbers of risk factors and biomarkers have been introduced, a broadly relevant platform for early detection of a wide range of cancers remains elusive. As various types of cancers can change the composition of blood plasma—even in their early stages—one promising approach for early detection is molecular blood analysis for biomarkers. Although this strategy has already worked for a few cancers (like PSA for prostate cancer), there are not yet specific biomarkers for early detection of the majority of cancers. For such cancers (e.g., lung), none of the defined candidate circulating biomarkers has been clinically validated, and very few have reached late-stage clinical development. Therefore, there is an urgent need for novel approaches to improve our ability to detect cancer, as well as other diseases, at very early stages.

[0101] To meet the need for high throughput, simple assays for detecting proteins in a sample, which can be used to detect proteins associated a particular disease at very early stages – the present disclosure provides particle panels and methods for using said particle panels to assay for peptides and proteins in a sample (e.g., a complex, biological sample such as plasma) in a simple, rapid, and high throughput manner. In particular, the present disclosure provides particle panels of multiple distinct particle types, which enrich proteins from a sample onto distinct biomolecule coronas formed on the surface of the distinct particle types. The particle types included in the particle panels disclosed herein are particularly well suited to enriching for a high number of proteins across a wide dynamic range in an unbiased fashion. The combinations of particle types selected for inclusion in a particle panel of the present disclosure are varied in their physicochemical properties (e.g., size, surface charge, core material, shell material, surface chemistry, porosity, morphology, and other properties). However, particle types may also share several of said physicochemical properties. For example, a particle panel disclosed herein can include a first particle type and a second particle type, wherein the first particle type and the second particle type share at least two physicochemical properties and differ by at least two physicochemical properties, such that the first particle type and the second particle type are different. Importantly, the variation in at least one physicochemical property between a first particle type and a second particle type of the particle panel can lead to the formation of distinct coronas, which form on the corresponding distinct particle types. Thus, the selection of particle types for inclusion in a particle panel for use in the methods disclosed herein enables the high number of proteins that can be enriched across a wide dynamic range in a sample (e.g., plasma).

[0102] The particle panels of the present disclosure can include particle types that have magnetic properties, which allow for them to be easily separated after incubation in a complex biological sample. For example, the present disclosure provides superparamagnetic iron oxide nanoparticles (SPIONs), which have unique magnetic properties and can rapidly separate biomolecules, drug delivery and contrast agents in magnetic resonance imaging (MRI). Superparamagnetic particles can have a core of solely iron oxide (e.g., an iron oxide core) or can have small iron oxide crystals embedded in a polystyrene core.

[0103] The present disclosure provides methods that have been developed for synthesis of SPIONs. In an example, a thermal decomposition of iron oleate in a nonpolar solvent can be used to synthesize small size (usually < 30 nm) monodisperse magnetic nanocrystals with high crystallinity. Those nanocrystals are hydrophobic and need to transfer to aqueous phase through the ligand exchange or chemical modifications. SPIONs generated using this method can meet requirement(s) for biomedical use. A solvothermal method is another way to synthesize SPIONs by reduction of iron (III) chloride with ethylene glycol. Highly water dispersible SPMNPs can be synthesized by a modified solvothermal approach using hydrophilic ligands such as citrate, polyacrylic acid (PAA) and polyvinylpyrrolidone (PVP). The particle surfaces can be further modified with different silanes which have functional groups via a Stöber process. The surface functionalities can also be achieved by a facile method through a surfactant-free seeded emulsion polymerization to form SPMNP@polymer composite particles.

[0104] The present disclosure provides compositions, systems, and methods of use thereof for large-scale, high-throughput, efficient, and cost-effective proteomic profiling and machine learning. Disclosed herein is a scalable parallel protein identification and quantification technology for assaying proteins in a sample using a particle panel with distinct particle types to enrich proteins in distinct biomolecule coronas formed on the distinct particle types.

“Biomolecule corona” as used herein can be used referred to interchangeably with the term “protein corona,” and refers to the formation of a layer of proteins on the surface of a particle after the particle has been contacted with a sample (e.g., plasma). This method may be referred to interchangeably as corona analysis or, in some examples, “Proteograph” analysis (depicted in **FIG. 22**), which combines a multi-particle type protein corona strategy with mass spectrometry (MS). Particle types included in the particle panels disclosed herein can be superparamagnetic and are, thus, rapidly separated or isolated from unbound protein (proteins that have not adsorbed onto the surface of a particle to form the corona) in a sample, after incubation of the particle in the sample.

[0105] To date, particles have been poorly characterized for high-throughput translation proteomic analysis, due to steps in processing the proteins in the protein corona (e.g., centrifugation or membrane filtration to separate corona proteins from free plasma proteins and washing to remove loosely attached proteins from particles), which confound data and lack reproducibility and accuracy. The corona analysis (e.g., “Proteograph”) methods disclosed herein can integrate overlapping but distinct particle type protein coronas with, for example, liquid chromatography-mass spectrometry (LC-MS) for potential use in large-scale efficient proteomic profiling and machine learning. The particle type platform can be unbiased (e.g., not limited to a predetermined analyte), and the MS data acquisition platform can be unbiased in terms of analyte measurement, both of which can be amenable to automation. The formation of a layer of proteins on the surface of particles upon their contact with plasma, which is referred to as protein corona (**FIG. 22A**) is disclosed herein as a method for identifying proteins. The composition and quantity of the corona proteins can depend on the physiochemical properties of the particle type, and changes in these engineered properties can result in reproducibly different proteins in the corona in terms of identity and/or quantity.

[0106] In some embodiments, the particles disclosed herein can be superparamagnetic iron oxide nanoparticles (SPIONs). SPIONs can be distinct from one another by being synthesized to have distinct surface chemistries. In some embodiments, SPIONs of different surface chemistries can be combined in analysis of proteins formed on their protein coronas. SPIONs, other particle types, or a combination thereof can be combined into panels of particle types that can be used for proteomic analysis of a sample.

[0107] In some embodiments, disclosed herein is a panel of three particle types with distinct surface chemistries, synthesized and used for the formation of protein corona, which can be rapidly separated by magnet from unbound proteins. Each particle type can reproducibly generate a unique protein corona pattern by capture of both high and low abundance proteins. For instance, by integrating the distinct proteomic profiles generated from at least three particle types, greater than 1,500 proteins of a single pooled colorectal cancer (CRC) plasma sample can be identified of which many can be FDA-cleared/approved biomarkers. For example, in some embodiments a screen of three particle types can detect over 1,500 proteins, of which 65 are FDA-cleared/approved biomarkers.

[0108] In some embodiments, the corona analysis workflow with Proteograph (**FIG. 22B**) can take ~4-6 hours to prepare a batch of 96 corona samples for MS analysis. The protein identification in the CRC pool can be done using just three total MS fractions analyzed in about one hour runs each, hence a total of about 3 hours MS time.

[0109] In some embodiments, three distinct particle types can be used identify greater than 1,500 proteins from a single pooled plasma within 8 hours including sample preparation and LC-MS, in contrast to less than 500 proteins without using the compositions, systems, and methods disclosed herein for using particle type corona strategy.

[0110] The corona analysis technology can be used to identify a disease. For example, the particles and methods of use thereof disclosed herein can be used to analyze serum samples from patients with non-small cell lung cancer (NSCLC) and age- and gender-matched healthy subjects. MS features can be discovered using this platform, including known and novel features that can distinguish between NSCLC and control samples. Thus, the corona analysis platform technology is capable of larger and more robust validation and replication studies. Moreover, the unique properties of the corona analysis for high-throughput and unbiased proteomic sampling can enable annotation of genomic data and application of machine learning classification methods. The multi-particle type protein corona-based platform technology described herein can facilitate efficient and comprehensive proteomics profiling, enabling larger-sized studies for biomarker discovery and validation.

[0111] In some embodiments, the compositions and methods of use thereof disclosed herein exhibit high assay accuracy, as demonstrated by addition of an increasing concentration of a reference, C-reactive protein (CRP), to plasma samples, and subsequent detection of CRP levels in the protein coronas, showing a slope of 0.9 (95% CI 0.81-0.98) for CRP levels in particle corona versus spiked plasma. In some embodiments, the median precision of the platform in assay replicates can be ~24 CV% across 8,738 measured MS features taken from three distinct particle type protein coronas.

[0112] SPIONs with distinct surface chemistries can be applied for protein corona analysis of a single pooled plasma sample. For instance, as down in the present disclosure, the resulting proteomic data demonstrates that increasing the number of particle types in a particle panel can result in the identification of more proteins (particularly low abundance proteins). The addition of more distinct particle types can lead to even broader and deeper proteome profiling. The compositions of particles disclosed herein and the panels of particle types comprising said different particle types can be tailored to profile the proteome at different levels of depth and breadth by varying the number and type of particles in the panels – analogous to different levels of coverage in gene sequencing.

[0113] The multi-particle type protein corona-based assay disclosed herein has shown several equally important features for plasma proteome analysis. As compared to conventional proteomic techniques that usually involve time-consuming depletion and fractionation

workflows, the compositions and methods of use disclosed herein can avoid those complicated workflows and can be much faster. Notably, the corona analysis assay can be robustly automated, thus further increasing precision and reducing the amount of time required for sample analysis in, for example, a 96-well plate format. The corona analysis platform can sensitively measure differences between samples, while reducing the dynamic range of those comparisons, thus enabling more comparisons to be observed. The corona analysis technology can identify new biomarkers without targeting a pre-determined set of proteins. The scalability and efficiency of the corona analysis platform can be used for large proteomics studies, which can lead to deeper understanding of disease and biological mechanisms. For example, by adding proteomic data to multiomic data sets, and performing machine learning analyses, novel classifications can be generated and put into context genomic disease information that is not well-understood today, such as single nucleotide polymorphism (SNP) variants, changes in DNA methylation patterns and splice variants. Additionally, the technology can be extended to other biological fluids such as cerebrospinal fluid, cell lysate, and even tissue homogenate for rapid, accurate and precise profiling of proteomes, which can facilitate the discovery of new biomarkers for different diseases.

[0114] Methods for making superparamagnetic nanoparticles (SPMNs) or superparamagnetic iron oxide particles (SPIONs) are disclosed herein. These particles and embodiments thereof can be used in a protein corona assay.

[0115] The methods and systems of the present disclosure improve proteomic analysis by simplifying sample preparation and MS data acquisition. The methods and systems perform sample preparation in about 5 steps in about 0.25 days and acquire MS data for about 12 fractions in about 0.5 days per sample.

[0116] The present disclosure provides compositions and methods of use thereof for assaying a sample for proteins. Compositions described herein include particle panels comprising one or more than one distinct particle types. Particle panels described herein can vary in the number of particle types and the diversity of particle types in a single panel. For example, particles in a panel may vary based on size, polydispersity, shape and morphology, surface charge, surface chemistry and functionalization, and base material. Panels may be incubated with a sample to be analyzed for proteins and protein concentrations. Proteins in the sample adsorb to the surface of the different particle types in the particle panel to form a protein corona. The exact protein and the concentration of protein that adsorbs to a certain particle type in the particle panel may depend on the composition, size, and surface charge of said particle type. Thus, each particle type in a panel may have different protein coronas due to adsorbing a different set of proteins,

different concentrations of a particular protein, or a combination thereof. Each particle type in a panel may have mutually exclusive protein coronas or may have overlapping protein coronas. Overlapping protein coronas can overlap in protein identity, in protein concentration, or both.

[0117] The present disclosure also provides methods for selecting a particle types for inclusion in a panel depending on the sample type. Particle types included in a panel may be a combination of particles that are optimized for removal of highly abundant proteins. Particle types also consistent for inclusion in a panel are those selected for adsorbing particular proteins of interest. The particles can be nanoparticles. The particles can be microparticles. The particles can be a combination of nanoparticles and microparticles.

[0118] The present disclosure provides a method for selecting particle panels that exhibit broad coverage of proteins in a biological sample (e.g., a plasma sample). Particles are selected for inclusion in a particle panel using a combinatorial approach. Particles with a wide range of physicochemical properties are selected, for example, particles may vary by size, surface charge, core material, shell material, surface chemistry, porosity, morphology, and other properties. However, particles may also share several of said physicochemical properties. For example, a particle panel disclosed herein can include a first particle type and a second particle type, wherein the first particle type and the second particle type share at least two physicochemical properties and differ by at least two physicochemical properties, such that the first particle type and the second particle type are different. A particle panel disclosed herein can include a first particle type and a second particle type, wherein the first particle type and the second particle type share at least one physicochemical property and differ by at least two physicochemical properties, such that the first particle type and the second particle type are different. A particle panel disclosed herein can include a first particle type and a second particle type, wherein the first particle type and the second particle type share at least two physicochemical properties and differ by at least one physicochemical property, such that the first particle type and the second particle type are different. Non-limiting examples of physicochemical properties can include size, charge, core material, shell material, porosity, or surface hydrophobicity. Importantly, the variation in at least one physicochemical property between a first particle type and a second particle type of the particle panel can lead to the formation of distinct coronas, which form on the corresponding distinct particle types. For example, a first particle type and a second particle type, which vary in charge may each adsorb different proteins, different concentrations of the same proteins, or both different proteins and different concentrations of the same proteins. Thus, the first particle type and the second particle type would have distinct biomolecule coronas. Size is one example of a physicochemical property that may vary to yield this result. One or more than

one physicochemical properties (e.g., size, charge, core material, shell material, porosity, or surface hydrophobicity, or any combination thereof) can vary to yield distinct biomolecule coronas. Other optimization parameters for selection of particle types for a panel may include any particular annotation set, for example interactome, secretome, FDA markers, proteins with clinically relevant genetic polymorphisms. As seen in **TABLE 10** and **TABLE 12**, more than one of these particles are nanoparticles, but are made of different polymer coatings. As another example, more than one particle of **TABLE 10** and **TABLE 12** share similar surface charge and similar size but are made of different materials. As another example, more than one particle of **TABLE 10** and **TABLE 12** exhibit a porous surface. As another example, more than one particle of **TABLE 10** and **TABLE 12** exhibit a non-porous surface. As another example, more than one particle of **TABLE 10** and **TABLE 12** exhibit a carboxylate coated surface. As another example, more than one particle of **TABLE 10** and **TABLE 12** exhibit an amine coated surface. With all the many combinations of particles and particle types that can be in a particle panel, it is surprising and unexpected that the particle panels disclosed herein were capable of identifying a large number of proteins (e.g., plasma proteins) in a sample (e.g., a plasma sample) over a wide dynamic range in an unbiased manner, and were able to be used in a method of assaying proteins in a sample with a high level of reproducibility (e.g., quantile normalized coefficient of variation < 20%).

[0119] The present disclosure provides over 200 distinct particle types, with over 100 different surface chemistries and over 50 diverse physical properties. In particular, over 23 particle types have been characterized for use in a method of assaying proteins in a sample. Each of these particle types can be combined with other particle types in panels that are designed to optimally assay a particular protein of interest or to optimally identify biomarkers for a disease of interest. Panels can include any number of these particle types or any combination of particle types, and the variety of particle types disclosed herein can enable assaying and detection of a wide range of proteins with varying physicochemical properties.

[0120] In some embodiments, the present disclosure provides method of identifying proteins in a sample, the method comprising: incubating a panel comprising a plurality of particle types with the sample to form a plurality of protein corona; digesting the plurality of protein coronas to generate proteomic data; and identifying proteins in the sample by quantifying the proteomic data.

Particle Materials

[0121] The particle panels disclosed herein may comprise particle types made of a variety of different materials. Panels can be assembled with specific types of particles to identify a broad

range of proteins in the sample, or to selectively assay for a particular protein or set of proteins of interest. The particle types may include, for example, nanoparticles (NPs), microparticles, magnetic particles (MPs), magnetic nanoparticles (MNPs), superparamagnetic iron oxide nanoparticles (SPIONs), or superparamagnetic nanoparticles (SPMNP). Particles described herein may be magnetic particles. Magnetic particles herein may be superparamagnetic particles (SPMP), superparamagnetic nanoparticles (SPMNP), superparamagnetic iron oxide particles (SPIOP), or superparamagnetic iron oxide nanoparticles (SPION). In some cases, a SPMNP may be a SPION. Magnetism can be conferred via iron oxide core or iron oxide crystals grafted to particle. In some cases, we refer herein to SPMNP, which is a magnetic particle. SPMNP can also be synthesized to be a SPMP.

[0122] Particles can be made from various materials. For example, particles may be made of a polymer, a lipid, a metal, silica, a protein, a nucleic acid, a small molecule, or a large molecule. For example, particle materials consistent with the present disclosure include metals, metal oxides, magnetic materials, polymers, and lipids. Examples of metal materials include any one of or any combination of gold, silver, copper, nickel, cobalt, palladium, platinum, iridium, osmium, rhodium, ruthenium, rhenium, vanadium, chromium, manganese, niobium, molybdenum, tungsten, tantalum, iron and cadmium, or any other material described in US7749299. Metal oxide particles may be iron oxide particles or titanium oxide particles. Magnetic particles may be iron oxide nanoparticles.

[0123] Examples of polymers include any one of or any combination of polyethylenes, polycarbonates, polyanhydrides, polyhydroxyacids, polypropylfumerates, polycaprolactones, polyamides, polyacetals, polyethers, polyesters, poly(orthoesters), polycyanoacrylates, polyvinyl alcohols, polyurethanes, polyphosphazenes, polyacrylates, polymethacrylates, polycyanoacrylates, polyureas, polystyrenes, or polyamines, a polyalkylene glycol (e.g., polyethylene glycol (PEG)), a polyester (e.g., poly(lactide-co-glycolide) (PLGA), polylactic acid, or polycaprolactone), polystyrene, or a copolymer of two or more polymers, such as a copolymer of a polyalkylene glycol (e.g., PEG) and a polyester (e.g., PLGA). In some embodiments, the polymer is a lipid-terminated polyalkylene glycol and a polyester, or any other material disclosed in US9549901, which is incorporated by reference in its entirety herein.

[0124] Examples of lipids that can be used to form the particles of the present disclosure include cationic, anionic, and neutrally charged lipids. For example, particles can be made of any one of or any combination of dioleoylphosphatidylglycerol (DOPG), diacylphosphatidylcholine, diacylphosphatidylethanolamine, ceramide, sphingomyelin, cephalin, cholesterol, cerebroside and diacylglycerols, dioleoylphosphatidylcholine (DOPC), dimyristoylphosphatidylcholine

(DMPC), and dioleoylphosphatidylserine (DOPS), phosphatidylglycerol, cardiolipin, diacylphosphatidylserine, diacylphosphatidic acid, N-dodecanoyl phosphatidylethanolamines, N-succinyl phosphatidylethanolamines, N-glutarylphosphatidylethanolamines, lysylphosphatidylglycerols, palmitoyloleoylphosphatidylglycerol (POPG), lecithin, lysolecithin, phosphatidylethanolamine, lysophosphatidylethanolamine, dioleoylphosphatidylethanolamine (DOPE), dipalmitoyl phosphatidyl ethanolamine (DPPE), dimyristoylphosphoethanolamine (DMPE), distearoyl-phosphatidyl-ethanolamine (DSPE), palmitoyloleoyl-phosphatidylethanolamine (POPE) palmitoyloleoylphosphatidylcholine (POPC), egg phosphatidylcholine (EPC), distearoylphosphatidylcholine (DSPC), dioleoylphosphatidylcholine (DOPC), dipalmitoylphosphatidylcholine (DPPC), dioleoylphosphatidylglycerol (DOPG), dipalmitoylphosphatidylglycerol (DPPG), palmitoyloleoylphosphatidylglycerol (POPG), 16-O-monomethyl PE, 16-O-dimethyl PE, 18-1-trans PE, palmitoyloleoyl-phosphatidylethanolamine (POPE), 1-stearoyl-2-oleoyl-phosphatidylethanolamine (SOPE), phosphatidylserine, phosphatidylinositol, sphingomyelin, cephalin, cardiolipin, phosphatidic acid, cerebrosides, dicetylphosphate, and cholesterol, or any other material listed in US9445994, which is incorporated by reference in its entirety herein.

[0125] The particle panels disclosed herein may include specific particle types having structures that are particularly amenable to sampling proteins of a specific size, which are present in a sample. For example, the particle panel may include a hollow magnetic particle, as shown in **FIG. 37A**. The hollow magnetic particle comprises a nanoparticle with a hollow core, wherein the nanoparticle shell is made of smaller primary iron oxide crystals. Hollow magnetic particles may be synthesized by an autoclave reaction based on hydrothermal treatment of FeCl₃, citrate, polyacrylamide or sodium polyacrylate, and urea as described in Cheng, Wei, et al. ("One-step synthesis of superparamagnetic monodisperse porous Fe₃O₄ hollow and core-shell spheres." *Journal of Materials Chemistry* 20.9 (2010): 1799-1805), which is incorporated herein by reference in its entirety. The nanoparticle shell made of the smaller primary iron oxide crystals is porous, allowing the generation of protein coronas on the surface of the nanoparticle via size exclusive effects. Binding surfaces can be primarily inside pores, thus preventing large proteins from diffusing into the particle and binding. In some cases, large proteins may still bind to the outside and included in the overall corona, but these hollow particles can enrich smaller proteins over larger ones. These hollow magnetic particles may be included in any particle panel described herein and is still easily separated from unbound protein using a magnet.

[0126] As another example, the particle panel may include a nanoparticle with a hydrophobic pocket as shown in **FIG. 37B**. The nanoparticle with a hydrophobic pocket is particularly

amenable for sampling a molecule or protein of a specific solubility (*e.g.*, a poorly soluble protein), which are present in a sample. A nanoparticle with a hydrophobic pocket has a structure of a superparamagnetic iron oxide core and additionally has a polymeric coating. Nanoparticles with hydrophobic pockets can be synthesized using an autoclave reaction for SPION core synthesis, as described elsewhere herein, followed by a free radical polymerization for synthesizing a poly(glycidyl methacrylate) coating. This may be further followed by post-synthetic modification of the surface with hydrophobic amines, such as a benzyl amine moiety. These nanoparticles with a hydrophobic pocket are particularly well suited to capturing small molecules for metabolomics. The pore size of the nanoparticle can be modulated to exclude proteins to that only small molecules interact with the hydrophobic pockets. In some embodiments, pore size can be tuned during synthesis. For example, the synthesis may include swelling the particle to create porosity and the degree of swelling can impact the pore size. As another example, an erosion technique can be used to carve out different pores in a particle type with a more solid surface. Protein targets may also be sampled using the nanoparticles with a hydrophobic pocket.

[0127] In another example, the particle panel may include a shell-yolk SPION microgel hybrid nanoparticle, as shown in **FIG. 37C**. A shell-yolk SPION microgel hybrid nanoparticle has a structure of a SPION exterior and a microgel interior. Shell-yolk SPION microgel hybrid nanoparticles can be synthesized using an autoclave reaction based on hydrothermal treatment of FeCl_3 , citrate, polyacrylamide or sodium polyacrylate, and urea as described in Cheng et al. ("One-step synthesis of superparamagnetic monodisperse porous Fe_3O_4 hollow and core-shell spheres." *Journal of Materials Chemistry* 20.9 (2010): 1799-1805) and Zou et al. ("Facile synthesis of highly water-dispersible and monodispersed Fe_3O_4 hollow microspheres and their application in water treatment." *RSC Advances* 3.45 (2013): 23327-23334). In a second step of the synthesis, a hydrogel is formed inside the hollow nanoparticle.

[0128] In another example, the particle panel may include a particle surface that is engineered to capture proteins and/or peptides. A primary layer of proteins may form an initial corona on the particle surface either non-covalently or covalently. Direct non-covalent interactions with the particle surface may include ionic bonds, hydrophobic bonds, and hydrogen bonds. Additionally, these particles, which can be initially modified with small chemical entities, can bind other proteins in the plasma after formation of a primary protein corona. Modulating the chemical modifications present at the surface of the particle can be employed to tune the non-covalent interactions between the particle surface and peptides and/or proteins in a sample. Alternatively, or additionally, the solution phase composition (*e.g.*, pH) can be modulated to tune the non-

covalent interactions between the particles and peptides and/or proteins in a sample. Covalent coupling of proteins and/or peptides to the surface of particles may be performed by introducing a reactive group (e.g., an NHS ester, a maleimide, a carboxylate, etc.) to the surface of the particle. Thus, an NHS-ester bearing particle may be particularly amenable to sampling one or more proteins in solution. Alternatively, a coupling reagent that can sample and bind proteins out of a complex mixture may be a photoinitiated reactive group, which can react with proteins only after exposure to photons of a given wavelength (e.g., UV) and intensity. Advantages of utilizing particles functionalized with said photoinitiated reactive group can include, but are not limited to: (1) locking in the primary protein corona without loss of proteins during the step of washing the particles and/or loss of proteins due to displacement by higher affinity proteins, (2) capturing proteins with intermediate binding affinities because the covalent linkage can be established at any time during the binding process, (3) generating a wider range of surfaces than would result at equilibrium, and (4) generating surfaces with certain protein stoichiometry by use of defined protein mixtures (instead of plasma) for binding. A defined protein mixture can be any synthetically-derived or purified mixture of proteins, obtained or made recombinantly or isolated and then mixed with a defined stoichiometry. For example, for a particular protein of interest for protein-protein interactions (e.g., ubiquitin), the defined protein mixture may be a simple solution of that protein. As another example, the defined protein mixture can be a purified or enriched set of proteins from a certain class of interest (e.g., glycosylated proteins). Particles may also be modified to be functionalized with one half of a click-chemistry reaction pair and unnatural point mutated proteins in a sample contain an amino acid with the other half of the click-chemistry reaction pair. Particles and other proteins in a sample can be functionalized with one half of a click-chemistry reaction pair and unnatural point mutated proteins in a sample contain an amino acid with the other half of the click-chemistry reaction pair. In the presence of a chemical catalyst (e.g., copper) or light (e.g., a photoinitiated click chemistry reagent), the reaction is carried out leading to linkage of particles to the unnatural point mutated proteins in the sample and/or linkage of the unnatural point mutated proteins in the sample and other proteins in the samples. For example, the method may start with a simple solution of proteins that may contain a mutated protein that is enriched in the sample. The main advantage of these systems is that the surface of the particles can be engineered with respect to stoichiometry, protein/surface orientation, and protein/protein orientation. This allows for engineering of durable surfaces that can withstand assay steps described elsewhere herein (e.g., extensive washing). For example, proteins with specific unnatural amino acids at a location of interest in the protein sequence can be introduced as described in Lee et al. (Mol Cells. 2019 May

31;42(5):386-396. doi: 10.14348/molcells.2019.0078.). The unnatural amino acid that is introduced into the protein can have one half of the click-chemistry pair that can react to the other half of the click-chemistry pair on the surface of the particle. In this manner, the rather than random adsorption of proteins to the surface of a particle to form the corona, these modified proteins can bind to the surface of the particle in a particular orientation. The result is that the corona that forms on the surface of a particle type can be tuned with the proteins engineered in a specific 3-D orientation that is controlled. This same general methodology can be used to link protein complexes to the surface of the particle type. Here, one or more subunits of the complex can be modified to be covalently linked together then linked to the surface of a particle type either in a second step of the synthesis or using a different chemistry, which can be performed later in the particle surface modification process. A schematic is shown in **FIG. 38**. Particles that have a surface engineered to non-covalently or covalently capture proteins and/or peptides may still be SPION or polymer-modified SPION particles, which can be synthesized in a variety of ways including standard SPION synthesis via solvothermal methods, ligand exchange processes, silica coating processes, and/or activation or installation of a specific reagent coupling strategy. Advantages of these systems include bio-surface generation, exploitation of interactome, and directed corona assembly.

[0129] As another example, the particle panel may include functionalized particles for histone capture. For example, these particles may be anionic. Additionally, or alternatively, the assay conditions may be optimized to enrich for histones in a sample and labeling techniques may be optimized to improve mass spectrometry detection for histones and post translational modifications. These functionalized particles for histone capture may be made of polymers, silica, target ligand, and or any combination thereof. Functionalized particles can be synthesized using a variety of approaches including standard SPION synthesis via solvothermal methods, ligand exchange processes, surface-initiated polymerization. Anionic particles surfaces can be synthesized by functionalizing the surfaces with polymers such as polycarboxylate, various ligand such as dendrimers, branched ligand, or carboxylate derivatives, and/or sulfanilamide acids. Optimization of assay conditions may include buffering the binding solution to a pH of about 9. While many proteins would exhibit diminished binding to an anionic surface at this pH, histones are basic proteins with a primary sequence having a pI ~11 (e.g., H4_Human pI ~11.3, H3_Human pI ~11) and, this, will remain almost entirely positively charged. As a result, under basic pH conditions, histones can strongly interact with particle surfaces via ionic bonds and can, thus, be selectively enriched on particle surfaces. Additionally, histones may be selectively enriched on particle surfaces by modifying particle surfaces with histone binding proteins. Thus,

a histone protein corona can be obtained using the particles disclosed herein. Optimizing labeling methodologies can help simplify the interpretation of mass spectrometry data and allow for improvements in post-translational modification (PTM) identification and assignment. As the type, location, and occupancy of a post-translational modification on a histone can be different and can help regulate gene expression, these particles can be useful for selectively enriching histones in a sample and interrogate the PTM, thus providing information about the how genes in a sample are being regulated. This may in turn help inform various disease conditions in which regulation of gene expression is aberrant.

[0130] Examples of particle types consistent with the present disclosure are shown in **FIG. 21** and in **TABLE 1** below.

TABLE 1 – Particle Types

P#	Description
HX-13 or SP-001	Carboxylate (Citrate)
HX-19 or SP-002	Phenol-formaldehyde resin coated
HX-31 or SP-004	Polystyrene coated
HX-38 or SP-005	Carboxylated Poly(styrene-co-methacrylic acid), P(St-co-MAA)
HX-42 or SP-006	N-(3-Trimethoxysilylpropyl)diethylenetriamine coated
HX-57 or SP-008	1,2,4,5-Benzenetetracarboxylic acid coated
HX-58 or SP-009	Vinylbenzyltrimethylammonium chloride (PVBTMAC) coated
HX-59 or SP-010	Carboxylated, Poly(acrylic acid), PAA
SP-333	Carboxylate microparticle, surfactant free
SP-339	Polystyrene carboxyl functionalized
SP-341	Carboxylic acid, 150 nm
SP-347	Silica coated, 200 nm
SP-348	Carboxylic acid
SP-353	Amino surface microparticle, 0.4-0.6 μm
SP-356	Silica amino functionalized microparticle, 0.1-0.39 μm
SP-363	Jeffamine surface, 0.1-0.39 μm
SP-364	Polystyrene microparticle, 2.0-2.9 μm
SP-365	Silica
SP-369	Carboxylated Original coating, 50 nm
SP-373	Dextran based coating, 0.13 μm
SP-374	Silica Silanol coated with lower acidity
HX-20 or SP-003	Silica-coated superparamagnetic iron oxide NPs (SPION)
HX-56 or SP-007	poly(N-(3-(dimethylamino)propyl) methacrylamide) (PDMAEMA)-coated SPION

P#	Description
HX-86 or SP-011	poly(oligo(ethylene glycol) methyl ether methacrylate) (POEGMA)-coated SPION

Properties of Particles

[0131] Particles that are consistent with the present disclosure can be made and used in methods of forming protein coronas after incubation in a biofluid at a wide range of sizes. For example, the particles disclosed herein can have a diameter of at least 10 nm, at least 100 nm, at least 200 nm, at least 300 nm, at least 400 nm, at least 500 nm, at least 600 nm, at least 700 nm, at least 800 nm, at least 900 nm, at least 1000 nm, at least 1100 nm, at least 1200 nm, at least 1300 nm, at least 1400 nm, at least 1500 nm, at least 1600 nm, at least 1700 nm, at least 1800 nm, at least 1900 nm, at least 2000 nm, at least 2100 nm, at least 2200 nm, at least 2300 nm, at least 2400 nm, at least 2500 nm, at least 2600 nm, at least 2700 nm, at least 2800 nm, at least 2900 nm, at least 3000 nm, at least 3100 nm, at least 3200 nm, at least 3300 nm, at least 3400 nm, at least 3500 nm, at least 3600 nm, at least 3700 nm, at least 3800 nm, at least 3900 nm, at least 4000 nm, at least 4100 nm, at least 4200 nm, at least 4300 nm, at least 4400 nm, at least 4500 nm, at least 4600 nm, at least 4700 nm, at least 4800 nm, at least 4900 nm, at least 5000 nm, at least 5100 nm, at least 5200 nm, at least 5300 nm, at least 5400 nm, at least 5500 nm, at least 5600 nm, at least 5700 nm, at least 5800 nm, at least 5900 nm, at least 6000 nm, at least 6100 nm, at least 6200 nm, at least 6300 nm, at least 6400 nm, at least 6500 nm, at least 6600 nm, at least 6700 nm, at least 6800 nm, at least 6900 nm, at least 7000 nm, at least 7100 nm, at least 7200 nm, at least 7300 nm, at least 7400 nm, at least 7500 nm, at least 7600 nm, at least 7700 nm, at least 7800 nm, at least 7900 nm, at least 8000 nm, at least 8100 nm, at least 8200 nm, at least 8300 nm, at least 8400 nm, at least 8500 nm, at least 8600 nm, at least 8700 nm, at least 8800 nm, at least 8900 nm, at least 9000 nm, at least 9100 nm, at least 9200 nm, at least 9300 nm, at least 9400 nm, at least 9500 nm, at least 9600 nm, at least 9700 nm, at least 9800 nm, at least 9900 nm, at least 10000 nm or from 10 nm to 50 nm, from 50 nm to 100 nm, from 100 nm to 150 nm, from 150 nm to 200 nm, from 200 nm to 250 nm, from 250 nm to 300 nm, from 300 nm to 350 nm, from 350 nm to 400 nm, from 400 nm to 450 nm, from 450 nm to 500 nm, from 500 nm to 550 nm, from 550 nm to 600 nm, from 600 nm to 650 nm, from 650 nm to 700 nm, from 700 nm to 750 nm, from 750 nm to 800 nm, from 800 nm to 850 nm, from 850 nm to 900 nm, from 100 nm to 300 nm, from 150 nm to 350 nm, from 200 nm to 400 nm, from 250 nm to 450 nm, from 300 nm to 500 nm, from 350 nm to 550 nm, from 400 nm to 600 nm, from 450 nm to 650 nm, from 500 nm to 700 nm, from 550 nm to 750 nm, from 600 nm to 800 nm, from 650 nm to 850 nm, from 700 nm to 900 nm, or from 10 nm to 900 nm, from 10 to 100 nm, from 100 to

200 nm, from 200 to 300 nm, from 300 to 400 nm, from 400 to 500 nm, from 500 to 600 nm, from 600 to 700 nm, from 700 to 800 nm, from 800 to 900 nm, from 900 to 1000 nm, from 1000 to 1100 nm, from 1100 to 1200 nm, from 1200 to 1300 nm, from 1300 to 1400 nm, from 1400 to 1500 nm, from 1500 to 1600 nm, from 1600 to 1700 nm, from 1700 to 1800 nm, from 1800 to 1900 nm, from 1900 to 2000 nm, from 2000 to 2100 nm, from 2100 to 2200 nm, from 2200 to 2300 nm, from 2300 to 2400 nm, from 2400 to 2500 nm, from 2500 to 2600 nm, from 2600 to 2700 nm, from 2700 to 2800 nm, from 2800 to 2900 nm, from 2900 to 3000 nm, from 3000 to 3100 nm, from 3100 to 3200 nm, from 3200 to 3300 nm, from 3300 to 3400 nm, from 3400 to 3500 nm, from 3500 to 3600 nm, from 3600 to 3700 nm, from 3700 to 3800 nm, from 3800 to 3900 nm, from 3900 to 4000 nm, from 4000 to 4100 nm, from 4100 to 4200 nm, from 4200 to 4300 nm, from 4300 to 4400 nm, from 4400 to 4500 nm, from 4500 to 4600 nm, from 4600 to 4700 nm, from 4700 to 4800 nm, from 4800 to 4900 nm, from 4900 to 5000 nm, from 5000 to 5100 nm, from 5100 to 5200 nm, from 5200 to 5300 nm, from 5300 to 5400 nm, from 5400 to 5500 nm, from 5500 to 5600 nm, from 5600 to 5700 nm, from 5700 to 5800 nm, from 5800 to 5900 nm, from 5900 to 6000 nm, from 6000 to 6100 nm, from 6100 to 6200 nm, from 6200 to 6300 nm, from 6300 to 6400 nm, from 6400 to 6500 nm, from 6500 to 6600 nm, from 6600 to 6700 nm, from 6700 to 6800 nm, from 6800 to 6900 nm, from 6900 to 7000 nm, from 7000 to 7100 nm, from 7100 to 7200 nm, from 7200 to 7300 nm, from 7300 to 7400 nm, from 7400 to 7500 nm, from 7500 to 7600 nm, from 7600 to 7700 nm, from 7700 to 7800 nm, from 7800 to 7900 nm, from 7900 to 8000 nm, from 8000 to 8100 nm, from 8100 to 8200 nm, from 8200 to 8300 nm, from 8300 to 8400 nm, from 8400 to 8500 nm, from 8500 to 8600 nm, from 8600 to 8700 nm, from 8700 to 8800 nm, from 8800 to 8900 nm, from 8900 to 9000 nm, from 9000 to 9100 nm, from 9100 to 9200 nm, from 9200 to 9300 nm, from 9300 to 9400 nm, from 9400 to 9500 nm, from 9500 to 9600 nm, from 9600 to 9700 nm, from 9700 to 9800 nm, from 9800 to 9900 nm, from 9900 to 10000 nm. The diameter can be measured by dynamic light scattering (DLS) as an indirect measure of size. The DLS measurement can be an 'intensity-weighted' average, which means the size distribution that the mean is calculated from can be weighted by the sixth power of radius. This can be referred to herein as 'z-average' or 'intensity-mean'.

[0132] Alternatively, particles disclosed herein can have a radius of at least 10 nm, at least 100 nm, at least 200 nm, at least 300 nm, at least 400 nm, at least 500 nm, at least 600 nm, at least 700 nm, at least 800 nm, at least 900 nm, at least 1000 nm, at least 1100 nm, at least 1200 nm, at least 1300 nm, at least 1400 nm, at least 1500 nm, at least 1600 nm, at least 1700 nm, at least 1800 nm, at least 1900 nm, at least 2000 nm, at least 2100 nm, at least 2200 nm, at least 2300 nm, at least 2400 nm, at least 2500 nm, at least 2600 nm, at least 2700 nm, at least 2800 nm, at

least 2900 nm, at least 3000 nm, at least 3100 nm, at least 3200 nm, at least 3300 nm, at least 3400 nm, at least 3500 nm, at least 3600 nm, at least 3700 nm, at least 3800 nm, at least 3900 nm, at least 4000 nm, at least 4100 nm, at least 4200 nm, at least 4300 nm, at least 4400 nm, at least 4500 nm, at least 4600 nm, at least 4700 nm, at least 4800 nm, at least 4900 nm, at least 5000 nm, at least 5100 nm, at least 5200 nm, at least 5300 nm, at least 5400 nm, at least 5500 nm, at least 5600 nm, at least 5700 nm, at least 5800 nm, at least 5900 nm, at least 6000 nm, at least 6100 nm, at least 6200 nm, at least 6300 nm, at least 6400 nm, at least 6500 nm, at least 6600 nm, at least 6700 nm, at least 6800 nm, at least 6900 nm, at least 7000 nm, at least 7100 nm, at least 7200 nm, at least 7300 nm, at least 7400 nm, at least 7500 nm, at least 7600 nm, at least 7700 nm, at least 7800 nm, at least 7900 nm, at least 8000 nm, at least 8100 nm, at least 8200 nm, at least 8300 nm, at least 8400 nm, at least 8500 nm, at least 8600 nm, at least 8700 nm, at least 8800 nm, at least 8900 nm, at least 9000 nm, at least 9100 nm, at least 9200 nm, at least 9300 nm, at least 9400 nm, at least 9500 nm, at least 9600 nm, at least 9700 nm, at least 9800 nm, at least 9900 nm, at least 10000 nm or from 10 nm to 50 nm, from 50 nm to 100 nm, from 100 nm to 150 nm, from 150 nm to 200 nm, from 200 nm to 250 nm, from 250 nm to 300 nm, from 300 nm to 350 nm, from 350 nm to 400 nm, from 400 nm to 450 nm, from 450 nm to 500 nm, from 500 nm to 550 nm, from 550 nm to 600 nm, from 600 nm to 650 nm, from 650 nm to 700 nm, from 700 nm to 750 nm, from 750 nm to 800 nm, from 800 nm to 850 nm, from 850 nm to 900 nm, from 100 nm to 300 nm, from 150 nm to 350 nm, from 200 nm to 400 nm, from 250 nm to 450 nm, from 300 nm to 500 nm, from 350 nm to 550 nm, from 400 nm to 600 nm, from 450 nm to 650 nm, from 500 nm to 700 nm, from 550 nm to 750 nm, from 600 nm to 800 nm, from 650 nm to 850 nm, from 700 nm to 900 nm, or from 10 nm to 900 nm, from 10 to 100 nm, from 100 to 200 nm, from 200 to 300 nm, from 300 to 400 nm, from 400 to 500 nm, from 500 to 600 nm, from 600 to 700 nm, from 700 to 800 nm, from 800 to 900 nm, from 900 to 1000 nm, from 1000 to 1100 nm, from 1100 to 1200 nm, from 1200 to 1300 nm, from 1300 to 1400 nm, from 1400 to 1500 nm, from 1500 to 1600 nm, from 1600 to 1700 nm, from 1700 to 1800 nm, from 1800 to 1900 nm, from 1900 to 2000 nm, from 2000 to 2100 nm, from 2100 to 2200 nm, from 2200 to 2300 nm, from 2300 to 2400 nm, from 2400 to 2500 nm, from 2500 to 2600 nm, from 2600 to 2700 nm, from 2700 to 2800 nm, from 2800 to 2900 nm, from 2900 to 3000 nm, from 3000 to 3100 nm, from 3100 to 3200 nm, from 3200 to 3300 nm, from 3300 to 3400 nm, from 3400 to 3500 nm, from 3500 to 3600 nm, from 3600 to 3700 nm, from 3700 to 3800 nm, from 3800 to 3900 nm, from 3900 to 4000 nm, from 4000 to 4100 nm, from 4100 to 4200 nm, from 4200 to 4300 nm, from 4300 to 4400 nm, from 4400 to 4500 nm, from 4500 to 4600 nm, from 4600 to 4700 nm, from 4700 to 4800 nm, from 4800 to 4900 nm, from 4900 to 5000

nm, from 5000 to 5100 nm, from 5100 to 5200 nm, from 5200 to 5300 nm, from 5300 to 5400 nm, from 5400 to 5500 nm, from 5500 to 5600 nm, from 5600 to 5700 nm, from 5700 to 5800 nm, from 5800 to 5900 nm, from 5900 to 6000 nm, from 6000 to 6100 nm, from 6100 to 6200 nm, from 6200 to 6300 nm, from 6300 to 6400 nm, from 6400 to 6500 nm, from 6500 to 6600 nm, from 6600 to 6700 nm, from 6700 to 6800 nm, from 6800 to 6900 nm, from 6900 to 7000 nm, from 7000 to 7100 nm, from 7100 to 7200 nm, from 7200 to 7300 nm, from 7300 to 7400 nm, from 7400 to 7500 nm, from 7500 to 7600 nm, from 7600 to 7700 nm, from 7700 to 7800 nm, from 7800 to 7900 nm, from 7900 to 8000 nm, from 8000 to 8100 nm, from 8100 to 8200 nm, from 8200 to 8300 nm, from 8300 to 8400 nm, from 8400 to 8500 nm, from 8500 to 8600 nm, from 8600 to 8700 nm, from 8700 to 8800 nm, from 8800 to 8900 nm, from 8900 to 9000 nm, from 9000 to 9100 nm, from 9100 to 9200 nm, from 9200 to 9300 nm, from 9300 to 9400 nm, from 9400 to 9500 nm, from 9500 to 9600 nm, from 9600 to 9700 nm, from 9700 to 9800 nm, from 9800 to 9900 nm, from 9900 to 10000 nm.

[0133] In certain examples, the particles disclosed herein have a diameter of 100 nm to 400 nm. In other examples, the particles disclosed herein have a radius of 100 nm to 400 nm. Particle size can be determined by a number of techniques, such as dynamic light scattering or electron microscopy (e.g., SEM, TEM). Particles disclosed herein can be nanoparticles or microparticles. **[0134]** Additionally, particles can have a homogenous size distribution or a heterogeneous size distribution. Polydispersity index (PDI), which can be measured by techniques such as dynamic light scattering, is a measure of the size distribution. A low PDI indicates a more homogeneous size distribution and a higher PDI indicates a more heterogeneous size distribution. For example, particles disclosed herein can have a PDI of less than 0.5, less than 0.4, less than 0.3, less than 0.2, less than 0.15, or less than 0.1. In particular embodiments, the particles disclosed herein have a PDI of less than 0.1.

[0135] Particles disclosed herein can have a range of different surface charges. Particles can be negatively charged, positively charged, or neutral in charge. In some embodiments, particles have a surface charge of -500 mV to -450 mV, -450 mV to -400 mV, -400 mV to -350 mV, -350 mV to -300 mV, -300 mV to -250 mV, -250 mV to -200 mV, -200 mV to -150 mV, -150 mV to -100 mV, -100 mV to -90 mV, -90 mV to -80 mV, -80 mV to -70 mV, -70 mV to -60 mV, -60 mV to -50 mV, -50 mV to -40 mV, -40 mV to -30 mV, -30 mV to -20 mV, -20 mV to -10 mV, -10 mV to 0 mV, 0 mV to 10 mV, 10 mV to 20 mV, 20 mV to 30 mV, 30 mV to 40 mV, 40 mV to 50 mV, 50 mV to 60 mV, 60 mV to 70 mV, 70 mV to 80 mV, 80 mV to 90 mV, 90 mV to 100 mV, 100 mV to 110 mV, 110 mV to 120 mV, 120 mV to 130 mV, 130 mV to 140 mV, 140 mV to 150 mV, 150 mV to 200 mV, 200 mV to 250 mV, 250 mV to 300 mV, 300 mV to 350 mV,

350 mV to 400 mV, 400 mV to 450 mV, 450 mV to 500 mV, -500 mv to -400 mV, -400 mv to -300 mV, -300 mv to -200 mV, -200 mv to -100 mV, -100 mv to 0 mV, 0 mv to 100 mV, 100 mv to 200 mV, 200 mv to 300 mV, 300 mv to 400 mV, or 400 mv to 500 mV. In particular examples, particles disclosed herein have a surface charge of -60 mV to 60 mV.

[0136] Various particle morphologies are consistent with the particle types in panels of the present disclosure. For example, particles may be spherical, colloidal, cube shaped, square shaped, rods, wires, cones, pyramids, and oblong. Particles of the present disclosure may be solid particles, porous particles, or meso porous particles. Particles may have a small surface area or a large surface area. Particles may have varied magnetic properties that can be measured by SQUID, which determines magnetism in response to an external field. In some cases, particles have a core-shell or yolk-shell structure.

Particle Panels

[0137] The particle panels disclosed herein can be used to identifying a number of proteins, peptides, or protein groups using the Proteograph workflow described herein (MS analysis of distinct biomolecule coronas corresponding to distinct particle types in the particle panel). Feature intensities, as disclosed herein, refers to the intensity of a discrete spike (“feature”) seen on a plot of mass to charge ratio versus intensity from a mass spectrometry run of a sample. These features can correspond to variably ionized fragments of peptides and/or proteins. Using the data analysis methods described herein, feature intensities can be sorted into protein groups. Protein groups refer to two or more proteins that are identified by a shared peptide sequence. Alternatively, a protein group can refer to one protein that is identified using a unique identifying sequence. For example, if in a sample, a peptide sequence is assayed that is shared between two proteins (Protein 1: XYZZX and Protein 2: XYZYZ), a protein group could be the “XYZ protein group” having two members (protein 1 and protein 2). Alternatively, if the peptide sequence is unique to a single protein (Protein 1), a protein group could be the “ZZX” protein group having one member (Protein 1). Each protein group can be supported by more than one peptide sequence. Protein detected or identified according to the instant disclosure can refer to a distinct protein detected in the sample (e.g., distinct relative other proteins detected using mass spectrometry). Thus, analysis of proteins present in distinct coronas corresponding to the distinct particle types in a particle panel, yields a high number of feature intensities. This number decreases as feature intensities are processed into distinct peptides, further decreases as distinct peptides are processed into distinct proteins, and further decreases as peptides are grouped into protein groups (two or more proteins that share a distinct peptide sequence).

[0138] The particle panels disclosed herein can be used to identify at least at least 100 proteins, at least 200 proteins, at least 300 proteins, at least 400 proteins, at least 500 proteins, at least 600 proteins, at least 700 proteins, at least 800 proteins, at least 900 proteins, at least 1000 proteins, at least 1100 proteins, at least 1200 proteins, at least 1300 proteins, at least 1400 proteins, at least 1500 proteins, at least 1600 proteins, at least 1700 proteins, at least 1800 proteins, at least 1900 proteins, at least 2000 proteins, at least 2100 proteins, at least 2200 proteins, at least 2300 proteins, at least 2400 proteins, at least 2500 proteins, at least 2600 proteins, at least 2700 proteins, at least 2800 proteins, at least 2900 proteins, at least 3000 proteins, at least 3100 proteins, at least 3200 proteins, at least 3300 proteins, at least 3400 proteins, at least 3500 proteins, at least 3600 proteins, at least 3700 proteins, at least 3800 proteins, at least 3900 proteins, at least 4000 proteins, at least 4100 proteins, at least 4200 proteins, at least 4300 proteins, at least 4400 proteins, at least 4500 proteins, at least 4600 proteins, at least 4700 proteins, at least 4800 proteins, at least 4900 proteins, at least 5000 proteins, at least 10000 proteins, at least 20000 proteins, at least 50000 proteins, at least 100000 proteins, from 100 to 5000 proteins, from 200 to 4700 proteins, from 300 to 4400 proteins, from 400 to 4100 proteins, from 500 to 3800 proteins, from 600 to 3500 proteins, from 700 to 3200 proteins, from 800 to 2900 proteins, from 900 to 2600 proteins, from 1000 to 2300 proteins, from 1000 to 3000 proteins, from 3000 to 4000 proteins, from 4000 to 5000 proteins, from 5000 to 6000 proteins, from 6000 to 7000 proteins, from 7000 to 8000 proteins, from 8000 to 9000 proteins, from 9000 to 10000 proteins, from 10000 to 11000 proteins, from 11000 to 12000 proteins, from 12000 to 13000 proteins, from 13000 to 14000 proteins, from 14000 to 15000 proteins, from 15000 to 16000 proteins, from 16000 to 17000 proteins, from 17000 to 18000 proteins, from 18000 to 19000 proteins, from 19000 to 20000 proteins, from 20000 to 25000 proteins, from 25000 to 30000 proteins, from 10000 to 20000 proteins, from 10000 to 50000 proteins, from 20000 to 100000 proteins, from 2000 to 20000 proteins, from 1800 to 20000 proteins, or from 10000 to 100000 proteins.

[0139] The particle panels disclosed herein can be used to identify at least at least 100 protein groups, at least 200 protein groups, at least 300 protein groups, at least 400 protein groups, at least 500 protein groups, at least 600 protein groups, at least 700 protein groups, at least 800 protein groups, at least 900 protein groups, at least 1000 protein groups, at least 1100 protein groups, at least 1200 protein groups, at least 1300 protein groups, at least 1400 protein groups, at least 1500 protein groups, at least 1600 protein groups, at least 1700 protein groups, at least 1800 protein groups, at least 1900 protein groups, at least 2000 protein groups, at least 2100 protein groups, at least 2200 protein groups, at least 2300 protein groups, at least 2400 protein groups, at

least 2500 protein groups, at least 2600 protein groups, at least 2700 protein groups, at least 2800 protein groups, at least 2900 protein groups, at least 3000 protein groups, at least 3100 protein groups, at least 3200 protein groups, at least 3300 protein groups, at least 3400 protein groups, at least 3500 protein groups, at least 3600 protein groups, at least 3700 protein groups, at least 3800 protein groups, at least 3900 protein groups, at least 4000 protein groups, at least 4100 protein groups, at least 4200 protein groups, at least 4300 protein groups, at least 4400 protein groups, at least 4500 protein groups, at least 4600 protein groups, at least 4700 protein groups, at least 4800 protein groups, at least 4900 protein groups, at least 5000 protein groups, at least 10000 protein groups, at least 20000 protein groups, at least 100000 protein groups, from 100 to 5000 protein groups, from 200 to 4700 protein groups, from 300 to 4400 protein groups, from 400 to 4100 protein groups, from 500 to 3800 protein groups, from 600 to 3500 protein groups, from 700 to 3200 protein groups, from 800 to 2900 protein groups, from 900 to 2600 protein groups, from 1000 to 2300 protein groups, from 1000 to 3000 protein groups, from 3000 to 4000 protein groups, from 4000 to 5000 protein groups, from 5000 to 6000 protein groups, from 6000 to 7000 protein groups, from 7000 to 8000 protein groups, from 8000 to 9000 protein groups, from 9000 to 10000 protein groups, from 10000 to 11000 protein groups, from 11000 to 12000 protein groups, from 12000 to 13000 protein groups, from 13000 to 14000 protein groups, from 14000 to 15000 protein groups, from 15000 to 16000 protein groups, from 16000 to 17000 protein groups, from 17000 to 18000 protein groups, from 18000 to 19000 protein groups, from 19000 to 20000 protein groups, from 20000 to 25000 protein groups, from 25000 to 30000 protein groups, from 10000 to 20000 protein groups, from 10000 to 50000 protein groups, from 20000 to 100000 protein groups, from 2000 to 20000 protein groups, from 1800 to 20000 protein groups, or from 10000 to 100000 protein groups.

[0140] The particle panels disclosed herein can be used to identify the number of distinct proteins disclosed herein, and/or any of the specific proteins disclosed herein, over a wide dynamic range. For example, the particle panels disclosed herein comprising distinct particle types, can enrich for proteins in a sample, which can be identified using the Proteograph workflow, over the entire dynamic range at which proteins are present in a sample (e.g., a plasma sample). In some embodiments, a particle panel including any number of distinct particle types disclosed herein, enriches and identifies proteins over a dynamic range of at least 2. In some embodiments, a particle panel including any number of distinct particle types disclosed herein, enriches and identifies proteins over a dynamic range of at least 3. In some embodiments, a particle panel including any number of distinct particle types disclosed herein, enriches and identifies proteins over a dynamic range of at least 4. In some embodiments, a particle panel

including any number of distinct particle types disclosed herein, enriches and identifies proteins over a dynamic range of at least 5. In some embodiments, a particle panel including any number of distinct particle types disclosed herein, enriches and identifies proteins over a dynamic range of at least 6. In some embodiments, a particle panel including any number of distinct particle types disclosed herein, enriches and identifies proteins over a dynamic range of at least 7. In some embodiments, a particle panel including any number of distinct particle types disclosed herein, enriches and identifies proteins over a dynamic range of at least 8. In some embodiments, a particle panel including any number of distinct particle types disclosed herein, enriches and identifies proteins over a dynamic range of at least 9. In some embodiments, a particle panel including any number of distinct particle types disclosed herein, enriches and identifies proteins over a dynamic range of at least 10. In some embodiments, a particle panel including any number of distinct particle types disclosed herein, enriches and identifies proteins over a dynamic range of at least 11. In some embodiments, a particle panel including any number of distinct particle types disclosed herein, enriches and identifies proteins over a dynamic range of at least 12. In some embodiments, a particle panel including any number of distinct particle types disclosed herein, enriches and identifies proteins over a dynamic range of at least 13. In some embodiments, a particle panel including any number of distinct particle types disclosed herein, enriches and identifies proteins over a dynamic range of at least 14. In some embodiments, a particle panel including any number of distinct particle types disclosed herein, enriches and identifies proteins over a dynamic range of at least 15. In some embodiments, a particle panel including any number of distinct particle types disclosed herein, enriches and identifies proteins over a dynamic range of at least 20. In some embodiments, a particle panel including any number of distinct particle types disclosed herein, enriches and identifies proteins over a dynamic range of from 2 to 100. In some embodiments, a particle panel including any number of distinct particle types disclosed herein, enriches and identifies proteins over a dynamic range of from 2 to 20. In some embodiments, a particle panel including any number of distinct particle types disclosed herein, enriches and identifies proteins over a dynamic range of from 2 to 10. In some embodiments, a particle panel including any number of distinct particle types disclosed herein, enriches and identifies proteins over a dynamic range of from 2 to 5. In some embodiments, a particle panel including any number of distinct particle types disclosed herein, enriches and identifies proteins over a dynamic range of from 5 to 10.

[0141] A particle panel including any number of distinct particle types disclosed herein, enriches and identifies a single protein or protein group. In some embodiments, the single protein or protein group may comprise proteins having different post-translational modifications. For

example, a first particle type in the particle panel may enrich a protein or protein group having a first post-translational modification, a second particle type in the particle panel may enrich the same protein or same protein group having a second post-translational modification, and a third particle type in the particle panel may enrich the same protein or same protein group lacking a post-translational modification. In some embodiments, the particle panel including any number of distinct particle types disclosed herein, enriches and identifies a single protein or protein group by binding different domains, sequences, or epitopes of the single protein or protein group. For example, a first particle type in the particle panel may enrich a protein or protein by binding to a first domain of the protein or protein group, and a second particle type in the particle panel may enrich the same protein or same protein group by binding to a second domain of the protein or protein group.

[0142] In some embodiments, particle panels can have more than one particle types. Increasing the number of particle types in a panel can be a method for increasing the number of proteins that can be identified in a given sample. An example of how increasing panel size may increase the number of identified proteins is shown in **FIG. 11**. For example, as shown in **FIG. 11**, a panel size of one particle type identified 419 unique proteins, a panel size of two particle types identified 588 proteins, a panel size of three particle types identified 727 proteins, a panel size of four particle types identified 844 proteins, a panel size of five particle types identified 934 proteins, a panel size of six particle types identified 1008 proteins, a panel size of seven particle types identified 1075 proteins, a panel size of eight particle types identified 1133 proteins, a panel size of nine particle types identified 1184 proteins, a panel size of 10 particle types identified 1230 proteins, a panel size of 11 particle types identified 1275 proteins, and a panel size of 12 particle types identified 1318 proteins. The particle types may include nanoparticle types.

[0143] In some embodiments, a panel size of one particle type is capable of identifying 200 to 600 unique proteins. In some embodiments, a panel size of two particle types is capable of identifying 300 to 700 unique proteins. In some embodiments, a panel size of three particle types is capable of identifying 500 to 900 unique proteins. In some embodiments, a panel size of four particle types is capable of identifying 600 to 1000 unique proteins. In some embodiments, a panel size of five particle types is capable of identifying 700 to 1100 unique proteins. In some embodiments, a panel size of six particle types is capable of identifying 800 to 1200 unique proteins. In some embodiments, a panel size of seven particle types is capable of identifying 850 to 1250 unique proteins. In some embodiments, a panel size of eight particle types is capable of identifying 900 to 1300 unique proteins. In some embodiments, a panel size of nine particle

types is capable of identifying 950 to 1350 unique proteins. In some embodiments, a panel size of 10 particle types is capable of identifying 1000 to 1400 unique proteins. In some embodiments, a panel size of 11 particle types is capable of identifying 1050 to 1450 unique proteins. In some embodiments, a panel size of 12 particle types is capable of identifying 1100 to 1500 unique proteins. The particle types may include nanoparticle types.

[0144] The present disclosure provides over 200 distinct particle types, with over 100 different surface chemistries, and over 50 diverse physical properties. Distinct particle types comprise at least one physicochemical property that differs between a first particle type and a second particle type. For example, the present disclosure provides a particle panel having at least 2 distinct particle types, at least 3 distinct particle types, at least 4 distinct particle types, at least 5 distinct particle types, at least 6 distinct particle types, at least 7 distinct particle types, at least 8 distinct particle types, at least 9 distinct particle types, at least 10 distinct particle types, at least 11 distinct particle types, at least 12 distinct particle types, at least 13 distinct particle types, at least 14 distinct particle types, at least 15 distinct particle types, at least 20 distinct particle types, at least 25 distinct particle types, at least 30 distinct particle types, at least 35 distinct particle types, at least 40 distinct particle types, at least 45 distinct particle types, at least 50 distinct particle types, at least 100 distinct particle types, at least 150 distinct particle types, at least 200 distinct particle types, at least 250 distinct particle types, at least 300 distinct particle types, at least 350 distinct particle types, at least 400 distinct particle types, at least 450 distinct particle types, at least 500 distinct particle types, from 2 to 500 distinct particle types, from 2 to 5 distinct particle types, from 5 to 10 distinct particle types, from 10 to 15 distinct particle types, from 15 to 20 distinct particle types, from 20 to 40 distinct particle types, from 40 to 60 distinct particle types, from 60 to 80 distinct particle types, from 80 to 100 distinct particle types, from 100 to 500 distinct particle types, from 4 to 15 distinct particle types, or from 2 to 20 distinct particle types. The particle types may include nanoparticle types.

[0145] In some embodiments, the present disclosure provide a panel size of at least 1 particle distinct type, at least 2 distinct particle types, at least 3 distinct particle types, at least 4 distinct particle types, at least 5 distinct particle types, at least 6 distinct particle types, at least 7 distinct particle types, at least 8 distinct particle types, at least 9 distinct particle types, at least 10 distinct particle types, at least 11 distinct particle types, at least 12 distinct particle types, at least 13 distinct particle types, at least 14 distinct particle types, at least 15 distinct particle types, at least 16 distinct particle types, at least 17 distinct particle types, at least 18 distinct particle types, at least 19 distinct particle types, at least 20 distinct particle types, at least 25 distinct particle types, at least 30 distinct particle types, at least 35 distinct particle types, at least 40 distinct particle

types, at least 45 distinct particle types, at least 50 distinct particle types, at least 55 distinct particle types, at least 60 distinct particle types, at least 65 distinct particle types, at least 70 distinct particle types, at least 75 distinct particle types, at least 80 distinct particle types, at least 85 distinct particle types, at least 90 distinct particle types, at least 95 distinct particle types, at least 100 distinct particle types, from 1 to 5 distinct particle types, from 5 to 10 distinct particle types, from 10 to 15 distinct particle types, from 15 to 20 distinct particle types, from 20 to 25 distinct particle types, from 25 to 30 distinct particle types, from 30 to 35 distinct particle types, from 35 to 40 distinct particle types, from 40 to 45 distinct particle types, from 45 to 50 distinct particle types, from 50 to 55 distinct particle types, from 55 to 60 distinct particle types, from 60 to 65 distinct particle types, from 65 to 70 distinct particle types, from 70 to 75 distinct particle types, from 75 to 80 distinct particle types, from 80 to 85 distinct particle types, from 85 to 90 distinct particle types, from 90 to 95 distinct particle types, from 95 to 100 distinct particle types, from 1 to 100 distinct particle types, from 20 to 40 distinct particle types, from 5 to 10 distinct particle types, from 3 to 7 distinct particle types, from 2 to 10 distinct particle types, from 6 to 15 distinct particle types, or from 10 to 20 distinct particle types. In particular embodiments, the present disclosure provides a panel size of from 3 to 10 particle types. In particular embodiments, the present disclosure provides a panel size of from 4 to 11 distinct particle types. In particular embodiments, the present disclosure provides a panel size of from 5 to 15 distinct particle types. In particular embodiments, the present disclosure provides a panel size of from 5 to 15 distinct particle types. In particular embodiments, the present disclosure provides a panel size of from 8 to 12 distinct particle types. In particular embodiments, the present disclosure provides a panel size of from 9 to 13 distinct particle types. In particular embodiments, the present disclosure provides a panel size of 10 distinct particle types. The particle types may include nanoparticle types.

[0146] For example, the present disclosure provides a particle panel having at least 2 distinct particle types, at least 3 different surface chemistries, at least 4 different surface chemistries, at least 5 different surface chemistries, at least 6 different surface chemistries, at least 7 different surface chemistries, at least 8 different surface chemistries, at least 9 different surface chemistries, at least 10 different surface chemistries, at least 11 different surface chemistries, at least 12 different surface chemistries, at least 13 different surface chemistries, at least 14 different surface chemistries, at least 15 different surface chemistries, at least 20 different surface chemistries, at least 25 different surface chemistries, at least 30 different surface chemistries, at least 35 different surface chemistries, at least 40 different surface chemistries, at least 45 different surface chemistries, at least 50 different surface chemistries, at least 100 different

surface chemistries, at least 150 different surface chemistries, at least 200 different surface chemistries, at least 250 different surface chemistries, at least 300 different surface chemistries, at least 350 different surface chemistries, at least 400 different surface chemistries, at least 450 different surface chemistries, at least 500 different surface chemistries, from 2 to 500 different surface chemistries, from 2 to 5 different surface chemistries, from 5 to 10 different surface chemistries, from 10 to 15 different surface chemistries, from 15 to 20 different surface chemistries, from 20 to 40 different surface chemistries, from 40 to 60 different surface chemistries, from 60 to 80 different surface chemistries, from 80 to 100 different surface chemistries, from 100 to 500 different surface chemistries, from 4 to 15 different surface chemistries, or from 2 to 20 different surface chemistries.

[0147] The present disclosure provides a particle panel having at least 2 different surface chemistries, at least 3 different surface chemistries, at least 4 different surface chemistries, at least 5 different surface chemistries, at least 6 different surface chemistries, at least 7 different surface chemistries, at least 8 different surface chemistries, at least 9 different surface chemistries, at least 10 different surface chemistries, at least 11 different surface chemistries, at least 12 different surface chemistries, at least 13 different surface chemistries, at least 14 different surface chemistries, at least 15 different surface chemistries, at least 20 different surface chemistries, at least 25 different surface chemistries, at least 30 different surface chemistries, at least 35 different surface chemistries, at least 40 different surface chemistries, at least 45 different surface chemistries, at least 50 different surface chemistries, at least 100 different surface chemistries, at least 150 different surface chemistries, at least 200 different surface chemistries, at least 250 different surface chemistries, at least 300 different surface chemistries, at least 350 different surface chemistries, at least 400 different surface chemistries, at least 450 different surface chemistries, at least 500 different surface chemistries, from 2 to 500 different surface chemistries, from 2 to 5 different surface chemistries, from 5 to 10 different surface chemistries, from 10 to 15 different surface chemistries, from 15 to 20 different surface chemistries, from 20 to 40 different surface chemistries, from 40 to 60 different surface chemistries, from 60 to 80 different surface chemistries, from 80 to 100 different surface chemistries, from 100 to 500 different surface chemistries, from 4 to 15 different surface chemistries, or from 2 to 20 different surface chemistries.

[0148] The present disclosure provides a particle panel having at least 2 different physical properties, at least 3 different physical properties, at least 4 different physical properties, at least 5 different physical properties, at least 6 different physical properties, at least 7 different physical properties, at least 8 different physical properties, at least 9 different physical properties, at least

10 different physical properties, at least 11 different physical properties, at least 12 different physical properties, at least 13 different physical properties, at least 14 different physical properties, at least 15 different physical properties, at least 20 different physical properties, at least 25 different physical properties, at least 30 different physical properties, at least 35 different physical properties, at least 40 different physical properties, at least 45 different physical properties, at least 50 different physical properties, at least 100 different physical properties, at least 150 different physical properties, at least 200 different physical properties, at least 250 different physical properties, at least 300 different physical properties, at least 350 different physical properties, at least 400 different physical properties, at least 450 different physical properties, at least 500 different physical properties, from 2 to 500 different physical properties, from 2 to 5 different physical properties, from 5 to 10 different physical properties, from 10 to 15 different physical properties, from 15 to 20 different physical properties, from 20 to 40 different physical properties, from 40 to 60 different physical properties, from 60 to 80 different physical properties, from 80 to 100 different physical properties, from 100 to 500 different physical properties, from 4 to 15 different physical properties, or from 2 to 20 different physical properties.

[0149] In some embodiments, panels that optimally identify proteins and associate biomarkers with diseases include panels selected from the particle types described in **TABLE 1**. For example, a panel that optimally identifies proteins and associate biomarkers with diseases include panels comprising SP-339, HX74, SP-356, SP-333, HX20, SP-374, HX42, SP-003, SP-007, and SP-011. Particle panels especially suitable to identifying high numbers of proteins (e.g., greater than 1500 proteins) in a sample include from 5 to 10 distinct particle types in an assay. The number of distinct particle types included in a particle panel can be tuned for a specific application (e.g., detection of a particular subset of proteins or detection of a group of markers associated with a particular disease). In some embodiments, panels with physicochemically distinct particle types that optimally identify proteins and associate biomarkers with diseases include silica-coated SPIONs, acrylamide-based SPIONs, and acrylate-based SPIONs. For example, a panel of particles disclosed herein that generates information rich proteomic data via their protein coronas, which can be associated with biomarkers and diseases with high sensitivity and specificity include silica-coated SPIONs (SP-003), poly(N-(3-(dimethylamino)propyl) methacrylamide) (PDMAPMA)-coated SPIONs (SP-007), and poly(oligo(ethylene glycol) methyl ether methacrylate) (POEGMA)-coated SPIONs (SP-011).

[0150] In some embodiments, the entire assay time from a single pooled plasma, including sample preparation and LC-MS, can be about 8 hours. In some embodiments, the entire assay

time from a single pooled plasma, including sample preparation and LC-MS, can be about at least 1 hour, at least 2 hours, at least 3 hours, at least 4 hours, at least 5 hours, at least 6 hours, at least 7 hours, at least 8 hours, at least 9 hours, at least 10 hours, under 20 hours, under 19 hours, under 18 hours, under 17 hours, under 16 hours, under 15 hours, under 14 hours, under 13 hours, under 12 hours, under 11 hours, under 10 hours, under 9 hours, under 8 hours, under 7 hours, under 6 hours, under 5 hours, under 4 hours, under 3 hours, under 2 hours, under 1 hour, at least 5 min to 10 min, at least 10 min to 20 min, at least 20 min to 30 min, at least 30 min to 40 min, at least 40 min to 50 min, at least 50 min to 60 min, at least 1 hour to 1.5 hours, at least 1.5 hour to 2 hours, at least 2 hour to 2.5 hours, at least 2.5 hour to 3 hours, at least 3 hour to 3.5 hours, at least 3.5 hour to 4 hours, at least 4 hour to 4.5 hours, at least 4.5 hour to 5 hours, at least 5 hour to 5.5 hours, at least 5.5 hour to 6 hours, at least 6 hour to 6.5 hours, at least 6.5 hour to 7 hours, at least 7 hour to 7.5 hours, at least 7.5 hour to 8 hours, at least 8 hour to 8.5 hours, at least 8.5 hour to 9 hours, at least 9 hour to 9.5 hours, or at least 9.5 hour to 10 hours.

Early Stage Detection

[0151] The panels and methods of use thereof described herein can be used for detection of markers in a sample from a subject, which are consistent with a particular disease state. As shown in **FIG. 18A** and **FIG. 18B**, early stage cancers can be separated up to 8 years before symptoms develop. The Golestan Cohort enrolled 50,000 healthy subjects between 2004 and 2008. As shown in **FIG. 18A**, banked plasma from enrollment was tested. 8 years after enrollment, approximately 1000 patients developed cancers. **FIG. 18B** illustrates classification of three cancers, Brain, Lung and Pancreatic from banked plasma, are classified by principle component analysis. Here, the corona results are plotted against the three principle component axes, showing three distinct statistical populations. corona analysis (involving measurement of multiple properties in order to profile a plurality of proteins) of banked plasma from enrollment date accurately classified cancers for 15 out of 15 subjects examined (5 patients each for 3 cancers). In some embodiments, the panels of the present disclosure can be used to diagnose a disease state up to one year prior, up to two years prior, up to three years prior, up to four years prior, up to five years prior, up to six years prior, up to seven years prior, up to eight years prior, up to nine years prior, up to 10 years prior, up to 15 years prior, up to 20 years prior, or up to 25 years prior to development of symptoms of that disease state.

[0152] The panels of the present disclosure can be used to detect a wide range of disease states in a given sample. For example, the panels of the present disclosure can be used to detect a cancer. The cancer may be brain cancer, lung cancer, pancreatic cancer, glioblastoma,

meningioma, myeloma, or pancreatic cancer. Corona analysis signals for these cancers are shown in **FIG. 17B** and **FIG. 18**.

[0153] The panels of the present disclosure can additionally be used to detect other cancers, such as any one of the cancers listed on <https://www.cancer.gov/types>, including acute lymphoblastic leukemia (ALL); acute myeloid leukemia (AML); cancer in adolescents; adrenocortical carcinoma; childhood adrenocortical carcinoma; unusual cancers of childhood; AIDS-related cancers; kaposi sarcoma (soft tissue sarcoma); AIDS-related lymphoma (lymphoma); primary cns lymphoma (lymphoma); anal cancer; appendix cancer - see gastrointestinal carcinoid tumors; astrocytomas, childhood (brain cancer); atypical teratoid/rhabdoid tumor, childhood, central nervous system (brain cancer); basal cell carcinoma of the skin - see skin cancer; bile duct cancer; bladder cancer; childhood bladder cancer; bone cancer (includes ewing sarcoma and osteosarcoma and malignant fibrous histiocytoma); brain tumors; breast cancer; childhood breast cancer; bronchial tumors, childhood; burkitt lymphoma - see non-hodgkin lymphoma; carcinoid tumor (gastrointestinal); childhood carcinoid tumors; carcinoma of unknown primary; childhood carcinoma of unknown primary; cardiac (heart) tumors, childhood; central nervous system; atypical teratoid/rhabdoid tumor, childhood (brain cancer); embryonal tumors, childhood (brain cancer); germ cell tumor, childhood (brain cancer); primary cns lymphoma; cervical cancer; childhood cervical cancer; childhood cancers; cancers of childhood, unusual; cholangiocarcinoma - see bile duct cancer; chordoma, childhood; chronic lymphocytic leukemia (CLL); chronic myelogenous leukemia (CML); chronic myeloproliferative neoplasms; colorectal cancer; childhood colorectal cancer; craniopharyngioma, childhood (brain cancer); cutaneous t-cell lymphoma - see lymphoma (mycosis fungoides and sézary syndrome); ductal carcinoma in situ (DCIS) - see breast cancer; embryonal tumors, central nervous system, childhood (brain cancer); endometrial cancer (uterine cancer); ependymoma, childhood (brain cancer); esophageal cancer; childhood esophageal cancer; esthesioneuroblastoma (head and neck cancer); ewing sarcoma (bone cancer); extracranial germ cell tumor, childhood; extragonadal germ cell tumor; eye cancer; childhood intraocular melanoma; intraocular melanoma; retinoblastoma; fallopian tube cancer; fibrous histiocytoma of bone, malignant, and osteosarcoma; gallbladder cancer; gastric (stomach) cancer; childhood gastric (stomach) cancer; gastrointestinal carcinoid tumor; gastrointestinal stromal tumors (GIST) (soft tissue sarcoma); childhood gastrointestinal stromal tumors; germ cell tumors; childhood central nervous system germ cell tumors (brain cancer); childhood extracranial germ cell tumors; extragonadal germ cell tumors; ovarian germ cell tumors; testicular cancer; gestational trophoblastic disease; hairy cell leukemia; head and neck cancer; heart tumors, childhood; hepatocellular (liver) cancer; histiocytosis, langerhans cell;

hodgkin lymphoma; hypopharyngeal cancer (head and neck cancer); intraocular melanoma; childhood intraocular melanoma; islet cell tumors, pancreatic neuroendocrine tumors; kaposi sarcoma (soft tissue sarcoma); kidney (renal cell) cancer; langerhans cell histiocytosis; laryngeal cancer (head and neck cancer); leukemia; lip and oral cavity cancer (head and neck cancer); liver cancer; lung cancer (non-small cell and small cell); childhood lung cancer; lymphoma; male breast cancer; malignant fibrous histiocytoma of bone and osteosarcoma; melanoma; childhood melanoma; melanoma, intraocular (eye); childhood intraocular melanoma; merkel cell carcinoma (skin cancer); mesothelioma, malignant; childhood mesothelioma; metastatic cancer; metastatic squamous neck cancer with occult primary (head and neck cancer); midline tract carcinoma with nut gene changes; mouth cancer (head and neck cancer); multiple endocrine neoplasia syndromes; multiple myeloma/plasma cell neoplasms; mycosis fungoides (lymphoma); myelodysplastic syndromes, myelodysplastic/myeloproliferative neoplasms; myelogenous leukemia, chronic (cml); myeloid leukemia, acute (AML); myeloproliferative neoplasms, chronic; nasal cavity and paranasal sinus cancer (head and neck cancer); nasopharyngeal cancer (head and neck cancer); neuroblastoma; non-hodgkin lymphoma; non-small cell lung cancer; oral cancer, lip and oral cavity cancer and oropharyngeal cancer (head and neck cancer); osteosarcoma and malignant fibrous histiocytoma of bone; ovarian cancer; childhood ovarian cancer; pancreatic cancer; childhood pancreatic cancer; pancreatic neuroendocrine tumors (islet cell tumors); papillomatosis (childhood laryngeal); paraganglioma; childhood paraganglioma; paranasal sinus and nasal cavity cancer (head and neck cancer); parathyroid cancer; penile cancer; pharyngeal cancer (head and neck cancer); pheochromocytoma; childhood pheochromocytoma; pituitary tumor; plasma cell neoplasm/multiple myeloma; pleuropulmonary blastoma; pregnancy and breast cancer; primary central nervous system (CNS) lymphoma; primary peritoneal cancer; prostate cancer; rectal cancer; recurrent cancer; renal cell (kidney) cancer; retinoblastoma; rhabdomyosarcoma, childhood (soft tissue sarcoma); salivary gland cancer (head and neck cancer); sarcoma; childhood rhabdomyosarcoma (soft tissue sarcoma); childhood vascular tumors (soft tissue sarcoma); ewing sarcoma (bone cancer); kaposi sarcoma (soft tissue sarcoma); osteosarcoma (bone cancer); soft tissue sarcoma; uterine sarcoma; sézary syndrome (lymphoma); skin cancer; childhood skin cancer; small cell lung cancer; small intestine cancer; soft tissue sarcoma; squamous cell carcinoma of the skin - see skin cancer; squamous neck cancer with occult primary, metastatic (head and neck cancer); stomach (gastric) cancer; childhood stomach (gastric) cancer; t-cell lymphoma, cutaneous - see lymphoma (mycosis fungoides and sézary syndrome); testicular cancer; childhood testicular cancer; throat cancer (head and neck cancer); nasopharyngeal cancer; oropharyngeal cancer; hypopharyngeal

cancer; thymoma and thymic carcinoma; thyroid cancer; transitional cell cancer of the renal pelvis and ureter (kidney (renal cell) cancer); carcinoma of unknown primary; childhood cancer of unknown primary; unusual cancers of childhood; ureter and renal pelvis, transitional cell cancer (kidney (renal cell) cancer; urethral cancer; uterine cancer, endometrial; uterine sarcoma; vaginal cancer; childhood vaginal cancer; vascular tumors (soft tissue sarcoma); vulvar cancer; wilms tumor and other childhood kidney tumors; or cancer in young adults. Further, the particle panels of the present disclosure can be used to detect other disease, such as Alzheimer's disease and multiple sclerosis.

Sample

[0154] The panels of the present disclosure can be used to generate proteomic data from protein coronas and subsequently associated with any of the biological states described herein. Samples consistent with the present disclosure include biological samples from a subject. The subject may be a human or a non-human animal. Biological samples may be a biofluid. For example, the biofluid may be plasma, serum, CSF, urine, tear, cell lysates, tissue lysates, cell homogenates, tissue homogenates, nipple aspirates, fecal samples, synovial fluid and whole blood, or saliva. Samples can also be non-biological samples, such as water, milk, solvents, or anything homogenized into a fluidic state. Said biological samples can contain a plurality of proteins or proteomic data, which may be analyzed after adsorption of proteins to the surface of the various particle types in a panel and subsequent digestion of protein coronas. Proteomic data can comprise nucleic acids, peptides, or proteins. Any of the samples herein can contain a number of different analytes, which can be analyzed using the compositions and methods disclosed herein. The analytes can be proteins, peptides, small molecules, nucleic acids, metabolites, lipids, or any molecule that could potentially bind or interact with the surface of a particle type.

[0155] Disclosed herein are compositions and methods for multi-omic analysis. "Multi-omic(s)" or "multiomic(s)" can refer to an analytical approach for analyzing biomolecules at a large scale, wherein the data sets are multiple omes, such as proteome, genome, transcriptome, lipidome, and metabolome. Non-limiting examples of multi-omic data includes proteomic data, genomic data, lipidomic data, glycomic data, transcriptomic data, or metabolomics data. "Biomolecule" in "biomolecule corona" can refer to any molecule or biological component that can be produced by, or is present in, a biological organism. Non-limiting examples of biomolecules include proteins (protein corona), polypeptides, polysaccharides, a sugar, a lipid, a lipoprotein, a metabolite, an oligonucleotide, a nucleic acid (DNA, RNA, micro RNA, plasmid, single stranded nucleic acid, double stranded nucleic acid), metabolome, as well as small molecules such as primary metabolites, secondary metabolites, and other natural products, or any combination

thereof. In some embodiments, the biomolecule is selected from the group of proteins, nucleic acids, lipids, and metabolomes.

[0156] In some embodiments, a sample of the present disclosure can be a plurality of samples. At least two samples of the plurality of samples can be spatially isolated. Spatially isolated refers to samples that are contained in separate volumes. For example, spatially isolated samples can refer to samples that are in separate wells in a plate or separate tubes. Spatially isolated samples can refer to samples that are in separate wells in a plate or separate tubes and assayed together on the same instrument. In some embodiments, the present disclosure provides particle panels and methods of use thereof that are compatible with analyzing a plurality of samples, such as at least 2 spatially isolated samples, at least 5 spatially isolated samples, at least 10 spatially isolated samples, at least 15 spatially isolated samples, at least 20 spatially isolated samples, at least 25 spatially isolated samples, at least 30 spatially isolated samples, at least 35 spatially isolated samples, at least 40 spatially isolated samples, at least 45 spatially isolated samples, at least 50 spatially isolated samples, at least 55 spatially isolated samples, at least 60 spatially isolated samples, at least 65 spatially isolated samples, at least 70 spatially isolated samples, at least 75 spatially isolated samples, at least 80 spatially isolated samples, at least 85 spatially isolated samples, at least 90 spatially isolated samples, at least 95 spatially isolated samples, at least 96 spatially isolated samples, at least 100 spatially isolated samples, at least 120 spatially isolated samples, at least 140 spatially isolated samples, at least 160 spatially isolated samples, at least 180 spatially isolated samples, at least 200 spatially isolated samples, at least 220 spatially isolated samples, at least 240 spatially isolated samples, at least 260 spatially isolated samples, at least 280 spatially isolated samples, at least 300 spatially isolated samples, at least 320 spatially isolated samples, at least 340 spatially isolated samples, at least 360 spatially isolated samples, at least 380 spatially isolated samples, at least 400 spatially isolated samples, at least 420 spatially isolated samples, at least 440 spatially isolated samples, at least 460 spatially isolated samples, at least 480 spatially isolated samples, at least 500 spatially isolated samples, at least 600 spatially isolated samples, at least 700 spatially isolated samples, at least 800 spatially isolated samples, at least 900 spatially isolated samples, at least 1000 spatially isolated samples, at least 1100 spatially isolated samples, at least 1200 spatially isolated samples, at least 1300 spatially isolated samples, at least 1400 spatially isolated samples, at least 1500 spatially isolated samples, at least 1600 spatially isolated samples, at least 1700 spatially isolated samples, at least 1800 spatially isolated samples, at least 1900 spatially isolated samples, at least 2000 spatially isolated samples, at least 5000 spatially isolated samples, at least 10000 spatially isolated samples, from 2 to 10 spatially isolated samples, from 2 to 100 spatially isolated samples, from 2 to 200 spatially

isolated samples, from 2 to 300 spatially isolated samples, from 50 to 150 spatially isolated samples, from 10 to 20 spatially isolated samples, from 20 to 30 spatially isolated samples, from 30 to 40 spatially isolated samples, from 40 to 50 spatially isolated samples, from 50 to 60 spatially isolated samples, from 60 to 70 spatially isolated samples, from 70 to 80 spatially isolated samples, from 80 to 90 spatially isolated samples, from 90 to 100 spatially isolated samples, from 100 to 150 spatially isolated samples, from 150 to 200 spatially isolated samples, from 200 to 250 spatially isolated samples, from 250 to 300 spatially isolated samples, from 300 to 350 spatially isolated samples, from 350 to 400 spatially isolated samples, from 400 to 450 spatially isolated samples, from 450 to 500 spatially isolated samples, from 500 to 600 spatially isolated samples, from 600 to 700 spatially isolated samples, from 700 to 800 spatially isolated samples, from 800 to 900 spatially isolated samples, from 900 to 1000 spatially isolated samples, from 1000 to 2000 spatially isolated samples, from 2000 to 3000 spatially isolated samples, from 3000 to 4000 spatially isolated samples, from 4000 to 5000 spatially isolated samples, from 5000 to 6000 spatially isolated samples, from 6000 to 7000 spatially isolated samples, from 7000 to 8000 spatially isolated samples, from 8000 to 9000 spatially isolated samples, or from 9000 to 10000 spatially isolated samples.

[0157] The methods disclosed herein include isolating a particle panel (having a plurality of particle types) from one or more than one sample. The particle panels having particle types that are superparamagnetic can be rapidly isolated or separated from the sample using a magnetic. Moreover, multiple samples that are spatially isolated can be processed in parallel. Thus, the methods disclosed herein provide for isolating or separating a particle panel from unbound protein in a plurality of spatially isolated panels at the same time, by using a magnet. For example, particle panels may be incubated with a plurality of spatially isolated samples, wherein each spatially isolated sample is in a well in a well plate (e.g., a 96-well plate). After incubation, the particle panels in each of the wells of the well plate can be separated from unbound protein present in the spatially isolated samples by placing the entire plate on a magnet. This simultaneously pulls down the superparamagnetic particles in the particle panel. The supernatant in each well can be removed to remove the unbound protein. These steps (incubate, pull down using a magnet) can be repeated to effectively wash the particles, thus removing residual background unbound protein that may be present in a sample. This is one example, but one of skill in the art could envision numerous other scenarios in which superparamagnetic particles are rapidly isolated from one or more than one spatially isolated samples at the same time.

[0158] In some embodiments, the panels of the present disclosure provides identification and measurement of particular proteins in the biological samples by processing of the proteomic data

via digestion of coronas formed on the surface of particles. Examples of proteins that can be identified and measured include highly abundant proteins, proteins of medium abundance, and low-abundance proteins. A low abundance protein may be present in a sample at concentrations at or below about 10 ng/mL. A high abundance protein may be present in a sample at concentrations at or above about 10 µg/mL. A protein of moderate abundance may be present in a sample at concentrations between about 10 ng/mL and about 10 µg/mL. Examples of proteins that are highly abundant proteins include albumin, IgG, and the top 14 proteins in abundance that contribute 95% of the mass in plasma. Additionally, any proteins that may be purified using a conventional depletion column may be directly detected in a sample using the particle panels disclosed herein. Examples of proteins may be any protein listed in published databases such as Keshishian et al. (Mol Cell Proteomics. 2015 Sep;14(9):2375-93. doi:

10.1074/mcp.M114.046813. Epub 2015 Feb 27.), Farr et al. (J Proteome Res. 2014 Jan 3;13(1):60-75. doi: 10.1021/pr4010037. Epub 2013 Dec 6.), or Pernemalm et al. (Expert Rev Proteomics. 2014 Aug;11(4):431-48. doi: 10.1586/14789450.2014.901157. Epub 2014 Mar 24.).

[0159] In some embodiments, examples of proteins that can be measured and identified using the particle panels disclosed herein include albumin, IgG, lysozyme, CEA, HER-2/neu, bladder tumor antigen, thyroglobulin, alpha-fetoprotein, PSA, CA125, CA19.9, CA 15.3, leptin, prolactin, osteopontin, IGF-II, CD98, fascin, sPigR, 14-3-3 eta, troponin I, B-type natriuretic peptide, BRCA1, c-Myc, IL-6, fibrinogen, EGFR, gastrin, PH, G-CSF, desmin, NSE, FSH, VEGF, P21, PCNA, calcitonin, PR, CA125, LH, somatostatin, S100, insulin, alpha-prolactin, ACTH, Bcl-2, ER alpha, Ki-67, p53, cathepsin D, beta catenin, VWF, CD15, k-ras, caspase 3, EPN, CD10, FAS, BRCA2, CD30L, CD30, CGA, CRP, prothrombin, CD44, APEX, transferrin, GM-CSF, E-cadherin, IL-2, Bax, IFN-gamma, beta-2-MG, TNF alpha, c-erbB-2, trypsin, cyclin D1, MG B, XBP-1, HG-1, YKL-40, S-gamma, NESP-55, netrin-1, geminin, GADD45A, CDK-6, CCL21, BrMS1, 17betaHDI, PDGFRA, Pcaf, CCL5, MMP3, claudin-4, and claudin-3. In some embodiments, other examples of proteins that can be measured and identified using the particle panels disclosed herein are any proteins or protein groups listed in the open targets database for a particular disease indication of interest (e.g., prostate cancer, lung cancer, or Alzheimer's disease).

Methods of Analysis

[0160] The proteomic data of the sample can be identified, measured, and quantified using a number of different analytical techniques. For example, proteomic data can be analyzed using SDS-PAGE or any gel-based separation technique. Peptides and proteins can also be identified, measured, and quantified using an immunoassay, such as ELISA. Alternatively, proteomic data

can be identified, measured, and quantified using mass spectrometry, high performance liquid chromatography, LC-MS/MS, Edman Degradation, immunoaffinity techniques, methods disclosed in EP3548652, WO2019083856, WO2019133892, each of which is incorporated herein by reference in its entirety, and other protein separation techniques.

Computer Control Systems

[0161] The present disclosure provides computer control systems that are programmed to implement methods of the disclosure. This determination, analysis or statistical classification is done by methods known in the art, including, but not limited to, for example, a wide variety of supervised and unsupervised data analysis and clustering approaches such as hierarchical cluster analysis (HCA), principal component analysis (PCA), Partial least squares Discriminant Analysis (PLSDA), machine learning (also known as random forest), logistic regression, decision trees, support vector machine (SVM), k-nearest neighbors, naive bayes, linear regression, polynomial regression, SVM for regression, K-means clustering, and hidden Markov models, among others. The computer system can perform various aspects of analyzing the protein sets or protein corona of the present disclosure, such as, for example, comparing/analyzing the biomolecule corona of several samples to determine with statistical significance what patterns are common between the individual biomolecule coronas to determine a protein set that is associated with the biological state. The computer system can be used to develop classifiers to detect and discriminate different protein sets or protein corona (e.g., characteristic of the composition of a protein corona). Data collected from the presently disclosed sensor array can be used to train a machine learning algorithm, specifically an algorithm that receives array measurements from a patient and outputs specific biomolecule corona compositions from each patient. Before training the algorithm, raw data from the array can be first denoised to reduce variability in individual variables.

[0162] Machine learning can be generalized as the ability of a learning machine to perform accurately on new, unseen examples/tasks after having experienced a learning data set. Machine learning may include the following concepts and methods. Supervised learning concepts may include AODE; Artificial neural network, such as Backpropagation, Autoencoders, Hopfield networks, Boltzmann machines, Restricted Boltzmann Machines, and Spiking neural networks; Bayesian statistics, such as Bayesian network and Bayesian knowledge base; Case-based reasoning; Gaussian process regression; Gene expression programming; Group method of data handling (GMDH); Inductive logic programming; Instance-based learning; Lazy learning; Learning Automata; Learning Vector Quantization; Logistic Model Tree; Minimum message length (decision trees, decision graphs, etc.), such as Nearest Neighbor Algorithm and

Analogical modeling; Probably approximately correct learning (PAC) learning; Ripple down rules, a knowledge acquisition methodology; Symbolic machine learning algorithms; Support vector machines; Random Forests; Ensembles of classifiers, such as Bootstrap aggregating (bagging) and Boosting (meta-algorithm); Ordinal classification; Information fuzzy networks (IFN); Conditional Random Field; ANOVA; Linear classifiers, such as Fisher's linear discriminant, Linear regression, Logistic regression, Multinomial logistic regression, Naive Bayes classifier, Perceptron, Support vector machines; Quadratic classifiers; k-nearest neighbor; Boosting; Decision trees, such as C4.5, Random forests, ID3, CART, SLIQ SPRINT; Bayesian networks, such as Naive Bayes; and Hidden Markov models. Unsupervised learning concepts may include; Expectation-maximization algorithm; Vector Quantization; Generative topographic map; Information bottleneck method; Artificial neural network, such as Self-organizing map; Association rule learning, such as, Apriori algorithm, Eclat algorithm, and FPgrowth algorithm; Hierarchical clustering, such as Singlelinkage clustering and Conceptual clustering; Cluster analysis, such as, K-means algorithm, Fuzzy clustering, DBSCAN, and OPTICS algorithm; and Outlier Detection, such as Local Outlier Factor. Semi-supervised learning concepts may include; Generative models; Low-density separation; Graph-based methods; and Co-training. Reinforcement learning concepts may include; Temporal difference learning; Q-learning; Learning Automata; and SARSA. Deep learning concepts may include; Deep belief networks; Deep Boltzmann machines; Deep Convolutional neural networks; Deep Recurrent neural networks; and Hierarchical temporal memory. A computer system may be adapted to implement a method described herein. The system includes a central computer server that is programmed to implement the methods described herein. The server includes a central processing unit (CPU, also "processor") which can be a single core processor, a multi core processor, or plurality of processors for parallel processing. The server also includes memory (e.g., random access memory, read-only memory, flash memory); electronic storage unit (e.g. hard disk); communications interface (e.g., network adaptor) for communicating with one or more other systems; and peripheral devices which may include cache, other memory, data storage, and/or electronic display adaptors. The memory, storage unit, interface, and peripheral devices are in communication with the processor through a communications bus (solid lines), such as a motherboard. The storage unit can be a data storage unit for storing data. The server is operatively coupled to a computer network ("network") with the aid of the communications interface. The network can be the Internet, an intranet and/or an extranet, an intranet and/or extranet that is in communication with the Internet, a telecommunication or data network. The

network in some cases, with the aid of the server, can implement a peer-to-peer network, which may enable devices coupled to the server to behave as a client or a server.

[0163] The storage unit can store files, such as subject reports, and/or communications with the data about individuals, or any aspect of data associated with the present disclosure.

[0164] The computer server can communicate with one or more remote computer systems through the network. The one or more remote computer systems may be, for example, personal computers, laptops, tablets, telephones, Smart phones, or personal digital assistants.

[0165] In some applications the computer system includes a single server. In other situations, the system includes multiple servers in communication with one another through an intranet, extranet and/or the internet.

[0166] The server can be adapted to store measurement data or a database as provided herein, patient information from the subject, such as, for example, medical history, family history, demographic data and/or other clinical or personal information of potential relevance to a particular application. Such information can be stored on the storage unit or the server and such data can be transmitted through a network.

[0167] Methods as described herein can be implemented by way of machine (or computer processor) executable code (or software) stored on an electronic storage location of the server, such as, for example, on the memory, or electronic storage unit. During use, the code can be executed by the processor. In some cases, the code can be retrieved from the storage unit and stored on the memory for ready access by the processor. In some situations, the electronic storage unit can be precluded, and machine-executable instructions are stored on memory. Alternatively, the code can be executed on a second computer system.

[0168] Aspects of the systems and methods provided herein, such as the server, can be embodied in programming. Various aspects of the technology may be thought of as "products" or "articles of manufacture" typically in the form of machine (or processor) executable code and/or associated data that is carried on or embodied in a type of machine readable medium. Machine-executable code can be stored on an electronic storage unit, such memory (e.g., read-only memory, random-access memory, flash memory) or a hard disk. "Storage" type media can include any or all of the tangible memory of the computers, processors or the like, or associated modules thereof, such as various semiconductor memories, tape drives, disk drives and the like, which may provide non-transitory storage at any time for the software programming. All or portions of the software may at times be communicated through the Internet or various other telecommunication networks. Such communications, for example, may enable loading of the software from one computer or processor into another, for example, from a management server

or host computer into the computer platform of an application server. Thus, another type of media that may bear the software elements includes optical, electrical, and electromagnetic waves, such as used across physical interfaces between local devices, through wired and optical landline networks and over various air-links. The physical elements that carry such waves, such as wired or wireless links, optical links, or the like, also may be considered as media bearing the software. As used herein, unless restricted to non-transitory, tangible "storage" media, terms such as computer or machine "readable medium" can refer to any medium that participates in providing instructions to a processor for execution.

[0169] The computer systems described herein may comprise computer-executable code for performing any of the algorithms or algorithms-based methods described herein. In some applications the algorithms described herein will make use of a memory unit that is comprised of at least one database.

[0170] Data relating to the present disclosure can be transmitted over a network or connections for reception and/or review by a receiver. The receiver can be but is not limited to the subject to whom the report pertains; or to a caregiver thereof, e.g., a health care provider, manager, other health care professional, or other caretaker; a person or entity that performed and/or ordered the analysis. The receiver can also be a local or remote system for storing such reports (e.g. servers or other systems of a "cloud computing" architecture). In one embodiment, a computer-readable medium includes a medium suitable for transmission of a result of an analysis of a biological sample using the methods described herein.

[0171] Aspects of the systems and methods provided herein can be embodied in programming. Various aspects of the technology may be thought of as "products" or "articles of manufacture" typically in the form of machine (or processor) executable code and/or associated data that is carried on or embodied in a type of machine readable medium. Machine-executable code can be stored on an electronic storage unit, such as memory (e.g., read-only memory, random-access memory, flash memory) or a hard disk. "Storage" type media can include any or all of the tangible memory of the computers, processors or the like, or associated modules thereof, such as various semiconductor memories, tape drives, disk drives and the like, which may provide nontransitory storage at any time for the software programming. All or portions of the software may at times be communicated through the Internet or various other telecommunication networks. Such communications, for example, may enable loading of the software from one computer or processor into another, for example, from a management server or host computer into the computer platform of an application server. Thus, another type of media that may bear the software elements includes optical, electrical and electromagnetic waves, such as used across

physical interfaces between local devices, through wired and optical landline networks and over various air-links. The physical elements that carry such waves, such as wired or wireless links, optical links or the like, also may be considered as media bearing the software. As used herein, unless restricted to non-transitory, tangible "storage" media, terms such as computer or machine "readable medium" refer to any medium that participates in providing instructions to a processor for execution.

[0172] Hence, a machine readable medium, such as computer- executable code, may take many forms, including but not limited to, a tangible storage medium, a carrier wave medium or physical transmission medium. Non-volatile storage media include, for example, optical or magnetic disks, such as any of the storage devices in any computer(s) or the like, such as may be used to implement the databases, etc. shown in the drawings. Volatile storage media include dynamic memory, such as main memory of such a computer platform. Tangible transmission media include coaxial cables; copper wire and fiber optics, including the wires that comprise a bus within a computer system. Carrier-wave transmission media may take the form of electric or electromagnetic signals, or acoustic or light waves such as those generated during radio frequency (RF) and infrared (IR) data communications. Common forms of computer-readable media therefore include for example: a floppy disk, a flexible disk, hard disk, magnetic tape, any other magnetic medium, a CD-ROM, DVD or DVD-ROM, any other optical medium, punch cards paper tape, any other physical storage medium with patterns of holes, a RAM, a ROM, a PROM and EPROM, a FLASH-EPROM, any other memory chip or cartridge, a carrier wave transporting data or instructions, cables or links transporting such a carrier wave, or any other medium from which a computer may read programming code and/or data. Many of these forms of computer readable media may be involved in carrying one or more sequences of one or more instructions to a processor for execution.

Classification of Protein Corona Using Machine Learning

[0173] The method of determining a set of proteins associated with the disease or disorder and/or disease state include the analysis of the corona of the at least two samples. This determination, analysis or statistical classification is done by methods known in the art, including, but not limited to, for example, a wide variety of supervised and unsupervised data analysis, machine learning, deep learning, and clustering approaches including hierarchical cluster analysis (HCA), principal component analysis (PCA), Partial least squares Discriminant Analysis (PLS-DA), random forest, logistic regression, decision trees, support vector machine (SVM), k-nearest neighbors, naive bayes, linear regression, polynomial regression, SVM for regression, K-means clustering, and hidden Markov models, among others. In other words, the

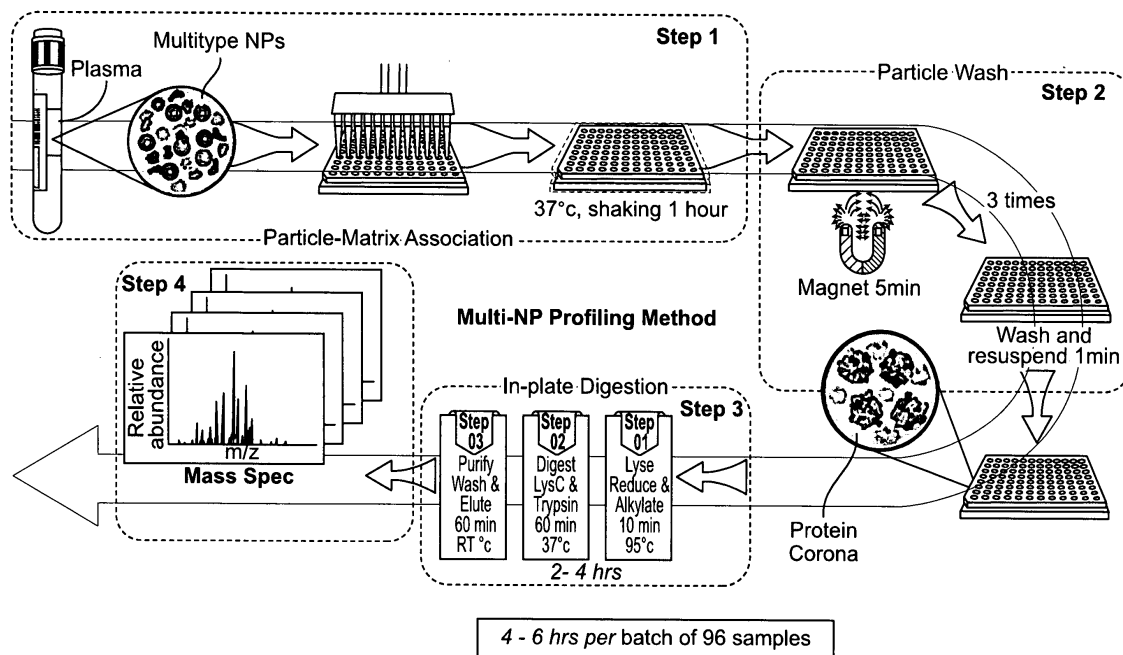


FIG. 22B

nine different particle types, at least 10 different particle types, at least 11 different particle types, at least 12 different particle types, at least 13 different particle types, at least 14 different particle types, at least 15 different particles, or at least 20 different particle types. 7. The method of any one of embodiments 1-6, wherein the panel comprises at least four different particle types. 8. The method of any one of embodiments 1-7, wherein at least one particle type of the panel comprises a physical feature that is different from a second particle type of the panel. 9. The method of embodiment 8, wherein the physical feature is size, polydispersity index, surface charge, or morphology. 10. The method of any one of embodiments 1-9, wherein the size of at least one particle type of the plurality of particle types in the panel is from 10 nm to 500 nm. 11. The method of any one of embodiments 1-10, wherein the polydispersity index of at least one particle type of the plurality of particle types in the panel is from 0.01 to 0.25. 12. The method of any one of embodiments 1-11, wherein the morphology of at least one particle type of the plurality of particle types comprises spherical, colloidal, square shaped, rods, wires, cones, pyramids, or oblong. 13. The method of embodiment 1-12, wherein the surface charge of at least one particle type of the plurality of particle types comprises a positive surface charge. 14. The method of any one of embodiments 1-12, wherein the surface charge of at least one particle type of the plurality of particle types comprises a negative surface charge. 15. The method of any one of embodiments 1-12, wherein the surface charge of at least one particle type of the plurality of particle types comprises a neutral surface charge. 16. The method of any one of embodiments 1-15, wherein at least one particle type of the plurality of particle types comprises a chemical feature that is different from a second particle type of the panel. 17. The method of embodiment 16, wherein the chemical feature is a surface functional chemical group. 18. The method of embodiment 17, wherein the functional chemical group is an amine or a carboxylate. 19. The method of any one of embodiments 1-18, wherein at least one particle type of the plurality of particle types is made of a material comprising a polymer, a lipid, or a metal, silica, a protein, a nucleic acid, a small molecule, or a large molecule. 20. The method of embodiment 19, wherein the polymer comprises polyethylenes, polycarbonates, polyanhydrides, polyhydroxyacids, polypropylfumerates, polycaprolactones, polyamides, polyacetals, polyethers, polyesters, poly(orthoesters), polycyanoacrylates, polyvinyl alcohols, polyurethanes, polyphosphazenes, polyacrylates, polymethacrylates, polycyanoacrylates, polyureas, polystyrenes, or polyamines, a polyalkylene glycol (e.g., polyethylene glycol (PEG)), a polyester (e.g., poly(lactide-co-glycolide) (PLGA), polylactic acid, or polycaprolactone), polystyrene, or a copolymer of two or more polymers. 21. The method of embodiment 19, wherein the lipid comprises dioleoylphosphatidylglycerol (DOPG), diacylphosphatidylcholine,

diacylphosphatidylethanolamine, ceramide, sphingomyelin, cephalin, cholesterol, cerebroside and diacylglycerols, dioleoylphosphatidylcholine (DOPC), dimyristoylphosphatidylcholine (DMPC), and dioleoylphosphatidylserine (DOPS), phosphatidylglycerol, cardiolipin, diacylphosphatidylserine, diacylphosphatidic acid, N-dodecanoyl phosphatidylethanolamines, N-succinyl phosphatidylethanolamines, N-glutarylphosphatidylethanolamines, lysylphosphatidylglycerols, palmitoyloleyolphosphatidylglycerol (POPG), lecithin, lysolecithin, phosphatidylethanolamine, lysophosphatidylethanolamine, dioleoylphosphatidylethanolamine (DOPE), dipalmitoyl phosphatidyl ethanolamine (DPPE), dimyristoylphosphoethanolamine (DMPE), distearoyl-phosphatidyl-ethanolamine (DSPE), palmitoyloleyolphosphatidylethanolamine (POPE) palmitoyloleyolphosphatidylcholine (POPC), egg phosphatidylcholine (EPC), distearoylphosphatidylcholine (DSPC), dioleoylphosphatidylcholine (DOPC), dipalmitoylphosphatidylcholine (DPPC), dioleoylphosphatidylglycerol (DOPG), dipalmitoylphosphatidylglycerol (DPPG), palmitoyloleyolphosphatidylglycerol (POPG), 16-O-monomethyl PE, 16-O-dimethyl PE, 18-1-trans PE, palmitoyloleyolphosphatidylethanolamine (POPE), 1-stearoyl-2-oleoyl-phosphatidylethanolamine (SOPE), phosphatidylserine, phosphatidylinositol, sphingomyelin, cephalin, cardiolipin, phosphatidic acid, cerebroside, dicetylphosphate, or cholesterol. 22. The method of embodiment 19, wherein the metal comprises gold, silver, copper, nickel, cobalt, palladium, platinum, iridium, osmium, rhodium, ruthenium, rhenium, vanadium, chromium, manganese, niobium, molybdenum, tungsten, tantalum, iron, or cadmium, titanium, or gold. 23. The method of any one of embodiments 1-22, wherein at least one particle type of the plurality of particle types is surface functionalized with a polymer comprising polyethylenes, polycarbonates, polyanhydrides, polyhydroxyacids, polypropylfumerates, polycaprolactones, polyamides, polyacetals, polyethers, polyesters, poly(orthoesters), polycyanoacrylates, polyvinyl alcohols, polyurethanes, polyphosphazenes, polyacrylates, polymethacrylates, polycyanoacrylates, polyureas, polystyrenes, or polyamines, a polyalkylene glycol (e.g., polyethylene glycol (PEG)), a polyester (e.g., poly(lactide-co-glycolide) (PLGA), polylactic acid, or polycaprolactone), polystyrene, or a copolymer of two or more polymers polyethylene glycol. 24. The method of any one of embodiments 3-23, wherein the method associates the protein profile to the biological state with at least 70% accuracy, at least 75% accuracy, at least 80% accuracy, at least 85% accuracy, at least 90% accuracy, at least 92% accuracy, at least 95% accuracy, at least 96% accuracy, at least 97% accuracy, at least 98% accuracy, at least 99% accuracy, or 100 % accuracy. 25. The method of any one of embodiments 3-24, wherein the method associates the protein profile to the biological state with at least 70% sensitivity, at least 75% sensitivity, at least 80% sensitivity, at least 85% sensitivity, at least 90%

sensitivity, at least 92% sensitivity, at least 95% sensitivity, at least 96% sensitivity, at least 97% sensitivity, at least 98% sensitivity, at least 99% sensitivity, or 100 % sensitivity. 26. The method of any one of embodiments 3-25, wherein the method associates the protein profile to the biological state with at least 70% specificity, at least 75% specificity, at least 80% specificity, at least 85% specificity, at least 90% specificity, at least 92% specificity, at least 95% specificity, at least 96% specificity, at least 97% specificity, at least 98% specificity, at least 99% specificity, or 100 % specificity. 27. The method of any one of embodiments 1-26, wherein the method identifies at least 100 unique proteins, at least 200 unique proteins, at least 300 unique proteins, at least 400 unique proteins, at least 500 unique proteins, at least 600 unique proteins, at least 700 unique proteins, at least 800 unique proteins, at least 900 unique proteins, at least 1000 unique proteins, at least 1100 unique proteins, at least 1200 unique proteins, at least 1300 unique proteins, at least 1400 unique proteins, at least 1500 unique proteins, at least 1600 unique proteins, at least 1700 unique proteins, at least 1800 unique proteins, at least 1900 unique proteins, or at least 2000 unique proteins. 28. The method of any one of embodiments 1-27, wherein at least one particle type of the plurality of particle types comprises a superparamagnetic iron oxide nanoparticle. 29. The method of any one of embodiments 1-28, wherein the sample is a biofluid. 30. The method of embodiment 29, wherein the biofluid comprises plasma, serum, CSF, urine, tear, or saliva. 31. A method of selecting a panel for protein corona analysis, comprising selecting a plurality of particle types with at least three different physicochemical properties. 32. The method of embodiment 31, wherein the different physicochemical properties is selected from a group consisting of surface charge, surface chemistry, size, and morphology. 33. The method of embodiment 32, wherein the different physicochemical properties comprises surface charge. 34. A composition comprising a panel of particles, wherein the panel comprises a plurality of particle types and wherein the plurality of particle types comprises at least three different physicochemical properties. 35. The composition of embodiment 35, wherein the different physicochemical properties is selected from a group consisting of surface charge, surface chemistry, size, and morphology. 36. The composition of embodiment 36, wherein the different physicochemical properties comprises surface charge. 37. A system of comprising the panel of any one of embodiments 1-34. 38. A system comprising a panel, wherein the panel comprises a plurality of particle types. 39. The system of embodiment 38, wherein the plurality of particle types comprises at least three different physicochemical properties. 40. The system of embodiment 38, wherein the panel comprises at least 3, at least 4, at least 5, at least 6, at least 7, at least 8, at least 9, at least 10, at least 11, or at least 12 different particle types. 41. The system of embodiment 38, wherein the plurality of particle types are capable of adsorbing a plurality of

proteins from a sample to form a plurality of protein coronas. 42. The system of embodiment 41, wherein the plurality of protein coronas are digested to determine a protein profile. 43. The system of embodiment 42, wherein the protein profile is associated with a biological state using a trained classifier.

EXAMPLES

[0176] The following examples are included to further describe some aspects of the present disclosure, and should not be used to limit the scope of the invention.

EXAMPLE 1

Synthesis of SPMNPs or Superparamagnetic Iron Oxide Nanoparticles (SPIONs)

[0177] SPMNPs or SPIONs were synthesized by following the method in the literature (Angew. Chem. Int. Ed. 2009, 48, 5875 – 5879 & Langmuir 2012, 28, 3271 – 3278) via solvothermal reaction at 200 °C by reduction of FeCl_3 with ethylene glycol (EG) in the presence of sodium acetate (NaOAc) as an alkali source and trisodium citrate (Na_3Cit) as an electrostatic stabilizer. The excess EG acted as both the solvent and reductant.

[0178] Starting materials: Iron (III) chloride hexahydrate ($\text{FeCl}_3 \cdot 6\text{H}_2\text{O}$), MW 270.30, CAS# 10025-77-1; Sodium acetate (NaOAc), MW 82.03, CAS# 127-09-3; Trisodium citrate dihydrate ($\text{Na}_3\text{Cit} \cdot 2\text{H}_2\text{O}$), MW 294.10, CA# 6132-04-3; Ethylene glycol (EG), MW 62.07, CAS# 107-21-1.

[0179] Procedure for Fe_3O_4 nanoparticles via Solvothermal Reaction:

[0180] (1) Typically, FeCl_3 (0.65 g, 4.0 mmol) and sodium citrate (0.20 g, 0.68 mmol) were first dissolved in EG (20 mL), afterward, sodium acetate (1.20 g, 14.6 mmol) was added with stirring. The mixture was stirred vigorously for 30 min at 160 °C and then sealed in a Teflon-lined stainless-steel autoclave (50 mL capacity). (2) The autoclave was heated at 200 °C and maintained for 12 h, and then allowed to cool to room temperature. (3) The black products were isolated by a magnet and washed with DI water for > 5 times. (4) The final Fe_3O_4 nanoparticle product was dried in vacuum at 60°C for 12 h or freeze dried to a black powder. $\text{Fe}_3\text{O}_4@\text{SiO}_2$ core/shell colloids were prepared through a modified Stöber process by following the method in the literature (J. Am. Chem. Soc. 2008, 130, 28 - 29 & J. Mater. Chem. B, 2013, 1, 4684 – 4691)

[0181] Starting materials: Fe_3O_4 nanoparticles synthesized via the solvothermal reaction; Tetraethyl orthosilicate (TEOS), MW 208.33, CAS# 78-10-4; Ammonia solution 25%; Cetrimonium bromide (CTAB), MW 364.45, CAS# 57-09-0; (3-Aminopropyl)triethoxysilane (APTES), MW 221.37, CAS# 919-30-2.

[0182] Procedure for $\text{Fe}_3\text{O}_4@\text{SiO}_2$ Core/Shell nanoparticles:

[0183] (1) Superparamagnetic Fe₃O₄ NPs were synthesized according to the previously reported solvothermal reaction (Angew. Chem. Int. Ed. 2009, 48, 5875 – 5879 & Langmuir 2012, 28, 3271 – 3278). Then the obtained Fe₃O₄ nanoparticles were used to prepare highly aminated superparamagnetic mesoporous composite nanoparticles through a two-step coating procedure. (2) In brief, 0.08 g of the Fe₃O₄ nanoparticles were homogeneously dispersed in the mixture of ethanol (50 mL), DI water (1 mL), and concentrated ammonia aqueous solution (1.7 mL, 25 wt%), followed by the addition of TEOS (140 µL). After stirring at 40 °C for 6 h, amorphous silica coated superparamagnetic nanoparticles (denoted as Fe₃O₄@SiO₂) were obtained and washed 5 times with water. (3) Then, the Fe₃O₄@SiO₂ nanoparticles were coated with highly aminated mesoporous silica shell via base-catalyzed sol-gel silica reactions by using CTAB as a template. Typically, the above prepared the Fe₃O₄@SiO₂ nanoparticles (5 mg) were dispersed in a mixed solution containing CTAB (0.08 g), ethyl acetate (0.7 mL), DI water (113 mL), and concentrated ammonia (2.42 mL, 25 wt%). TEOS (0.18 mL) and APTES (0.22 mL) were added to the dispersion with a stirring speed of 300 rpm. After reaction at room temperature for 3 h, the products were collected with a magnet and washed repeatedly with water and ethanol, respectively.

[0184] (4) To remove the pore-generating template (CTAB), the as-synthesized materials were transferred to ethanol (60 mL) with continual stirring at 60 °C for 3 h. The surfactant extraction step was repeated two times to ensure the removal of CTAB. The template-removed products were washed with ethanol twice, resulting in sandwich structured highly aminated superparamagnetic mesoporous composite nanoparticles (Fe₃O₄@SiO₂@mSiO₂-NH₂).

[0185] Fe₃O₄@polymer composite nanoparticles were synthesized through surfactant-free seeded emulsion polymerization (Langmuir 2012, 28, 3271 – 3278).

[0186] Fe₃O₄ nanoparticles synthesized via the solvothermal reaction.

[0187] Starting materials: Fe₃O₄ nanoparticles synthesized via the solvothermal reaction; Tetraethyl orthosilicate (TEOS), MW 208.33, CAS# 78-10-4; 3-(trimethoxysilyl)propyl methacrylate (MPS), MW 248.35, CAS# 2530-85-0; Ammonia solution 25%; Divinylbenzene (DVB), MW 130.19, CAS# 1321-74-0; Styrene (St), MW 104.15, CAS# 100-42-5; Methacrylic acid (MAA), MW 86.09, CAS# 79-41-4; Ammonium persulfate (APS), MW 228.20, CAS# 7727-54-0.

[0188] Procedure for Fe₃O₄@Polymer Core-Shell nanoparticles:

[0189] (1) SPIONs were synthesized according to the previously reported solvothermal reaction (Angew. Chem. Int. Ed. 2009, 48, 5875 – 5879 & Langmuir 2012, 28, 3271 – 3278). (2) Fe₃O₄@MPS were prepared through a modified Stöber process. Typically, 1 g of Fe₃O₄

nanoparticles were homogeneously dispersed in the mixture of ethanol (50 mL), DI water (2 mL), and concentrated ammonia aqueous solution (2 mL, 25 wt%), followed by the addition of TEOS (200 μ L) and MPS (2 mL). After stirring at 70 °C for 24 h, the MPS coated superparamagnetic NPs were obtained and washed 5 times with water and freeze dried to a dark brown powder and stored at -20 °C. (3) Fe_3O_4 @Polymer nanoparticles were synthesized through surfactant-free seeded emulsion polymerization. Typically, 100 mg of Fe_3O_4 @MPS were homogeneously dispersed in 125 mL of DI water. After bubbling with N_2 for 30 min, 2 mL of St, 0.2 mL of DVB and 0.4 mL of MAA were added into the Fe_3O_4 @MPS suspension. After addition of 5 mL of 0.2 g of NaOH and 40 mg of APS aqueous solution, the resulting mixture was heated to 75 °C overnight. (4) After cooling down, Fe_3O_4 @P(St-co-MAA) were obtained and washed 5 times with water and freeze dried to a dark brown powder.

EXAMPLE 2

Building Panels of Particle Types

[0190] This example describes building panels of particle types. A particle library was built comprising ~170 total particle types. Biomolecule coronas were produced for each particle type, by incubating each particle with a biological sample. Proteomic data from protein coronas were analyzed for each particle type, including qualitative analysis based on electrophoresis and quantitative analysis based on mass spectrometry data and heat maps. Panels were built by choosing certain particle types based on particle and corona properties. Particle types were selected for particle panels based on the broadness of coverage a particle type had for proteins in the plasma sample. FIG. 5 illustrates the process for generating proteomic data and the process for panel selection. As shown in FIG. 6, particle properties include size/geometry, charge, surface functionality, magnetism, in addition to other properties. Each of these properties can be assayed by a variety of tests in fully characterizing a particle type before adding it to a panel. As shown in FIG. 7 dynamic light scattering was used to characterize the size distribution of two particle types: SP-002 (phenol-formaldehyde coated particles) and SP-010 (carboxylate, PAA coated particles). As shown in FIG. 8, TEM was used to characterize the size and morphology of two particle types including SP-002 (phenol-formaldehyde coated particles) (FIG. 8A) and SP-339 (polystyrene carboxyl particles) (FIG. 8B). As shown in FIG. 9, XPS can be used to analyze chemical groups present at the surface of various particle types including SP-333 (carboxylate), SP-339 (polystyrene carboxylate), SP-356 (silica amino), SP-374 (silica silanol), HX-20 (silica coated), HX-42 (silica coated, amine), and HX-74 (PDMPAPMA coated (dimethylamine)).

EXAMPLE 3

Synthesis and Characterization of Iron Oxide NPs with Distinct Surface Chemistries

[0191] This example describes synthesis and characterization of iron oxide NPs with distinct surface chemistries. To address the need for robust particles that can be easily separated, without the need for, but which is also capable of withstanding, repeated centrifugation or membrane filtration to separate particle protein corona from free plasma proteins and to wash away loosely attached proteins from the particles, superparamagnetic iron oxide NPs (SPIONs) were developed (FIG. 23, at top) for protein corona formation. The iron oxide particle core facilitated rapid separation of the particles from plasma solution in < 30 sec using a magnet (FIG. 4). This drastically reduced the time needed for extraction of particle protein corona for LC-MS/MS analysis. Moreover, SPIONs were robustly modified with different surface chemistries, which facilitated the generation of distinct patterns of protein corona for more broadly interrogating the proteome.

[0192] Three SPIONs (SP-003, SP-007, and SP-011) with different surface functionalization were synthesized (FIG. 28). SP-003 was coated with a thin layer of silica by a modified Stöber process using tetraethyl orthosilicate (TEOS). For synthesis of poly(dimethyl aminopropyl methacrylamide) (PDMAPMA)-coated SPIONs (SP-007) and poly(ethylene glycol) (PEG)-coated SPIONs (SP-011), the iron oxide particle core was first modified with vinyl groups by a modified Stöber process using TEOS and 3-(trimethoxysilyl)propyl methacrylate. Next, the vinyl group-functionalized SPIONs were surface modified by free radical polymerization with *N*-[3-(dimethylamino)propyl] methacrylamide and poly(ethylene glycol) methyl ether methacrylate, respectively, to prepare SP-007 and SP-011.

[0193] The three SPIONs were characterized using various techniques, including scanning electron microscopy (SEM), dynamic light scattering (DLS), transmission electron microscopy (TEM), high-resolution TEM (HRTEM), and X-ray photoelectron spectroscopy (XPS), to evaluate the size, morphology, and surface properties of SPIONs (FIG. 23). The results of DLS measurements showed that SP-003, SP-007, and SP-011 had average sizes of ~233 nm, ~283 nm, and ~238 nm, respectively. This was consistent with SEM measurements, which showed that all three SPIONs had spherical and semi-spherical morphologies with sizes ranging from 200 nm to 300 nm. The surface charge of SPIONs was evaluated by zeta potential (ζ) analysis, which showed ζ -potential values of -36.9 mV, +25.8 mV, and -0.4 mV for SP-003, SP-007, and SP-011, respectively, at pH 7.4 (TABLE 2-4).

TABLE 2 – Particle diameter and zeta potential of SP-003 SPION, as measured by DLS

Measurement #	Z-average size	PDI	Zeta potential (mV)
1	233.8	0.053	-36.4
2	235.3	0.039	-36.8
3	230.4	0.055	-37.4
Average	233.2 nm	0.05	-36.9 mV

TABLE 3 – Particle diameter and zeta potential of SP-007 SPION, as measured by DLS

Measurement #	Z-average size	PDI	Zeta potential (mV)
1	284.4	0.049	25.7
2	286.1	0.119	25.9
3	279.7	0.113	25.9
Average	283.4 nm	0.09	+25.8 mV

TABLE 4 – Particle diameter and zeta potential of SP-011 SPION, as measured by DLS

Measurement #	Z-average size	PDI	Zeta potential (mV)
1	236.5	0.207	0.08
2	238.9	0.198	-0.67
3	237.6	0.201	-0.74
Average	237.7 nm	0.2	-0.4 mV

[0194] This indicated that the SP-003, SP-007, and SP-011 had negative, positive, and neutral surfaces, which was consistent with the charge of coating functionalities used to modify the surface of each particle as shown in the schematics of **FIG. 23**. The thickness of the coatings was evaluated using HRTEM. For SP-003, a complete amorphous shell was observed around the iron oxide core with a thickness greater than 10 nm (**FIG. 23**, column 5 at top). For SP-007 and SP-011, a relatively thin (<10 nm) amorphous feature was observed at the surface of particles (arrows in **FIG. 23**; column 5, at middle and bottom). In addition, XPS was performed for surface analysis, which, along with HRTEM images, confirmed the successful coating of the particles with respective functional groups.

EXAMPLE 4

Detection of Proteins with a Panel and Association of Protein Profiles with a Cancer

[0195] This example describes detection of proteins with a panel and association of protein profiles with a cancer. The panel of particles includes three different cross-reactive liposomes with various surface charges (anionic (DOPG (1,2-dioleoyl-sn-glycero-3-phospho-*l*-rac-glycerol))), cationic (DOTAP (1,2-Dioleoyl-3-trimethylammoniumpropane)- DOPE

(dioleoylphosphatidylethanolamine)), and neutral (dioleoylphosphatidylcholine (DOPC) with cholesterol).

[0196] **FIG. 17A** shows a schematic of the processes of the present application including collection of samples from healthy and cancer patients, isolation of plasma from the samples, incubation with uncoated liposomes to form protein coronas, and enrichment of select plasma proteins. Protein corona formation can be different based on the physicochemical properties of particles. **FIG. 17B** shows corona analysis signals for a three-particle type panel. Plasma was collected from 45 subjects (8 from each of five cancers including glioblastoma, lung cancer, meningioma, myeloma, and pancreatic cancer and 5 healthy controls). Corona analyses were created for each particle in the three-particle type panel. Random forest models were built in each of 1000 rounds of cross-validation. There is strong evidence for robust corona analysis signal. Initial exploratory analysis was done via PCA. **FIG. 18A** and **FIG. 18B** show that early stage cancers can be separated up to 8 years before symptoms develop. The Golestan Cohort enrolled 50,000 healthy subjects between 2004 and 2008. As shown in **FIG. 18A**, banked plasma from enrollment was tested. 8 years after enrollment, approximately 1000 patients developed cancers. **FIG. 18B** shows the classification of the banked plasma. Corona analysis of banked plasma from enrollment date accurately classified cancers for 15 out of 15 subjects examined (5 patients each for 3 cancers). **FIG. 19** shows the robust classification of five cancers using a three-particle type corona analysis with an overall accuracy of 95%. The data shows that adding particle type diversity increases performance. Three different liposomes with negative, neutral, and positive net charge on the surfaces (at pH 7.4) were used.

EXAMPLE 5

Rapid and Deep Proteomic Analysis by the Corona Analysis Workflow

[0197] This example describes rapid and deep proteomic analysis by the corona analysis workflow. To evaluate the multi-particle type protein corona analysis platform (**FIG. 22B**) for analysis of plasma proteome, SPIONs were tested with a pooled plasma sample combined from eight colorectal cancer (CRC) cancer subjects. Each of these three particle types was first incubated with the plasma sample for about 1 hour at about 37 °C for protein corona formation, followed by a magnet-based purification of particles from unbound proteins (6 min per cycle for 3 times). The proteins bound onto particle were then lysed, digested, purified and eluted; these steps taking ~2-4 hours combined, before MS analysis. Notably, this preparation workflow required only ~4-6 hours in total for a batch of 96 corona samples.

[0198] After MS analysis and data processing, the resulting MS2 peptide-spectral matches (PSM) were used to identify proteins present in each particle type corona. In parallel, proteins

were also detected from a neat plasma sample directly, without particle corona formation. Comparing the identified proteins from the samples to a compiled database of MS measured or inferred plasma protein concentrations, the depth and extent of coverage by particle corona or plasma was examined by plotting observed proteins versus the database values of published protein concentrations (**FIG. 24**). First, the 1,255 proteins from the database covering almost 11-orders of magnitude in order from most abundant to least abundant protein were plotted. For each of the experimentally evaluated samples (neat plasma vs. SP-003/SP-007/SP-011 particle corona), the proteins matching the database were similarly plotted. As can be seen in **FIG. 24**, the measured plasma proteome's dynamic range as defined by the range of concentrations for database-matching proteins was 2-fold greater for particle corona (e.g., from 40 mg/mL to 0.54 ng/mL for SP-007) than it was for neat plasma (from 40 mg/mL to 1.2 ng/mL) with a 10-fold increase in the number of low abundant proteins present below 100 ng/mL (842 for particles and 84 for neat plasma). There were only 12 proteins annotated in the database with a lower concentration than the lowest protein detected on the particles. In addition, the total number of unique proteins for each of the particle type corona (~1,000) is greater (>2-fold) than that observed for neat plasma (<500), as clearly demonstrated in **TABLE 5**.

TABLE 5 – Coverage of proteins identified by SP-003, SP-007, and SP-011 particles versus neat plasma

Group	Total Proteins	Match to Database	Fraction in Database
Plasma	492	272	0.55
SP-003	1062	387	0.36
SP-007	991	383	0.39
SP-011	1062	393	0.37

[0199] In addition, the fraction of proteins that were previously unobserved by comparison to the literature MS compilation was greater (61-64%) for particles as compared to neat plasma (45%). In other words, more proteins unannotated with a prior MS concentration in the published database were identified in particle corona than were observed in neat plasma. The plot of the particle protein identifications which overlap the database confirm that different particle types select differential subsets of the plasma proteins. This could be attributable to the different surface properties of the three SPION particle types, which largely determine the protein composition of corona.

[0200] In order to evaluate the ability of particles to compress the measured dynamic range, measured and identified protein feature intensities were compared to the published values for the concentration of the same protein. First, the resulting peptide features for each protein (as

presented in **FIG. 24**) was selected with the maximum MS-determined intensity of all possible features for a protein (using the OpenMS MS data processing tools to extract monoisotopic peak values), and then the intensities were modeled against the published abundance levels for those same proteins (**FIG. 25**). By comparing the regression model slopes and the intensity span of the measured data, the particle coronas contain more proteins at lower abundances (measured or reported) than does plasma, similar to **FIG. 24**. The dynamic range of those measured values was compressed (the slope of the regression model is reduced) for particle measurements as compared to plasma measurements. This was consistent with previous observations that particle can effectively compress the measured dynamic range for abundances in the resulting corona as compared to the original dynamic range in plasma, which could be attributable to the combination of absolute concentration of a protein, its binding affinity to particles, and its interactions with neighboring proteins. All the above results indicate that the multi-particle type protein corona strategy facilitated the identification of a broad spectrum of plasma proteins, particularly those in the low abundance that are challenging for rapid detection by conventional proteomic techniques.

[0201] To evaluate the robustness of protein identification using the particle corona MS assay, full-assay triplicates were performed using the three particle type panel to create individual protein corona samples from the same pooled CRC plasma sample. For each combination of particle types ranging from any one, to all groups of two, to the single group of three, the number of unique proteins enumerated by the combination is shown in **TABLE 6**.

TABLE 6 – Summary of the protein coverage from the combinations of SP-003, SP-007 and SP-011 Particles

Particle Type Combination	Only One	Any One	All Three
SP-003	1058 ± 27.8	1313	844
SP-007	961 ± 87.4	1277	660
SP-011	1022 ± 37.8	1249	821
SP-003:SP-007	1412 ± 18.9	1816	1052
SP-003:SP-011	1272 ± 22.5	1595	973
SP-007:SP-011	1372 ± 27.3	1746	1026
SP-003:SP-007:SP-011	1576 ± 14.5	2030	1150

[0202] In the ‘Only One’ column, the protein counts were developed using each of the three replicates independently and then finding the mean and standard deviation for all of the combination counts. As can be seen, more proteins were discovered when increasing the number of particle types in the particle panel, with >1,500 unique proteins by the group of three particle types (65 of which are FDA-cleared/approved biomarkers, as listed in **TABLE 7**, below). In the

‘Any One’ replicate column, the protein counts were developed using the union of a particle type replicate protein lists. In the ‘All Three’ replicates column, the protein counts were developed using the intersection of a particle type replicate protein lists. As an additional measure of particle replicate overlap of identified proteins, the Jaccard Index, a metric for set similarity, was calculated for each pairwise-comparison. The values for SP-003, SP-007, and SP-011 were 0.74 ± 0.018 , 0.65 ± 0.078 , and 0.76 ± 0.019 (mean $\pm$ sd), respectively. Enumeration of protein content in a given MS sample is subject to the stochastic nature of MS2 data collection and may represent an undercount of the proteins represented within a sample or shared in common between samples. PSM mapping to shared MS1 features represents one approach that may alleviate this issue and will be developed for future analysis.

TABLE 7 – FDA-Cleared/Approved Biomarkers

UP_Accession	UP_Name	Class
P02647	APOA1_HUMAN	Particles
P00747	PLMN_HUMAN	Particles
P02671	FIBA_HUMAN	Particles
P02675	FIBB_HUMAN	Particles
P04114	APOB_HUMAN	Particles
P02775	CXCL7_HUMAN	Particles
P02768	ALBU_HUMAN	Particles
P02679	FIBG_HUMAN	Particles
P0C0L4	CO4A_HUMAN	Particles
P0C0L5	CO4B_HUMAN	Particles
P61626	LYSC_HUMAN	Particles
P0DOY2	IGLC2_HUMAN	Particles
P01024	CO3_HUMAN	Particles
P08519	APOA_HUMAN	Particles
P04075	ALDOA_HUMAN	Particles
P00738	HPT_HUMAN	Particles
P00736	C1R_HUMAN	Particles
P00488	F13A_HUMAN	Particles
P02765	FETUA_HUMAN	Particles
P01023	A2MG_HUMAN	Particles
P61769	B2MG_HUMAN	Particles
P01009	A1AT_HUMAN	Particles
P01834	IGKC_HUMAN	Particles
P00751	CFAB_HUMAN	Particles
P02746	C1QB_HUMAN	Particles
P07225	PROS_HUMAN	Particles
P02751	FINC_HUMAN	Particles
P00450	CERU_HUMAN	Particles
P02747	C1QC_HUMAN	Particles

UP_Accession	UP_Name	Class
P01031	CO5_HUMAN	Particles
P05155	IC1_HUMAN	Particles
P09871	C1S_HUMAN	Particles
P02790	HEMO_HUMAN	Particles
P02745	C1QA_HUMAN	Particles
P01034	CYTC_HUMAN	Particles
P08697	A2AP_HUMAN	Particles
P02741	CRP_HUMAN	Particles
P17936	IBP3_HUMAN	Particles
P01008	ANT3_HUMAN	Particles
P04278	SHBG_HUMAN	Particles
P19652	A1AG2_HUMAN	Particles
P02787	TRFE_HUMAN	Particles
P02786	TFR1_HUMAN	Particles
P02763	A1AG1_HUMAN	Particles
P04275	VWF_HUMAN	Particles
P07195	LDHB_HUMAN	Particles
P00338	LDHA_HUMAN	Particles
P30613	KPYR_HUMAN	Particles
P02766	TTHY_HUMAN	Particles
P09972	ALDOC_HUMAN	Particles
O75874	IDHC_HUMAN	Particles
P06858	LIPL_HUMAN	Particles
P05164	PERM_HUMAN	Particles
P05121	PAI1_HUMAN	Particles
P00740	FA9_HUMAN	Particles
P05543	THBG_HUMAN	Particles
P04070	PROC_HUMAN	Particles
P08833	IBP1_HUMAN	Particles
P00742	FA10_HUMAN	Particles
P07477	TRY1_HUMAN	Particles
P07478	TRY2_HUMAN	Particles
P02753	RET4_HUMAN	Particles
P43251	BTD_HUMAN	Particles
P24666	PPAC_HUMAN	Particles
P05160	F13B_HUMAN	Particles
P01023	A2MG_HUMAN	Plasma
P02768	ALBU_HUMAN	Plasma
P02671	FIBA_HUMAN	Plasma
P01008	ANT3_HUMAN	Plasma
P01024	CO3_HUMAN	Plasma
P00450	CERU_HUMAN	Plasma
P02775	CXCL7_HUMAN	Plasma
P02787	TRFE_HUMAN	Plasma
P08697	A2AP_HUMAN	Plasma

UP_Accession	UP_Name	Class
P01031	CO5_HUMAN	Plasma
P0C0L4	CO4A_HUMAN	Plasma
P0C0L5	CO4B_HUMAN	Plasma
P01009	A1AT_HUMAN	Plasma
P00736	C1R_HUMAN	Plasma
P02647	APOA1_HUMAN	Plasma
P02751	FINC_HUMAN	Plasma
P09871	C1S_HUMAN	Plasma
P00738	HPT_HUMAN	Plasma
P04114	APOB_HUMAN	Plasma
P00740	FA9_HUMAN	Plasma
P0DOY2	IGLC2_HUMAN	Plasma
P02675	FIBB_HUMAN	Plasma
P00751	CFAB_HUMAN	Plasma
P05543	THBG_HUMAN	Plasma
P02679	FIBG_HUMAN	Plasma
P02790	HEMO_HUMAN	Plasma
P05155	IC1_HUMAN	Plasma
P02765	FETUA_HUMAN	Plasma
P61769	B2MG_HUMAN	Plasma
P01834	IGKC_HUMAN	Plasma
P07225	PROS_HUMAN	Plasma
P00338	LDHA_HUMAN	Plasma
P07195	LDHB_HUMAN	Plasma
P00488	F13A_HUMAN	Plasma
P19652	A1AG2_HUMAN	Plasma
P00747	PLMN_HUMAN	Plasma
P02747	C1QC_HUMAN	Plasma
P08519	APOA_HUMAN	Plasma
P43251	BTD_HUMAN	Plasma
P02763	A1AG1_HUMAN	Plasma
P02741	CRP_HUMAN	Plasma
P04275	VWF_HUMAN	Plasma
P02746	C1QB_HUMAN	Plasma
P17936	IBP3_HUMAN	Plasma
P02745	C1QA_HUMAN	Plasma
P00742	FA10_HUMAN	Plasma
P04075	ALDOA_HUMAN	Plasma
P01034	CYTC_HUMAN	Plasma
P05160	F13B_HUMAN	Plasma
P02753	RET4_HUMAN	Plasma
P04070	PROC_HUMAN	Plasma
P06744	G6PI_HUMAN	Plasma
P02766	TTHY_HUMAN	Plasma
P61626	LYSC_HUMAN	Plasma

UP_Accession	UP_Name	Class
P05062	ALDOB_HUMAN	Plasma
P06276	CHLE_HUMAN	Plasma
P04278	SHBG_HUMAN	Plasma
P02786	TFR1_HUMAN	Plasma

[0203] Dynamic Range. The three-particle type panel was assessed for its ability to assay proteins in a sample across a wide dynamic range of protein concentrations. Feature intensities corresponding to proteins that were identified by mass spectrometry were compared to the values determined by other assays for the same protein at the same concentration. After mass spectrometry analysis and data processing, MS2 peptide-spectral matches (PSM) were used to identify peptides and associated proteins present in the corona of the distinct particles types in the particle panel. In parallel, peptides were also directly detected in a plasma sample, without the use of the three-particle type panel for corona analysis via the Proteograph workflow. Resulting peptide features having the maximum MS-determined intensity of all observed features, as determined using the OpenMS MS data processing tools to extract monoisotopic peak values, was selected for each protein. The MS-determined intensities were then modeled against comparable published abundance levels for the same proteins. **FIG. 25** shows a correlation between the maximum intensities of proteins in distinct coronas from the distinct nanoparticle types for each particle type in the three-particle type panel relative to plasma proteins and concentration of the same proteins determined using other methods. As shown by the regression model slopes and the intensity span of the measured data, the particle coronas contained more protein hits at lower abundances than does plasma. Additionally, the dynamic range of those measured values was compressed, as shown by a reduced slope of the regression models, for particle measurements as compared to plasma measurements, showing that particles effectively compressed the measured dynamic range of protein abundance in the corona as compared to in plasma. This may be attributed to a combination of absolute protein concentration, protein binding affinity to particles, and protein interactions with neighboring proteins. These results indicate that the methods disclosed herein of using a multi-particle type panel for enrichment of proteins in distinct coronas corresponding to the distinct particle types facilitated the identification of a broad spectrum of plasma proteins, particularly those in the low abundance that are challenging for rapid detection by conventional proteomic techniques.

EXAMPLE 6

Precision of the Corona Analysis Assay

[0204] This example describes the precision of the coronal analysis assay. Precision, a measure of repeatability and reproducibility of an assay, was assessed by comparing multiple measurements under the same conditions and determining the variability between the individual measurements. To investigate the reproducibility of the particle protein corona analysis Proteograph workflow, the peptide MS feature intensities were extracted and compared from the three full-assay replicates for each of the three particle types. The raw MS files for each replicate were converted to mzML format, which is a standard, interchangeable MS file format, using the msconvert.exe utility from the openMS suite of programs. Also using openMS processing pipeline, MS1 features were extracted from the raw data and aligned into groups by overlapping retention time and *mz* value. Groups were selected which contained a feature from each of the three replicates, and filtered to remove the bottom decile based on the clustering algorithm's quality score (90% of feature groups retained for subsequent precision analysis). For the SP-003, SP-007, and SP-011 nanoparticles, a total of 2,744, 2,785, and 3,209, respectively, clustered feature groups were used for the precision analysis. The distribution of log-transformed raw intensities for each of the replicates for these feature groups were plotted in the FIG. 26 with the value of each particle type displayed in the labeled panel. As shown in FIG. 26, the feature data for each particle type was highly reproducible and this reproducibility was consistent across both high intensity and low intensity features.

[0205] For a more quantitative assessment of performance, beyond visual inspection of raw data, the overall precision of the particle coronas after quantile normalizing the group feature intensities was estimated. This normalization method was based on the assumption that all compared distributions should be identical and accordingly adjusts the intensities for each compared distribution. This assumption is reasonable given that the reproducibility of the physical characteristics of the particle types themselves and from separate analyses of these particles (e.g., with X-ray photoelectron spectroscopy, high-resolution transmission electron microscopy, and other analytical methods). With the normalized values, the standard deviations were evaluated and the coefficients of variation (CVs) were determined using the appropriate transformation of log-treated data. For each particle, the median CVs (percent of quantile normalized CV or QNCV%) are shown in TABLE 8. This result demonstrates that the particle-measured protein MS feature intensities have sufficient precision across the thousands of MS feature intensities observed to detect relatively small differences in reasonable small studies. For

example, given a CV of 25%, there was approximately 100% power to detect two-fold changes with Bonferroni-corrected significance.

[0206] The overall precision of particle coronas was estimated by normalizing the group feature intensities using quantile normalization, which makes the prior assumption that all compared distributions should be identical and adjusts the intensities for each compared distribution appropriately. With the normalized values, the standard deviations were evaluated and the coefficients of variation (CVs) were determined using the appropriate transformation of log-treated data. For each particle type, the median CVs (percent of quantile normalized CV or QNCV%) are shown in **TABLE 8**. A low coefficient of variation (CV) was indicative of a high degree of assay precision.

TABLE 8 – Median QNCV% for precision evaluation of the particle protein corona-based Proteograph workflow

Particle	Median QNCV%	Count
SP-003	23	2744
SP-007	29	2785
SP-011	20	3209

[0207] This result demonstrated that the particle-measured protein MS feature intensities had sufficient precision across the thousands of MS feature intensities observed to detect relatively small differences in reasonable small studies.

EXAMPLE 7

Accuracy of the Corona Analysis Assay

[0208] This example describes the accuracy of the corona analysis assay. The accuracy of a method should be sufficiently robust for detecting a true difference between groups of samples in biomarker discovery and validation studies. Accuracy of the corona analysis assay was determined by comparing corona analysis assay results to those obtained by other methods. To evaluate the corona analysis assay's accuracy, a spike recovery study was performed using the SP-007 nanoparticles. C-reactive protein (CRP) was selected for analysis based on the measurement of its endogenous levels. Using the enzyme-linked immunosorbent assay (ELISA)-determined endogenous plasma levels for CRP, known amounts of the purified protein (see Methods) were spiked to achieve testable multiples of the endogenous levels. The CRP levels after spiking were determined empirically by ELISA to be 4.11, 7.10, 11.5, 22.0, and 215.0 µg/mL for the 1× (unspiked), 2×, 5×, 10×, and 100× samples, respectively. The extracted MS1 feature intensities were plotted for the four indicated CRP tryptic peptides detected by MS on the SP-007 particles versus the CRP concentrations (**FIG. 14A**). **FIG. 30** also shows the accuracy of

measurements for CRP proteins on the SP-007 particles in a spike-recovery experiment for four different peptides. The MS1 feature intensity cannot be detected for two of the peptides at the unspiked $1\times$ concentration of CRP. The fitted lines were linear models using the given feature's spike intensities.

[0209] Fitting a regression model to all 4 of the CRP tryptic peptides resulted in a slope of 0.9 (95% CI 0.81 – 0.98) for the response of corona MS signal intensity versus ELISA plasma level, which is close to a slope of 1 that would be considered to be perfect analytical performance. In contrast, a similar regression model fitted to 1,308 other (non-spiked) MS features identified in at least 4 of the 5 plasma samples, for whom the signals from associated MS features should not vary across the samples, had a slope of -0.086 (95% CI -0.1 – -0.068). These results indicated the ability of that particle type to accurately describe differences between samples will provide a useful tool to quantify potential markers in comparative studies. If a protein level changes in a sample due to some factor, the methods disclosed herein will detect a similar level change of protein bound to particle types of the particle panel, which is a critical property of the present particle type to be effective in any given assay. Moreover, the response of the spiked-protein peptide features also suggests that with appropriate calibration, the particle protein corona method could be used to determined absolute analyte levels as opposed to just relative quantitation.

EXAMPLE 8

Proteomic analysis of NSCLC samples and healthy controls.

[0210] This example describes proteomic analysis of NSCLC samples and healthy controls. To demonstrate the potential utility of the corona analysis platform, the platform's ability was evaluated using a single particle type, SP-007, and serum samples from 56 subjects (28 with Stage IV NSCLC and 28 age- and gender-matched controls) to observe differences between the groups. The selected subject samples represented a reasonably balanced study to identify potential MS features that are different between the groups. The age and gender characteristics of the subjects are summarized in TABLE 6 and full data on subject annotation including disease status and co-morbidities are compiled in TABLE 9.

TABLE 9 - Gender and age information for the patients from whom the serum samples were obtained

Class	Gender	Mean Age	Sd Age	Number
Control	F	71.1	7.7	19
	M	72.4	11.1	9
Diseased	F	70.7	7.5	19

	M	15.6	13.6	9
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[0211] After collection and filtering of the MS1 features followed by log2 transformation of their intensity, the datasets were median scaled without respect to class.

[0212] **FIG. 29** shows the normalized intensity distributions for all 56 subject datasets. All 56 sample MS raw data files from the NSCLC versus control study were processed by OpenMS pipeline scripts to extract MS1 features and their intensities and cluster them into feature groups based on overlapping m/z and RT values within specified tolerances. Only those feature groups were retained that 1) had at least 50% presence of a feature in the group from at least one of the arms of the comparison and 2) had a feature group cluster quality above the 25th percentile. The retained features were median normalized without respect to class and used for subsequent univariate analytical comparison. There were no outliers by inspection of the distributions and all datasets were retained for the univariate analysis.

[0213] There did not appear to be any outlier datasets by inspection. Univariate comparison of feature group intensities between the classes was performed with a non-parametric, Wilcoxon Test (two-sided). The resulting p-value for the comparison was corrected for multiple testing using the method of Benjamini-Hochberg. Using an adjusted p-value cut-off of 0.05, a total of seven feature groups demonstrated statistical significance, as summarized in **FIG. 27**.

[0214] All five of the proteins identified as differentially abundant between the NSCLC-diseased and control groups have previously been implicated in cancer if not actually NSCLC itself. PON1, or paraoxanase-1, has a complicated pattern in lung cancer including the involvement of a relatively common minor allele variant (Q192R) as a risk factor. At the protein level, PON1 is modestly decreased in lung adenocarcinoma. SAA1 is an acute phase protein that has been shown to be overexpressed in NSCLC in MS-related studies, and the identified peptide was found to be increased 5.4-fold in diseased subjects. The matrisome factor tenascin C (TENA) has been shown to be increased in primary lung tumors and associated lymph node metastases compared with normal tissue, and the associated MS feature was found to be increased by 2-fold in this study. Neural cell adhesion molecule 1 (NCAM1) serves as a marker for diagnosing lung neuroendocrine tumors. FIBA peptides were identified by MS analysis with increased levels correlating with advancing progression of lung cancer. Of special note are the two unknown features, Group2 and Group7, which show differences between control and diseased subjects. Group2 was found in 54 out of 56 subjects and had a modest 33% decrease in diseased subjects. In contrast, Group7 was found only in diseased subjects (14 out of 28 members of the class). These results demonstrated the potential utility for the particle corona to aid in identifying known and unknown markers for different disease states.

EXAMPLE 9**Particle Panel for Assaying Proteins in a Sample**

[0215] This example illustrates a 10-particle type particle panel for assaying proteins in a sample. This particle panel shown in **TABLE 10** includes 10 distinct particle types, which differ in size, charge, and polymer coating. All particle types in this particle panel are superparamagnetic. The panel shown in below was used to assay proteins in samples.

TABLE 10 – 10 Particle Type Particle Panel

Particle ID	Particle Description	Mean DLS diameter (nm)	Mean Zeta Potential (mV)
SP-003	Thick silica coated SPION	262	-36.9
SP-006	N-(3-Trimethoxysilylpropyl) diethylenetriamine coated	232	20.9
SP-007	PDMA-PMA-coated SPION	259	25.8
SP-010	Carboxylated, PAA	366	-47.9
SP-353	Amino surface microparticle, 0.4-0.6 μm	606	27.2
SP-333	Carboxylate microparticle, surfactant free	1300	-28.5
SP-339	Polystyrene carboxyl functionalized	410	-31.4
SP-347	Silica coated, 200 nm	281	-21.8
SP-365	Silica	231	-39.0
SP-373	Dextran based coating, 0.13 μm	169	-0.5

[0216] **Protein coverage of V1 panel.** To evaluate the total protein group coverage seen across multiple samples in a clinical sample set, plasma samples from 16 individuals were evaluated for a panel of ten distinct particle types shown in **TABLE 10** and referred to as the V1 panel. using the sample preparation, MS data acquisition and MS data analysis methods described herein. A mix of non-small-cell lung carcinoma (NSCLC) patients and healthy individuals (n = 8 for each) was used to provide a diverse set of proteins and protein groups, present in both healthy and cancer cells, for analysis and identification using the methods described herein. At the 1% FDR

(protein and peptide) rate, a total of 2,009 protein groups were efficiently identified. For comparison, in the previously mentioned published study, 4,500 protein groups were detected across 16 individual plasma samples in a complex workflow comprised by more than 70 steps and more than 30 MS fractions per sample, likely taking weeks to complete.

EXAMPLE 10

10-Particle Type Particle Panel for Protein Assaying

[0217] This example illustrates the development of a 10-particle type particle panel for methods of assaying proteins using biomolecule corona analysis, as described herein.

[0218] **Particle Screen.** To demonstrate the ability of the corona analysis platform to expand its coverage through guided particle addition, biomolecule coronas from 43 particles types with distinct physicochemical properties and screened in a similar manner to the three-particle type particle panel disclosed herein.

TABLE 11 – Particles for Screening

Particle type	Particle Description	DLS Diameter (nm)	DLS PDI	Zeta potential (mV)
SP-001	Carboxylated citrate coated	374	0.23	-34.0
SP-002	Phenol-formaldehyde resin coated	335	0.39	-29.0
SP-003	Silica coated SPION	233	0.05	-36.9
SP-004	Polystyrene coated	411	0.32	-45.7
SP-005	Carboxylate Poly(styrene-co-methacrylic acid)	247	0.19	-36.5
SP-006	N-(3-Trimethoxysilylpropyl)diethylenetriamine coated	232	0.30	20.9
SP-007	PDMA-PMA-coated SPION	283	0.09	25.8
SP-008	1,2,4,5-Benzenetetracarboxylic acid coated	426	0.43	-34.5
SP-009	PVB-TMAC coated	229	0.11	35.9
SP-010	Carboxylated, Polyacrylic acid	366	0.23	-47.9
SP-016	Titanium(IV) oxide coated	1623	0.92	-32.1
SP-019	Phenylboronic acid coated	305	0.44	-36.4
SP-047	Poly(glycidyl methacrylate-benzylamine) coated	1255	0.54	18.1
SP-060	Maleimide base surface	302	0.15	-40.8
SP-064	Poly(N-[3-(Dimethylamino)propyl]methacrylamide-co-[2-(methacryloyloxy)ethyl]dimethyl-(3-sulfopropyl)ammonium hydroxide, P(DMAPMA-co-SBMA) coated	302	0.25	27.7
SP-065	Modified Random 30 nt ssDNA	364	0.21	-43.5
SP-066	Smaller size carboxylated citrate coated	210	0.25	-35.3
SP-369	Carboxylated, Original coating, 50 nm	104	0.15	-31.5
SP-373	Dextran based coating, 0.13 μ m	169	0.07	-0.6
SP-374	Silica Silanol coated with lower acidity	225	0.11	-25.6
SP-389	BioMag®Plus Wheat Germ Agglutinin coated microparticle	3514	0.97	-21.6

Particle type	Particle Description	DLS Diameter (nm)	DLS PDI	Zeta potential (mV)
SP-390	Oleic acid- Hydrophilic / hydrophobe surface	98	0.10	-38.0
SP-391	Rare earth doped phosphor particles	130	0.15	-16.0
SP-392	Gadolinium oxide nanopowder coated	1199	0.82	-4.9
SP-393	Oligonucleotide-philic Apostle MiniMax TM Magnetic Nanoparticles	614	0.23	-41.9
SP-394	Iron Oxide Nanoparticles with Azide Groups coating, 30 nm	64	0.11	-17.0
SP-397	DEAE starch coated	99	0.18	13.6
SP-398	Poly(maleic acid-co-olefin) amphiphilic coating	393	0.31	-27.8
SP-399	Polyvinyl alcohol coated	163	0.10	-8.9
SP-300	Poly(4-vinylpyridine) (P4VP) coated	177	0.21	-19.3
SP-301	Poly-diallyldimethylamine coated, strong anion exchanger	114	0.14	24.6
SP-305	Amine small clusters	75	0.17	-9.5
SP-406	Boronated nanopowder surface	491	0.45	-40.7
SP-413	Nanotrap Blue VSA CS Magnetic Porous surface	3500	0.77	-3.0
SP-333	Carboxylate microparticle, surfactant free	1348	0.66	-28.5
SP-339	Polystyrene carboxyl functionalized	410	0.03	-31.4
SP-341	Carboxylic acid, 150 nm	154	0.10	-26.0
SP-347	Silica coated, 200 nm	281	0.18	-21.8
SP-353	Amino surface microparticle, 0.4-0.6 μ m	1723	0.75	31.4
SP-356	Silica amino functionalized microparticle, 0.1-0.39 μ m	2634	0.62	19.8
SP-363	Jeffamine, 0.1-0.39 μ m	253	0.13	-35.4
SP-364	Polystyrene microparticle, 2.0-2.9 μ m	3176	0.96	-55.9
SP-365	Silica	231	0.02	-39.0

[0219] The 43 particle types were evaluated using 6 conditions, as described in the methods sections, and the most optimal conditions were used in a secondary analysis to select the best combination based on total identified protein number. The 43-particle type screen was conducted using a plasma pool of healthy and lung cancer patients, different from the CRC pool used for the three-particle type particle panel, to demonstrate platform validation across biological samples. A pooled sample was used to increase protein diversity. Strict criteria were used to identify potential proteins for panel selection and optimization. For maximum potential evaluation, a protein had to be represented by at least one peptide-spectral-match (PSM; 1% false discovery rate (FDR)) in each of three full assay replicates to be counted as “identified.” The panel with the largest number of individual unique Uniprot identifiers was selected for the 10-particle type particle panel.

[0220] **Protein Coverage of 10-Particle Type Particle Panel.** Data disclosed herein confirms that the particle panels provided can be used to determine changes in proteomic content across many biological samples. The particle panels disclosed herein have high precision and accuracy

and provide methods that take an unbiased approach that doesn't require specific ligands to known proteins. Thus, these panels are particularly well suited to biomarker discovery. The breadth and depth of plasma protein coverage using the 10-particle type panel was investigated. Using a database ($n = 5,304$) of MS-derived plasma protein intensities (a close correlate to concentration), the coverage of the 10-particle type panel was compared against the full extent of the database as well as against the coverage obtained by MS evaluation of simple plasma (direct MS analysis of the same plasma sample without particle-based sampling). **FIG. 36** shows matching and coverage of a particle panel of the 10 distinct particle types to a 5,304 plasma protein database of MS intensities. The ranked intensities for the database proteins are shown in the top panel ("Database"), the intensities for proteins from simple plasma MS evaluation are shown in the second panel ("Plasma") and the intensities for the optimal 10-particle panel are shown in the remaining panels. The plasma protein intensities database is from Keshishian et al. (2015). Multiplexed, Quantitative Workflow for Sensitive Biomarker Discovery in Plasma Yields Novel Candidates for Early Myocardial Injury. *Molecular & Cellular Proteomics*, 14(9), 2375–2393. The results, shown in **FIG. 36**, confirmed and extended the results shown for the particle panel of 3 distinct particle types described above, which were used in precision experiments shown **FIG. 26**. The particle panel of 10 distinct particle types identified 1,598 proteins vs. 268 proteins for simple plasma. Furthermore, each individual particle type detected substantially more proteins than direct MS analysis of simple plasma. Unlike MS analysis on simple plasma, the particle panel of 10 distinct particle types interrogated the entire spectrum of the concentration of plasma proteins. Said differently, while the proteins identified from the simple plasma sample were skewed toward the higher intensity proteins (that is, higher abundance proteins), the proteins identified from the particle panel of 10 distinct particle types extended over 8 orders of magnitude in dynamic range of the concentrations in the database. Only 21 proteins in the database had intensities lower than the lowest protein matched from the particle panel of 10 distinct particle types. As demonstrate in **FIG. 36**, the particle panel of 10 distinct particle types demonstrated high precision, accuracy, and broad coverage across a wide range of protein concentrations in plasma and enables broad-scale, unbiased proteomic analyses in parallel across large numbers of biological samples, and can match the cost and speed of what is possible in genomic data acquisition today.

[0221] Precision of a Particle Panel Including 10 Distinct Particle Types. This example describes reproducibility of particle corona for a particle panel including 10 distinct nanoparticle types. Particles were analyzed to determine the coefficient of variation (CV) of each feature group between the replicate runs for each particle type of the particle panel including 10 distinct

nanoparticle types. A low CV indicated high precision and reproducibility between replicate runs. The data was processed using the software program OpenMS and retained feature groups which contained an observed precursor feature from each of three replicates. The bottom 5% of the data was removed to eliminate statistical outliers based on a quality score of the clustering algorithm. Group feature intensities were median normalized, and the overall precision of the coronas of each particle type was estimated. Normalization was performed such that the overall median intensity for each injection remained the same, and intensities were adjusted for each compared distribution to account for intensity shifts due to, for example, overall differences in instrument response. Differences in instrument response may arise in a variety of analysis methods, including X-ray photoelectron spectroscopy, high-resolution transmission electron microscopy, and other analytical methods. The normalized values of the coefficients of variation (CVs) of each feature group were then evaluated for each particle type of the particle panel including 10 distinct nanoparticle types. **TABLE 12** shows the optimized panel of 10 distinct particle types.

TABLE 12 – 10 Particle Type Particle Panel

Particle Type	Particle Description
SP-333	Carboxylate microparticle, surfactant free
SP-339	Polystyrene carboxyl functionalized
SP-347	Silica coated, 200 nm
SP-365	Silica
SP-373	Dextran based coating, 0.13 μ m
SP-390	Oleic acid- Hydrophilic / hydrophobe surface
SP-406	Boronated nanopowder surface
SP-007	PDMA-PMA-coated SPION
SP-047	Poly(glycidyl methacrylate-benzylamine) coated
SP-064	Poly(N-[3-(Dimethylamino)propyl]methacrylamide-co-[2-(methacryloyloxy)ethyl]dimethyl-(3-sulfopropyl)ammonium hydroxide, P(DMA-PMA-co-SBMA) coated

[0222] **TABLE 13** shows the median percent of quantile normalized CV (QNCV%) for precision evaluation of the protein corona-based Proteograph workflow for plasma and a particle panel including 10 distinct particle types for features, peptides and proteins. A 1% peptide and 1% protein false discovery rate (FDR) was applied. Data was processed using MaxLFQ analysis

software, applying the condition that each protein group have at least one peptide ratio-count and detection in all replicates, which reduced the number of groups used for the precision analysis. For each particle type of the particle panel including 10 distinct nanoparticle types, the median CVs, including percent of quantile normalized CV or QNCV%, are shown in **TABLE 13**. A similar analysis was performed at a peptide and protein level using MaxQuant to align identifiable feature groups to features, peptides, and proteins (**TABLE 13**). The number of identifiable features decreases from features to peptides to proteins, as peptides can comprise multiple features and proteins can comprise multiple peptides. This nanoparticle panel detected 1,184 protein groups with a 1% false discovery rate (FDR).

TABLE 13 Median QNCV% for a particle panel including 10 distinct nanoparticle types

Particle	Features (OpenMS)		Peptides (MaxQuant)		Proteins (MaxQuant)	
	# Features	Median CV	# Peptides	Median CV	# Proteins	Median CV
Plasma	2141	22.5	976	22.7	162	17.1
SP-333	2163	17.2	1192	20.5	250	18.2
SP-339	2330	19.4	1406	20.8	296	17.9
SP-347	2792	15.4	2105	19.9	469	16.4
SP-365	2322	17.9	1867	22.4	447	18.4
SP-373	2796	27.1	2091	30.3	479	25.5
SP-390	2267	29.3	1265	25.8	216	19.1
SP-406	3823	28.7	1947	30.8	410	28.3
SP-007	2351	21.1	1292	21.5	250	17.1
SP-047	2233	36.5	1176	35.7	279	30.8
SP-064	2984	20.2	2112	23.3	433	19.3

[0223] Coefficients of variation (CVs) were examined at the level of features, peptides and proteins independently. Analysis of feature, peptide, and protein CVs provide complementary views of assay precision. OpenMS and MaxQuant software engines were used for feature, peptide, and protein matching. MaxQuant was used to for protein grouping with FDR. OpenMS was used to perform peptide-spectrum-matching (PSM) using the X!Tandem matching tool. MaxQuant was configured to use the Andromeda algorithm. Peptide CVs and protein CVs were used to assess precision of the platform for use with biological variables. The mean CV decreased with increasing peptide size, such that the mean CV was lower for peptides than for proteins. The particles maintain a CV similar to plasma, while particles have higher occurrences of features, peptides, and proteins than plasma. In particular, the number of proteins on particles of any given particle type is higher than plasma (average: 218% higher, range: 133% – 296%

higher) while maintaining a comparable CV (21.1% vs 17.1% for particles and plasma, respectively). Furthermore, the panel of the particle types identified 1,184 proteins while only identifying 162 proteins for plasma alone.

[0224] Accuracy of a Particle Panel Including 10 Distinct Nanoparticle Types. The accuracy of for the particle panel including 10 distinct nanoparticle types to detect a real difference between groups of samples in biomarker discovery and validation studies was assessed.

Accuracy was determined by measuring spike recovery data in the presence a nanoparticle types SP-007, and C-reactive protein (CRP). Spike recovery data was further measured in the presence of one three additional polypeptides (S100A8/9, and Angiogenin) in combination with each of three particle types (SP-006, SP-339, SP-374). Known amounts of each polypeptide were spiked in at different concentrations, increasing by factors of 10 (e.g., 1X, 2X, 5X, 10X, and 100X).

The level of each polypeptide was measured by ELISA. Derived peptide and protein intensities were plotted against the ELISA protein concentration. Peptide intensities were derived using OpenMS MS1/MS2 pipeline to find clustered feature groups that have a target protein MS2 ID assigned to at least one feature within the cluster. Only cluster groups with representation in at least one replicate for the top spike levels were used for the analysis. Protein intensities were derived using the MaxQuant software. Intensity values for each protein were summarized. and the data was scaled such that the maximal concentration was 2. MS datasets were performed in triplicate for each spike concentration (e.g., 1X, 2X, 5X, 10X, and 100X), providing 15 individual protein or peptide measurements. Not all peptides were detected in all particle types or particle type replicates. Results of the MS datasets are shown in **FIG. 31-34**. **FIG. 31** shows the accuracy of peptide feature measurements of Angiogenin in a spike-recovery experiment. **FIG. 32** shows the accuracy of peptide feature measurements of S10A8 in a spike-recovery experiment. **FIG. 33** shows the accuracy of peptide feature measurements of S10A9 in a spike-recovery experiment. **FIG. 34** shows the accuracy of peptide feature measurements of CRP in a spike-recovery experiment. The fitted lines are linear fits to the spike intensities of each feature.

[0225] FIG. 31-34 illustrate the results of three spike recovery experiments to determine the accuracy of peptide feature measurements of Angiogenin, S10A8, S10A9, and CRP, respectively. The data demonstrated high degrees of correlation between individual measurements for peptides (mean r^2 is 0.81) and proteins (mean r^2 is 0.97). The mean slope across all proteins is 1.06. **TABLE 14** showed the r^2 correlation per comparison and also the mean r^2 correlation per protein. Out of 20 peptides, only two showed no correlation between ELISA assays on two different particles types, in which one peptide presented in two charge states. The aberrations decreased with increasing peptide size, such that the frequency of

aberrations was lower for peptides than for proteins. The two peptides that showed now correlation with the ELISA on two different particles showed a high degree of correlation to ELISA in the other particle types. The offending peptide may be co-eluting with another peptide that masks its signal, for example through charge stealing.

[0226] **TABLE 14** provides a summary of regression fits to protein intensity as measured by corona analysis or ELISA. Values are shown for individual particle types and averaged between four repeats per particle type. The protein concentrations, as measured by corona analysis, were consistent across a range of conditions and a range of particle types. As shown in **TABLE 14**, protein measurements were well correlated, as shown by high r^2 values (mean 0.97, range across individual particles 0.92 – 1.0; range averaged across particles 0.94 – 0.99). This consistent behavior across the four proteins as measured by an ELISA illustrates the accuracy of the corona analysis assay.

TABLE 14. Summary of protein intensity regression fit.

Protein	Particle Type	intercept	slope	r_sq	adj_r_sq	intercept	slope	r_sq	adj_r_sq
ANG	SP-006	0.16	1.05	0.94	0.91	0.30	0.96	0.97	0.95
ANG	SP-007	0.75	0.78	0.93	0.90				
ANG	SP-339	0.05	1.05	1.00	1.00				
ANG	SP-374	0.23	0.98	0.99	0.99				
CRP	SP-006	-0.24	0.96	1.00	1.00	-0.85	1.22	0.99	0.99
CRP	SP-007	-0.48	1.07	0.99	0.99				
CRP	SP-339	-1.08	1.31	0.99	0.98				
CRP	SP-374	-1.60	1.54	NA	NA				
S100A8	SP-006	-0.12	1.02	1.00	1.00	0.03	0.98	0.97	0.95
S100A8	SP-007	-0.20	1.12	0.92	0.89				
S100A8	SP-339	0.34	0.81	0.99	0.98				
S100A8	SP-374	0.10	0.96	0.96	0.95				
S100A9	SP-006	-0.56	1.34	0.90	0.87	-0.09	1.06	0.94	0.92
S100A9	SP-007	-0.44	1.27	0.93	0.91				
S100A9	SP-339	0.51	0.68	0.98	0.97				
S100A9	SP-374	0.11	0.96	0.95	0.93				

[0227] **Comparison to other platforms.** The methods disclosed herein using multi-particle types panels to enrich proteins in distinct coronas corresponding to each protein type in the panel (e.g., corona analysis using the Proteograph workflow) provides wide and unbiased coverage of protein identification in the proteome. Other methods that attempt broad coverage of the

proteome require multiple fractionation steps, complex workflows, and are slow in comparison to the methods presented herein. Other methods lack the breadth and impartiality of the methods disclosed herein and are compared herein to the presently disclosed methods of assaying proteins.

[0228] Geyer et al (Cell Systems 2016) utilized a rapid shotgun proteomics approach and yielded an average of 284 protein groups per assay and 321 protein groups across all replicates. The assessment utilized a slower, multi-day protocol with fractionation that yielded approximately 1,000 protein groups. No replicates were performed, likely due to prohibitive costs and time requirements, and so no variance could be determined.

[0229] Geyer used a short run to generate 321 protein groups, and the CV of each protein was determined. The 321 groups assessed by Geyer and the 1,184 protein groups identified by the 10 particle type panel comprised 88 protein groups in common between the two methods. As protein groups may comprise multiple related proteins which may be differentially combined based on the detected peptides, identification of 88 common protein groups is unexpectedly high.

[0230] For the 88 common protein groups, the data from Geyer et al. was analyzed, and a median CV of 12.1% was determined. In contrast, the same 88 common protein groups, as analyzed by Proteograph, had a lower CV of only 7.2%. Thus, the instant methods of corona analysis using multi-particle type panels and the Proteograph workflow provided improved precision over the methods of Geyer et al. Additionally, Geyer et al.'s assessment showed an r^2 , indicative of assay accuracy, of 0.99 for 4 proteins. Similarly, the Proteograph assay showed an r^2 of 0.97.

[0231] Geyer et al. further assessed the number of protein groups with CVs < 20%, the commonly used cutoff for in vitro diagnostic assays. The particle panel methods detected 761 protein groups with CV < 20% which was 3.7 times greater than the number identified by Geyer et al. A further assessment by Dr. Mann (Niu et al, 2019) identified 272 protein groups with CV < 20%, 2.8-fold lower than the number identified by the multi particle type panels and methods of use thereof disclosed herein.

[0232] Bruderer et al. assessed protein group CV's using data generated by a Biognosys platform (Bruderer et al, 2019). This assessment identified 465 proteins, wherein those 465 proteins had a median CV of 5.2% and 404 of those proteins had CVs < 20%. In contrast, the best 465 proteins from the 1,184 proteins identified using the methods disclosed herein had a median CV of 4.7% and 761 of the 1,184 proteins identified by Proteograph had CV's < 20%.

[0233] In comparison to the assessments of Geyer et al., Niu et al, and Bruderer et al., the instant particle panels provided improved CVs for an equivalent number of proteins as well as number

of proteins meeting a CV threshold, over other identification methods. The methods disclosed herein additionally have reduced bias relative to other methods, such as targeted mass spectrometry and other analyte specific reagents (e.g., Olink). Such approaches measure a small number of pre-selected proteins, thereby introducing bias during the protein panel selection process. As a result, these approaches have low CVs and high r^2 for the proteins on their panel as compared to the proteins identified by Proteograph and are limited to detecting proteins on the panel.

EXAMPLE 11

Materials and Methods for Particle Synthesis

[0234] This example describes materials and methods for particle synthesis.

[0235] **Materials.** Iron (III) chloride hexahydrate ACS, sodium acetate (anhydrous ACS), ethylene glycol, ammonium hydroxide 28~30%, ammonium persulfate (APS) ($\geq 98\%$, Pro-Pure, Proteomics Grade), ethanol (reagent alcohol ACS) and methanol ($\geq 99.8\%$ ACS) were purchased from VWR. *N,N'*-Methylenebisacrylamide (99%) was purchased from EMD Millipore. Trisodium citrate dihydrate (ACS reagent, $\geq 99.0\%$), tetraethyl orthosilicate (TEOS) (reagent grade, 98%), 3-(trimethoxysilyl)propyl methacrylate (MPS) (98%) and poly(ethylene glycol) methyl ether methacrylate (OEGMA, average Mn 500, contains 100 ppm MEHQ as inhibitor, 200 ppm BHT as inhibitor) were purchased from Sigma-Aldrich. 4,4'-Azobis(4-cyanovaleric acid) (ACVA, 98%, cont. ca 18% water) and divinylbenzene (DVB, 80%, mixture of isomers) were purchased from Alfa Aesar and purified by passing a short silica column to remove the inhibitor. N-(3-Dimethylaminopropyl)methacrylamide (DMAPMA) was purchased from TCI and purified by passing a short silica column to remove the inhibitor. The ELISA kit to measure human C-reactive protein (CRP) was purchased from R&D Systems (Minneapolis, MN). Human CRP protein purified from human serum was from Sigma Aldrich.

[0236] **Synthesis of superparamagnetic iron oxide nanoparticle (SPION)-based SP-003, SP-007, and SP-011.** The iron oxide core was synthesized via solvothermal reaction (**FIG. 28A-E**, at top (**FIG. 28A**)) (Liu, J., et al. Highly water-dispersible biocompatible magnetite particles with low cytotoxicity stabilized by citrate groups. *Angew Chem Int Ed Engl* 48, 5875-5879 (2009); Xu, S., et al. Toward designer magnetite/polystyrene colloidal composite microspheres with controllable nanostructures and desirable surface functionalities. *Langmuir* 28, 3271-3278 (2012)). Typically, about 26.4 g of iron (III) chloride hexahydrate was dissolved in about 220 mL of ethylene glycol at about 160°C for ~10 min under mixing. Then about 8.5 g of trisodium citrate dihydrate and about 29.6 g sodium acetate anhydrous were added and fully dissolved by mixing for about an additional 15 min at about 160°C. The solution was then sealed in a Teflon-

lined stainless-steel autoclave (300 mL capacity) and heated to about 200 °C for about 12h. After cooling down to room temperature, the black paramagnetic product was isolated by a magnet and washed with DI water 3~5 times. The final product was freeze-dried to a black powder for further use.

[0237] The silica-coated iron oxide nanoparticles (SP-003) were prepared through a modified Stöber process as reported before (**FIG. 28B**)(Deng, Y., Qi, D., Deng, C., Zhang, X. & Zhao, D. Superparamagnetic high-magnetization microspheres with an $\text{Fe}_3\text{O}_4@\text{SiO}_2$ core and perpendicularly aligned mesoporous SiO_2 shell for removal of microcystins. *J Am Chem Soc* 130, 28-29 (2008); Teng, Z.G., et al. Superparamagnetic high-magnetization composite spheres with highly aminated ordered mesoporous silica shell for biomedical applications. *J Mater Chem B* 1, 4684-4691 (2013)). Typically, about 1 g of the SPIONs were homogeneously dispersed in the mixture of ethanol (about 400 mL), DI water (about 10 mL), and concentrated ammonia aqueous solution (about 10 mL, 28~30 wt%), followed by the addition of TEOS (about 2 mL). After stirring at about 70 °C for about 6 h, amorphous silica coated SPIONs (denoted as $\text{Fe}_3\text{O}_4@\text{SiO}_2$) were obtained and washed 3 times with methanol and additional 3 times with water and the final product was freeze-dried to a powder.

[0238] To prepare SP-007 (PDMA-PMA-modified SPION) and SP-011 (PEG-modified SPION), vinyl group functionalized SPIONs (denoted as $\text{Fe}_3\text{O}_4@\text{MPS}$) were first prepared through a modified Stöber process as previously reported (**FIG. 28C**) (Crutchfield, C.A., Thomas, S.N., Sokoll, L.J. & Chan, D.W. Advances in mass spectrometry-based clinical biomarker discovery. *Clin Proteomics* 13, 1 (2016)). Briefly, about 1 g of the SPIONs was homogeneously dispersed under the aid of vortexing (or sonication) in the mixture of ethanol (about 400 mL), DI water (about 10 mL), and concentrated ammonia aqueous solution (about 10 mL, 28~30 wt%), followed by the addition of TEOS (about 2 mL). After stirring at about 70 °C for about 6 h, about 2 mL of 3-(trimethoxysilyl)propyl methacrylate was added into the reaction mixture and stirred at about 70 °C overnight. Vinyl functionalized SPIONs were obtained and washed 3 times with methanol and additional 3 times with water and the final product was freeze-dried to a powder. Next, for synthesis of poly(dimethyl aminopropyl methacrylamide) (PDMA-PMA)-coated SPIONs (denoted as $\text{Fe}_3\text{O}_4@\text{PDMA-PMA}$, SP-007 in **FIG. 28D**), about 100 mg of $\text{Fe}_3\text{O}_4@\text{MPS}$ were homogeneously dispersed in about 125 mL of DI water. After bubbling with N_2 for about 30 min, about 2 g of *N*-[3-(dimethylamino)propyl] methacrylamide (DMA-PMA) and about 0.2 g of divinylbenzene (DVB) were added into the $\text{Fe}_3\text{O}_4@\text{MPS}$ suspension under N_2 protection. After the resulting mixture was heated to about 75 °C, about 40 mg of ammonium persulfate (APS) in about 5 mL DI water was added and stirred at about 75 °C overnight. After

cooling down, Fe₃O₄@PDMAEMA were isolated with a magnet and washed 3-5 times with water. The final product was freeze-dried to a dark brown powder. For synthesis of poly(ethylene glycol) (PEG)-coated SPIONs (denoted as Fe₃O₄@PEGOMA, SP-011 in FIG. 28E), about 100 mg of Fe₃O₄@MPS were homogeneously dispersed in about 125 mL of DI water. After bubbling with N₂ for about 30 min, about 2 g of poly(ethylene glycol) methyl ether methacrylate (OEGMA, average Mn 500) and about 50 mg of *N,N'*-Methylenebisacrylamide (MBA) were added into the Fe₃O₄@MPS suspension under N₂ protection. After the resulting mixture was heated to about 75 °C, about 50 mg of 4,4'-azobis(4-cyanovaleric acid) (ACVA) in about 5 mL ethanol was added and stirred at about 75 °C overnight. After cooling down, Fe₃O₄@POEGMA were isolated with a magnet and washed 3-5 times with water. The final product was freeze-dried to a dark brown powder.

EXAMPLE 12

Patient samples

[0239] This example describes patient samples used in the present disclosure. A set of 8 colorectal cancer (CRC) plasma samples with 8 age- and gender-matched controls was purchased from BioIVT (Westbury, NY). A set of 28 non-small cell lung cancer (NSCLC) serum samples with 28 controls matched by age and gender was also obtained from BioIVT. The detailed information regarding the CRC/NSCLC patient samples and controls are shown in TABLE 15 and TABLE 16.

TABLE 15 – NSCLC and Controls

Class	Age	Gender	Diagnosis	Medications
Diseased	53	Female	Non Small Cell Lung Cancer (NSCLC)	Alimta 800mg/Carboplatin 760mg, Advil 200mg, Compazine 10mg, Dexamethasone 4mg, Diclofenac Sodium 50mg, Dicyclomine 10mg, Folic Acid 1mg, Lactulose 10g/15ml, Lansoprazole 30mg, Multivitamin, Oxycodone 5mg, Reglan 10mg, Vitamin C 1000mg, Vitamin D2 50000iu
Diseased	64	Female	Non Small Cell Lung Cancer (NSCLC), Vitamin B Deficiency, Hypertension (HTN), Hyperlipidemia	Opdivo, Alendronate Sodium 10mg, Allegra Allergy 180mg, Anoro Ellipta 62.5mcg-25mcg, Aspirin 81mg, Bystolic 5mg, Calcium and D 500mg-200iu, Compazine 10mg, Crestor 40mg, Dilaudid 1200mg, Emla 2.5%-2.5%, Erythromycin 5mg, Fish Oil 340 mg-1000mg, Flonase Allergy Relief 50mcg, Hydromorphone 4mg, Isosorbide Mononitrate 60mg, Levothyroxine 75mcg, Lisinopril 20mg,

Class	Age	Gender	Diagnosis	Medications
				Medical Marijuana, Multivitamin 9mg-Iron 15ml, Neurontin 300mg, Nitro, Oxycodone 5mg, Plavix 75mg, Protonix 20mg, Unisom 25mg, Ventolin 90 mcg, Vitamin D3 5000iu, Xanax 1mg
Diseased	73	Female	Non Small Cell Lung Cancer (NSCLC), Impaired Fasting Glucose (IFG), Pulmonary Nodule	Carboplatin/Paclitaxel, Acetaminophen 325mg, Multivitamin 1000mg, Cymbalta 60mg, Eliquis 5mg, Guaifenesin 100mg/5ml, Neurontin 300mg, Synthroid 100mcg, Zofran 8mg
Diseased	75	Female	Non Small Cell Lung Cancer, Pneumothorax	Osimertinib, Colace 100mg, Flonase 50mcg, Zofran 8mg, Restasis 0.05%, Norco 5mg-325mg, Megace 400mg/10ml, Tagrisso 80mg
Diseased	65	Female	Non Small Cell Lung Cancer (NSCLC), Type 2 Diabetes, Multiple Sclerosis	Ceritinib 150mg, Cipro 500mg, Excedrin 500mg, Lasix 40mg, Glimepiride 4mg, Lamotrigine 200mg, Metformin 1000mg, Naproxen 500mg, Zofran 8mg, Slow Release Iron 142mg
Diseased	94	Male	Non Small Cell Lung Cancer (NSCLC), Anemia (CKD), Chronic Kidney Disease (CKD), Hyperlipidemia (HLD), Prostate Cancer	Keytruda 100mg/4ml, Betamethasone Dipropionate 0.05%, Eliquis 2.5mg, Fludrocortisone 0.1mg, Folic Acid 1mg, Lomotil 2.5mg-0.025mg, Midodrine 10mg, Omega Q, Prednisone 5mg, Ranitidine 150mg, Simvastatin 40mg
Diseased	65	Female	Non Small Cell Lung Cancer (NSCLC), Hypertension (HTN)	Atenolol 50mg, Biotin 2500mcg, Melatonin 3mg, Mometasone 0.1%, Vitamin D3 1000iu, Zofran 8mg
Diseased	79	Female	Non Small Cell Lung Cancer (NSCLC), Type 2 Diabetes, Hypercholesterolemia, Emphysema	Amlodipine 5mg, Amoxicillin 875mg, Estradiol 0.01%, Folic Acid 1mg, Januvia 100mg, Lidocaine/Prilocaine 2.5%, Losartan HCL 50mg, Nitrofurantoin 100mg, Pantoprazole 20mg, Simvastatin 40mg, Urinary Pain Relief 95mg, Zofran 8mg, Gemcitabine, Carboplatin
Diseased	57	Male	Non Small Cell Lung Cancer (NSCLC), Lung Mass, Primary Adenocarcinoma of Lower Lobe of Right Lung, Brain Metastases, Hypokalemia	Carboplatin/Etoposide, Norvasc 10mg, Lotensin HCT 20mg-12.5mg, Celexa 20mg, Mycellex 10mg, Lasix 20mg, Norco 7.5mg-325mg, Magnesium 400mg, Melatonin Gummies 2.5mg, Metformin 750mg, Mycostatin 100,000iu/mL, Zofran 8mg, Potassium Chloride 20mEq, Compazine 10mg
Diseased	63	Female	Non Small Cell Lung Cancer (NSCLC), Hypertension (HTN), Hypercholesterolemia, Gastroesophageal	Alimta, Carboplatin, Calcium-Vitamin D, Folvite 1mg, Keppra 500mg, Synthroid 125mcg, Prilosec 20mg, Zofran 8mg, Compazine 10mg, Zocor 40mg

Class	Age	Gender	Diagnosis	Medications
			Reflux Disease (GERD), Diverticulitis, Disease of Thyroid, Arthropathy, Actinic Keratosis	
Diseased	77	Male	Non Small Cell Lung Cancer (NSCLC), Hypertension (HTN), Myelodysplastic Syndromes, Anemia (Iron), Hypothyroidism, Prostate Cancer, Bradycardia	Singulair 10mg, Meclizine HCL 25mg, Xarelto 20mg, Synthroid 125mcg, Miralax 17g, Lidocaine 5%, Arnuity Ellipta 100mcg, Medipro Vegan Chocolate 23.28oz, Exos Catalyte, Zinc Picolinate 15mg, Albuterol Sulfate 90mcg, Vitamin B12/Folic Acid 500mcg/400mcg
Diseased	70	Female	Non Small Cell Lung Cancer (NSCLC), Hypertension (HTN), Polycythemia, Left Lower Extremity Edema, Cellulitis of Left Lower Extremity	Alimta/Carboplatin/Keytruda/Neulasta, Decadron 4mg, Breo Ellipta 200mcg/25mcg, Folvite 1mg, Lasix 40mg, Neurontin 300mg, Emla, Zestril 5mg, Magic Mouthwash, Glucophage 500mg, Aleve 220mg, Zofran 8mg, Potassium Chloride 10meq, ProAir HFA 108mcg, Spiriva 18mcg, Valtrex 1000mg
Diseased	70	Female	Non Small Cell Lung Cancer (NSCLC), Hypertension (HTN), Type 2 Diabetes	Taxotere 75mg-Cyamza 10mg-Nuelasta, Ativan 0.5mg, Basaglar 100iu/mL, Dexamethasone 4mg, Eliquis 5mg, Fentanyl 25mcg, Folic Acid 1mg, Glimepiride 2mg, Hydrochlorothiazide 12.5mg, Lorazepam 0.5mg, Magnesium 300mg, Metformin 1000mg, Multivitamin 9mg Iron/15mL, Oxycodone 5mg, Tramadol 50mg, Trazodone 50mg, Vitamin D3 2000iu
Diseased	78	Female	Non Small Cell Lung Cancer (NSCLC), Hypothyroidism	Folic Acid 1mg, Lasix 20mg, Atarax 25mg, Hydroxyzine 25mg, Klor Con 10meq, Emla, Methylprednisolone 4mg, Zofran 8mg, Synthroid 100mcg, Kenalog 0.025%
Diseased	68	Female	Non Small Cell Lung Cancer (NSCLC), Leukocytosis, Hypercalcemia, Asthma, Major Depressive Disorder, Hypothyroidism, Hyperlipidemia, Type 2 Diabetes	Abraxane 100mg, Procrit 40000iu, Aspirin 325mg, Benadryl 25mg, Calcium 500mg, Clopidogrel 75mg, Codeine- Guaifenesin 10mg-100mg/5ml, Imodium 2mg, Iron 325mg, Klor-Con 20meq, Lasix 20mg, Levothyroxine 50mcg, Metformin 500mg, Niacin 500mg, Ondansetron 8mg, Proventil 90mcg, Spiriva 18mcg, Symbicort 160mcg-4.5mcg, Tylenol 500mg, Xanax 0.5mg, Zolpidem 10mg
Diseased	78	Male	Non Small Cell Lung Cancer (NSCLC), Lymphadenitis,	Xgeva 120mg, Keytruda, Atorvastatin 40mg, Digoxin 125mcg, Furosemide 40mg, Lexapro 20mg, Medrol 4mg, Metoprolol

Class	Age	Gender	Diagnosis	Medications
			Hypertension (HTN), Hyperlipidemia, Atrial Fibrillation (AF), Malignant Neoplasm of Left Main Bronchus	Tartrate 100mg, Namzaric 21mg-10mg, Noxylane 500mg, Vitamin D2 50000iu, Warfarin 2mg
Diseased	79	Female	Non Small Cell Lung Cancer (NSCLC), Pancytopenia, Liver Cirrhosis, Zoster, Neuralgia, Neuritis, Essential Primary Hypertension	Feraheme Non-ESRD, Amlodipine 5mg, Aspirin 81mg, Atenolol 50mg, Bayer Aspirin 325mg, Calcium/Vitamin D3 1250mg, Caltrate/Vitamin D3 1500mg, Cartia XT 180mg, Crestor 20mg, Duragesic 25mcg, Eliquis 5mg, Folic Acid 1mg, Gabapentin 300mg, Oxycodone/Acetaminophen 5mg/325mg, Percocet 5mg/325mg, Prednisone 1mg, Procrit 40000iu/ml, Tessalon Perles 100mg, Vitamin D2 50000iu
Diseased	79	Male	Non Small Cell Lung Cancer (NSCLC), Prostate Cancer, Immune Thrombocytopenic Purpura, HTN, Hyperlipidemia	Octagam Liquid 10%, Calcium 600mg, Digoxin 125mcg, Folic Acid 400mcg, Metoprolol Tartrate 25mg, Probiotic, Rosuvastatin 10mg
Diseased	54	Male	Non Small Cell Lung Cancer (NSCLC), Type 2 Diabetes, Hypertension (HTN)	Pembrolizumab, Dexamethasone 4mg, Glipizide 5mg, Hydrocodone-Acetaminophen 10mg-325mg, Ipratropium Bromide 17mcg, Lantus, Lisinopril 10mg, Metformin 500mg, Pravastatin Sodium 40mg
Diseased	69	Male	Non Small Cell Lung Cancer (NSCLC), Unilateral Primary Osteoarthritis of Left Knee, Essential Primary Hypertension, Type 2 Diabetes	Aloxi 0.25mg/5ml, Cardizem 120mg, Crestor 20mg, Digoxin 250mcg, Eliquis 5mg, Furosemide 20mg, Glucosamine Chondroitin PLUS 375mg/100mg/36mg/54mg, Metformin ER 750mg, Potassium Chloride ER 10meq, Zofran 8mg
Diseased	81	Male	Non Small Cell Lung Cancer (NSCLC), Vascular Dementia, Hypertension (HTN), Lipid Disease	Ipratropium Albuterol 0.5mg/3mg, Metoprolol 50mg, Coumadin 7.5mg, Atorvastatin 80mg, Lovenox 80mg/0.8ml, Magace ES 625mg/5ml, Lexapro 10mg
Diseased	70	Female	Non Small Cell Lung Cancer (NSCLC), Anemia (Antineoplastic Chemotherapy), Idiopathic Thrombocytopenia (ITP), Malignant Neoplasm of Upper	Nplate, Procrit 40,000iu, Alimta 500mg, Ferrous Sulfate 325mg, Folic Acid 1mg, Medrol 4mg, Metformin 500mg, Simvastatin 40mg, Tudorza Pressair 400mcg

Class	Age	Gender	Diagnosis	Medications
			Left Lobe, Vitamin B12 Deficiency, Folic Acid Deficiency, Asthma, Type 2 Diabetes, Hyperlipidemia (HLD), Hypertension (HTN), Hypercholesterolemia	
Diseased	76	Female	Non Small Cell Lung Cancer (NSCLC), Anemia (Iron Deficiency), , Impaired Fasting Glucose (IFG)	Biotin 300mcg, Cleocin 1%, Fenofibrate 160mg, Flonase 50mcg, Medrol 4mg, Ranitidine 150mg, Tagrisso 80mg, Tarceva 150mg, Ventolin HFA 90mcg, Vitamin D2 50000iu
Diseased	91	Male	Non Small Cell Lung Cancer (NSCLC), Anemia (Iron Deficiency), Hypothyroidism, HTN	Clotrimazole 1%, Dextran, Digoxin 125mcg, Furosemide 20mg, Hydrocodone-Homatropine 5mg-1.5mg/5ml, Lasix 20mg, Levothyroxine 25mcg, Metoprolol Succinate 25mg, Miracle Mouthwash, Mucinex 30mg-600mg, Nystatin 100000iu, Omeprazole 20mg, Oxycodone 20mg, Pravastatin 10mg, Prednisone 10mg, Proair 90mcg, Procto-Med 2.5%, Relistor 150mg, Sodium Chloride 1g
Diseased	69	Female	Non Small Cell Lung Cancer (NSCLC), Anemia (Iron Deficiency), Vitamin B12 Deficiency, T-Cell Polymphocytic Leukemia, Hypertension (HTN)	Ativan 0.5mg, Trazodone 50mg
Diseased	65	Female	Non Small Cell Lung Cancer (NSCLC), Chronic Obstructive Pulmonary Disease (Emphysema), Cardiovascular Disease, Osteoporosis	Dexamethasone 4mg, Emla 2.5%, Loperamide 2mg, Lorazepam 1mg, Nystatin 100000iu/ml, Ondansetron 4mg, Oravig 50mg, Symbicort 160mcg/4.5mcg, Ventolin HFA 90mcg, Navelbine 30mg
Diseased	77	Female	Non Small Cell Lung Cancer (NSCLC)	Avastin 15mg/kg, Alimta 500mg/Carboplatin/Neulasta then Alimta 500mg, Aspirin 81mg, Chantix 1mg, Dexamethasone 4mg, Folic Acid 1mg, Instaflex, Metformin 500mg, Quinapril 40mg, Simvastatin 20mg, Vitamin D3 2000iu, Zofran 8mg
Diseased	85	Female	Non Small Cell Lung Cancer (NSCLC)	Aletinib
Control	53	Female	Normal Donor	None

Class	Age	Gender	Diagnosis	Medications
Control	64	Female	Normal Donor	None
Control	67	Female	Normal Donor, Hypercholesterolemia	Atorvastatin 40mg
Control	72	Female	Normal Donor	None
Control	73	Female	Normal Donor, Osteoarthritis (OA)	Prolia, Aciphex 20mg
Control	87	Male	Normal Donor, Donor with Fever	Vitamin B Complex, Zinc 50ml, Alka Seltzer, Vitamin B6, Vitamin B1, Vitamin B12, Pepsin 40mg
Control	65	Female	Normal Donor, Hypercholesterolemia	None
Control	80	Female	Normal Donor	None
Control	57	Male	Normal Donor	Multivitamin
Control	63	Female	Normal Donor	None
Control	75	Male	Normal Donor, Hypertension (HTN)	Lisinopril 2.5mg
Control	70	Female	Normal Donor	None
Control	70	Female	Normal Donor	Multivitamin 1000mg
Control	77	Female	Normal Donor	Lipitor 20mg, Prevacid 20mg
Control	68	Female	Normal Donor, Hypertension (HTN)	Lisinopril 10mg
Control	73	Male	Normal Donor	Tamsulosin HCL, Finasteride 5mg
Control	81	Female	Normal Donor	Norvasc, Ditropan
Control	77	Male	Normal Donor , Cataract, Progressive Hearing Loss, Hypertension (HTN), Hypercholesterolemia	Lipitor 20mg, Tricor 145mg, Metoprolol 50mg, Omeprazole 20mg, Aspirin 80mg
Control	56	Male	Normal Donor	Nexium 60mg, Zocor 40mg
Control	64	Male	Normal Donor	Protonix 40mg, Asiprin 325mg
Control	80	Male	Normal Donor	Vitamin D, Lipitor, Aspirin 81mg
Control	73	Female	Normal Donor, Allergic Rhinitis	Allegra 180mg
Control	77	Female	Normal Donor	None
Control	83	Male	Normal Donor	None
Control	68	Female	Normal Donor	Losartan 50mg, Lipitor 20mg
Control	66	Female	Normal Donor, Hypertension (HTN)	Lisinopril 10mg
Control	78	Female	Normal Donor	Lipitor 10mg, Toprol 50mg, Ambien 10mg
Control	86	Female	Normal Donor, Hypertension (HTN)	Amlodipine 2.5mg, Vitamin B

TABLE 16 – CRC and Controls

Class	Age	Gender	Diagnosis
Diseased	74	Female	Colorectal Cancer
Diseased	41	Male	Colorectal Cancer
Diseased	57	Male	Colorectal Cancer, Anemia (Iron Deficiency), Type 2 Diabetes
Diseased	78	Male	Colorectal Cancer, Chronic Lymphocytic Leukemia (CLL), Hypertension (HTN), Type 2 Diabetes, Arthritis
Diseased	60	Female	Colorectal Cancer, CKD, Iron Deficiency, RLS, Carcinoma of Colon, Carcinoma of Right Ovary, Anxiety
Diseased	37	Male	Colorectal Cancer, Erectile Dysfunction, Thrombocytopenia
Diseased	68	Female	Colorectal Cancer, Major Depressive Disorder (MDD), Type 2 Diabetes, Hernia with Obstruction, Ventral Hernia, Dysphonia, Hypercholesterolemia, Hyperlipidemia, Hypertension (HTN), Migraine, Obesity, Diabetic Polyneuropathy, Reflux Esophagitis, Edema, Asthma, Chronic Obstructive Pulmonary Disease (COPD), E Coil Bacteremia, Subdural Hematoma, Hepatic Abscess
Diseased	60	Female	Colorectal Cancer, Rectal Cancer, Type 1 Diabetes, Hypertension (HTN), Hypothyroidism
Control	75	Female	Normal Donor
Control	42	Male	Normal Donor
Control	56	Male	Normal Donor
Control	78	Male	Normal Donor
Control	58	Female	Normal Donor
Control	36	Male	Normal Donor
Control	68	Female	Normal Donor
Control	59	Female	Normal Donor

EXAMPLE 13**Characterization of Physicochemical Properties of Particle Types.**

[0240] This example describes characterization of particle physicochemical properties by various techniques. Dynamic light scattering (DLS) and zeta potential were performed on a Zetasizer Nano ZS (Malvern Instruments, Worcestershire, UK). Particles were suspended at 10 mg/mL in water with about 10 min of bath sonication prior to testing. Samples were then diluted to approximately 0.02 wt% for both DLS and zeta potential measurements in respective buffers. DLS was performed in water at about 25°C in disposable polystyrene semi-micro cuvettes (VWR, Randor, PA, USA) with a about 1 min temperature equilibration time and consisted of the average from 3 runs of about 1 min, with a 633nm laser in 173° backscatter mode. DLS results were analyzed using the cumulants method. Zeta potential was measured in 5% pH 7.4 PBS (Gibco, PN 10010-023, USA) in disposable folded capillary cells (Malvern Instruments, PN DTS1070) at about 25°C with an about 1 min equilibration time. 3 measurements were

performed with automatic measurement duration with a minimum of 10 runs and a maximum of 100 runs, and a 1 min hold between measurements. The Smoluchowski model was used to determine the zeta potential from the electrophoretic mobility.

[0241] Scanning electron microscopy (SEM) was performed by using a FEI Helios 600 Dual-Beam FIB-SEM. Aqueous dispersions of particles were prepared to a concentration of about 10 mg/mL from weighted particle powders re-dispersed in DI water by about 10 min sonication. Then, the samples were 4X diluted by methanol (from Fisher) to make a dispersion in water/methanol that was directly used for electron microscopy. The SEM substrates were prepared by drop-casting about 6 μ L of particle samples on the Si wafer from Ted Pella, and then the droplet was completely dried in a vacuum desiccator for about 24 hours prior to measurements.

[0242] A Titan 80-300 transmission electron microscope (TEM) with an accelerating voltage of 300kV was used for both low- and high-resolution TEM measurements. The TEM grids were prepared by drop-casting about 2 μ L of the particle dispersions in water-methanol mixture (25-75 v/v%) with a final concentration of about 0.25 mg/mL and dried in a vacuum desiccator for about 24 hours prior to the TEM analysis. All measurements were performed on the lacey holey TEM grids from Ted Pella.

[0243] X-Ray Photoelectron Spectroscopy (XPS) was performed by using a PHI VersaProbe and a ThermoScientific ESCALAB 250e III. XPS analysis was performed on the particle fine powders kept sealed and stored under desiccation prior to the measurements. Materials were mounted on a carbon tape to achieve a uniform surface for analysis. A monochromatic Al K-alpha X-ray source (50 W and 15 kV) was used over a 200 μ m² scan area with a pass energy of 140 eV, and all binding energies were referenced to the C-C peak at 284.8 eV. Both survey scans and high-resolution scans were performed to assess in detail elements of interest. The atomic concentration of each element was determined from integrated intensity of elemental photoemission features corrected by relative atomic sensitivity factors by averaging the results from two different locations on the sample. In some cases, four or more locations were averaged to assess uniformity.

EXAMPLE 14

Protein corona preparation and proteomic analysis

[0244] This example describes protein corona preparation and proteomic analysis. Plasma and serum samples were diluted 1:5 in a dilution buffer composed of TE buffer (10mM Tris, 1mM disodium EDTA, 150mM KCl) with 0.05% CHAPS. Particle powder was reconstituted by sonicating for about 10 min in DI water followed by vortexing for about 2-3 sec. To make a

protein corona, about 100 μ L of particle suspension (SP-003, 5mg/ml; SP-007, 2.5 mg/ml; SP-011, 10 mg/ml) was mixed with about 100 μ L of diluted biological samples in microtiter plates. The plates were sealed and incubated at 37°C for about 1 hour with shaking at 300 rpm. After incubation, the plate was placed on top of magnetic collection for about 5 mins to pellet down the nanoparticles. Unbound proteins in supernatant were pipetted out. The protein corona was further washed with about 200 μ L of dilution buffer for three times with magnetic separation. For the 10 particle type particle panel screen, the five additional assay conditions that were evaluated were identical to the description above with one of the following exceptions. First, a low concentration of particles was evaluated that was 50% the concentration of the original particle concentration (ranging from 2.5 – 15 mg/ml for each particle, depending on expected peptide yield). For the second and third assay variations, both low and high particle concentrations were run using an undiluted, neat plasma rather than diluting the plasma in buffer. For the fourth and fifth assay variations, both low and high particle concentrations were run using a pH 5 citrate buffer for both dilution and rinse.

[0245] To digest the proteins bound onto nanoparticles, a trypsin digestion kit (iST 96X, PreOmics, Germany) was used according to protocols provided. Briefly, about 50 μ L of Lyse buffer was added to each well and heated at about 95°C for about 10 min with agitation. After cooling down the plates to room temperature, trypsin digest buffer was added and the plate was incubated at about 37°C for about 3 hours with shaking. The digestion process was stopped with a stop buffer. The supernatant was separated from the nanoparticles by a magnetic collector and further cleaned up by a peptide cleanup cartridge included in the kit. The peptide was eluted with about 75 μ L of elution buffer twice and combined. Peptide concentration was measured by a quantitative colorimetric peptide assay kit from Thermo Fisher Scientific (Waltham, MA).

[0246] Next, the peptide eluates were lyophilized and reconstituted in 0.1% TFA. A 2 μ g aliquot from each sample was analyzed by nano LC-MS/MS with a Waters NanoAcquity HPLC system interfaced to an Orbitrap Fusion Lumos Tribrid Mass Spectrometer from Thermo Fisher Scientific. Peptides were loaded on a trapping column and eluted over a 75 μ m analytical column at 350nL/min; both columns were packed with Luna C18 resin from Phenomenex (Torrance, CA). The mass spectrometer was operated in a data-dependent mode, with MS and MS/MS performed in the Orbitrap at 60,000 FWHM resolution and 15,000 FWHM resolution, respectively. The instrument was run with a 3 sec cycle for MS and MS/MS.

EXAMPLE 15

Mass Spectrometry Data Analysis

[0247] This example describes mass spectrometry data analysis methods. The acquired MS data files were processed using the OpenMS suite of tools. These tools include modules and pipeline scripts for the conversion of vendor instrument raw files to mzML files, for MS1 feature identification and intensity extraction, for MS dataset run-time alignment and feature-group clustering, and for MS2 spectrum database matching with the X!Tandem search engine. During spectrum-database searching the precursor ion and fragment ion matching tolerances were set to 10 and 30 ppm, respectively. Default settings for fixed, Carbamidomethyl (C), and variable, Acetyl (N-term) and Oxidation (M), modifications were enabled. The UniProtKB/Swiss-Prot protein sequence database (accession date January 27, 2019) was used for searches and peptide spectral matches (PSMs) were scored using a standard reverse-sequence decoy database strategy at 1% FDR. Using the PSMs, protein lists for each particle type replicate were compiled using a single PSM as sufficient evidence to add a protein to a given particle type replicate's enumerated protein list. In addition, a PSM that matched more than one protein added all of the possible proteins to the given particle type replicate's enumerated protein list. Although this threshold for protein enumeration is permissive, and possibly includes false-positives (higher sensitivity, lower specificity), the more stringent test of requiring 2 or more peptides (including at least one unique peptide) suffers from the opposite problem of having false-negatives (lower sensitivity, higher specificity). For quantitative analysis of known peptides, a custom R script was used to assign MS2 PSMs to MS1 feature groups based on positional overlap with 1 da and 30 sec tolerances for m/z and retention time, respectively. In the event that more than one PSM initially mapped to an MS1 feature within the tolerances previously specified, the PSM which was closest to the MS1 feature (within MS datasets) or to the center of the MS1 feature cluster (between MS datasets) was used. It should be noted that not all MS2s have been assigned to MS1 feature group clusters, and not all MS1 feature group clusters have an assigned MS2; work continues in this area to improve mapping and subsequent peptide feature identification.

EXAMPLE 16

Identification of Protein Groups

[0248] This example describes methods for identification of protein groups by mass spectrometry. For protein group-level analysis, the MS data at the protein group level was performed as follows. MS raw files were processed with MaxQuant (v. 1.6.7(49) and Andromeda(50), searching MS/MS spectra against the UniProtKB human FASTA database (UP000005640, 74,349 forward entries; version from August 2019) employing standard settings.

Enzyme digestion specificity was set to trypsin allowing cleavage N-terminal to proline and up to 2 miscleavages. Minimum peptide length was set to 7 amino acids and maximum peptide mass was set to 4,600 Da. Methionine oxidation and protein N-terminus acetylation were configured as a variable modification, carbamidomethylation of cysteines was set as fixed modification. MaxQuant improves precursor ion mass accuracy by time-dependent recalibration algorithms and defines individual mass tolerances for each peptide. Initial maximum precursor mass tolerances allowed were 20 ppm during the first search and 4.5 ppm in the main search. The MS/MS mass tolerance was set to 20 ppm. For analysis, a false discovery rate (FDR) cutoff of 1% was applied at the peptide and protein level (in the proteinGroups.txt table, all protein groups are reported with their corresponding q-value). "Match between runs," was disabled. Number of identifications were counted based on protein intensities (counting only proteins with q-value lower than 1%) requiring at least one razor peptide. MaxLFQ normalized protein intensities (requiring at least 1 peptide ratio count) are reported in the raw output and were used only for the CV precision analysis. Peptides that could be distinguished were sorted into their own protein groups and proteins that could not be discriminated based on unique peptides were assembled in protein groups. Furthermore, proteins were filtered for a list of common contaminants included in MaxQuant. Proteins identified only by site modification were strictly excluded from analysis.

EXAMPLE 17

Spike Recovery

[0249] This example describes methods for spike recovery experiments of C-reactive protein (CRP). Baseline concentration of CRP in a pooled healthy plasma sample was measured with the ELISA kit as described above (Materials) according to the manufacturer-suggested protocols. A stock solution and appropriate dilutions of CRP were prepared and spiked into the identical pooled plasma samples to make final concentrations that were 2×, 5×, 10×, and 100× of baseline, endogenous concentrations for CRP. The volume of additions to the pooled plasma was 10% of the total sample volume. A spike control was made by adding same volume of buffer to the pooled plasma sample. Concentrations of spiked samples were measured again by ELISA to confirm the CRP levels in each spiking level. The samples were used to evaluate particle corona measurement accuracy as described in the Results above.

EXAMPLE 18**Proteomic analysis of NSCLC samples and healthy controls**

[0250] This example describes proteomic analysis of NSCLC samples and health controls. Serum samples from 56 subjects, 28 with Stage IV NSCLC and 28 age- and gender-matched controls were purchased commercially and evaluated with SP-007 nanoparticle corona formation (see above for sample acquisition and corona formation and processing). MS spectral data for each corona were collected as described and the raw data were processed as described above (MS data analysis). 19,214 groups of features were identified and extracted across the 56 subject samples with group sizes ranging from one (singleton features in just one sample, $n = 6,249$ or 0.29% of the data) to 56 (features present in all samples, $n = 450$ or 12% of the data). The clustering algorithm calculates a 'group_quality' metric which is related to the spatial uniformity of grouping of features with groups between datasets. The bottom quartile of groups, partitioned by group size, was then removed from consideration due to the skewed nature of the distribution of low-quality scores leaving 15,967 groups. As an additional filter prior to analysis, only those groups with features present in at least 50% of at least one of the classes, diseased or control, were carried forward leaving a set of 2,507 feature groups for analysis.

[0251] Peptide and protein identities were assigned to the feature groups as follows. MS2 PSMs and MS1 feature groups were assigned together as described above (MS data analysis). 25% of the 19,249 original feature groups were associated with a peptide sequence using this approach. All feature groups, with or without assigned peptide sequence, were carried through the univariate statistical comparison between the groups.

EXAMPLE 19**Statistical analysis**

[0252] This example describes statistical analysis of the data disclosed herein. Statistical analysis and visualization were performed using R (v3.5.2) with appropriate packages (R: A language and environment for statistical computing, R Foundation for Statistical Computing, Vienna, Austria. URL <https://www.R-project.org/>).

[0253] While preferred embodiments of the present invention have been shown and described herein, it will be obvious to those skilled in the art that such embodiments are provided by way of example only. Numerous variations, changes, and substitutions will now occur to those skilled in the art without departing from the invention. It should be understood that various alternatives to the embodiments of the invention described herein may be employed in practicing the invention. It is intended that the following claims define the scope of the invention and that methods and structures within the scope of these claims and their equivalents be covered thereby.

CLAIMS

WHAT IS CLAIMED IS:

1. A method of identifying proteins in a sample, the method comprising:
incubating a particle panel with the sample to form a plurality of distinct biomolecule coronas corresponding to distinct particle types of the particle panel;
magnetically isolating the particle panel from unbound protein in the sample to enrich proteins in the plurality of distinct biomolecule coronas; and
assaying the plurality of distinct biomolecule coronas to identify the enriched proteins.
2. The method of claim 1, wherein the assaying is capable of identifying from 1 to 20,000 protein groups.
3. The method of any one of claims 1-2, wherein the assaying is capable of identifying from 1000 to 10,000 protein groups.
4. The method of any one of claims 1-3, wherein the assaying is capable of identifying from 1,000 to 5,000 protein groups.
5. The method of any one of claims 1-4, wherein the assaying is capable of identifying from 1,200 to 2,200 protein groups.
6. The method of any one of claims 2-5, wherein the protein group comprises a peptide sequence having a minimum length of 7 amino acid residues.
7. The method of any one of claims 1-6, wherein the assaying is capable of identifying from 1,000 to 10,000 proteins.
8. The method of any one of claims 1-7, wherein the assaying is capable of identifying from 1,800 to 5,000 proteins.
9. The method of any one of claims 1-8, wherein the sample comprises a plurality of samples.
10. The method of claim 9, wherein the plurality of samples comprises at least two or more spatially isolated samples.

11. The method of claim 10, wherein the incubating comprises contacting the at least two or more spatially isolated samples with the particle panel at the same time.

12. The method of any one of claims 10-11, wherein the magnetically isolating comprises magnetically isolating the particle panel from unbound protein in the at least two or more spatially isolated samples of the plurality of samples at the same time.

13. The method of any one of claims 10-12, wherein the assaying comprises assaying the plurality of distinct biomolecule coronas to identify proteins in the at least two or more spatially isolated samples at the same time.

14. The method of any one of claims 1-13, further comprising repeating the methods of any one of claims 1-7, wherein, when repeated, the incubating, isolating, and assaying yields a percent quantile normalized coefficient (QNCV) of variation of 20% or less, as determined by comparing a peptide mass spectrometry feature from at least three full-assay replicates for each particle type in the particle panel.

15. The method of any one of claims 1-13, wherein, when repeated, the incubating, isolating, and assaying yields a percent quantile normalized coefficient (QNCV) of variation of 10% or less, as determined by comparing a peptide mass spectrometry feature from at least three full-assay replicates for each particle type in the particle panel.

16. The method of any one of claims 1-15, wherein the assaying is capable of identifying proteins over a dynamic range of at least 7, at least 8, at least 9, or at least 10.

17. The method of any one of claims 1-16, further comprising washing the particle panel at least one time or at least two times after magnetically isolating the particle panel from the unbound protein.

18. The method of any one of claims 1-17, wherein after the assaying the method further comprises lysing the proteins in the plurality of distinct biomolecule coronas.

19. The method of claim 18, further comprising digesting the proteins in the plurality of distinct biomolecule coronas to generate digested peptides.

20. The method of claim 19, further comprising purifying the digested peptides.

21. The method of any one of claims 1-20, wherein the assaying comprises using mass spectrometry to identify proteins in the sample.

22. The method of any one of claims 1-21, wherein the assaying is performed in about 2 to about 4 hours.

23. The method of any one of claims 1-22, wherein the method is performed in about 1 to about 20 hours.

24. The method of any one of claims 1-23, wherein the method is performed in about 2 to about 10 hours.

25. The method of any one of claims 1-24, wherein the method is performed in about 4 to about 6 hours.

26. The method of any one of claims 1-25, wherein the isolating takes no more than about 30 minutes, no more than about 15 minutes, no more than about 10 minutes, no more than about 5 minutes, or no more than about 2 minutes.

27. The method of any one of claims 3-26, wherein the plurality of samples comprises at least 10 spatially isolated samples, at least 50 spatially isolated samples, at least 100 spatially isolated samples, at least 150 spatially isolated samples, at least 200 spatially isolated samples, at least 250 spatially isolated samples, or at least 300 spatially isolated samples.

28. The method of claim 27, wherein the plurality of samples comprises at least 96 samples.

29. The method of any one of claims 1-28, wherein the particle panel comprises at least 2 distinct particle types, at least 3 distinct particle types, at least 4 distinct particle types, at least 5 distinct particle types, at least 6 distinct particle types, at least 7 distinct particle types, at least 8 distinct particle types, at least 9 distinct particle types, at least 10 distinct particle types, at least 11 distinct particle types, at least 12 distinct particle types, at least 13 distinct particle types, at least 14 distinct particle types, at least 15 distinct particle types, at least 20 distinct particle types, at least 25 particle types, or at least 30 distinct particle types.

30. The method of claim 29, wherein the particle panel comprises at least 10 distinct particle types.

31. The method of any one of claims 10-30, wherein the at least two spatially isolated samples differ by at least one physicochemical property.

32. The method of any one of claims 1-31, wherein the particle panel comprises a first distinct particle type and a second distinct particle type, wherein the first distinct particle type and the second distinct particle type share at least one physicochemical property and differ by at least one physicochemical property, such that the first distinct particle type and the second distinct particle type are different.

33. The method of any one of claims 1-32, wherein the particle panel comprises a first distinct particle type and a second distinct particle type, wherein the first distinct particle type and the second distinct particle type share at least two physicochemical properties and differ by at least two physicochemical properties, such that the first distinct particle type and the second distinct particle type are different.

34. The method of any one of claims 1-33, wherein the particle panel comprises a first distinct particle type and a second distinct particle type, wherein the first distinct particle type and the second distinct particle type share at least one physicochemical property and differ by at least two physicochemical properties, such that the first distinct particle type and the second distinct particle type are different.

35. The method of any one of claims 1-34, wherein the particle panel comprises a first distinct particle type and a second distinct particle type, wherein the first distinct particle type and the second distinct particle type share at least two physicochemical properties and differ by at least one physicochemical property, such that the first distinct particle type and the second distinct particle type are different.

36. The method of any one of claims 31-35, wherein the physicochemical property comprises size, charge, core material, shell material, porosity, or surface hydrophobicity.

37. The method of claim 36, wherein the size is diameter or radius, as measured by dynamic light scattering, SEM, TEM, or any combination thereof.

38. The method of any one of claims 1-37, wherein the particle panel comprises a first distinct particle type and a second distinct particle type, wherein the first distinct particle type and the second distinct particle type comprise a carboxylate material, wherein the first distinct particle is a microparticle, and wherein the second distinct particle type is a nanoparticle.

39. The method of any one of claims 1-37, wherein the particle panel comprises a first distinct particle type and a second distinct particle type, wherein the first distinct particle type

and the second distinct particle type comprise a surface charge of from 0 mV and -50 mV, wherein the first distinct particle type has a diameter of less than 200 nm, and wherein the second distinct particle type has a diameter of greater than 200 nm.

40. The method of any one of claims 1-37, wherein the particle panel comprises a first distinct particle type and a second distinct particle type, wherein the first distinct particle type and the second distinct particle type comprise a diameter of 100 to 400 nm, wherein the first distinct particle type has a positive surface charge, and wherein the second distinct particle type has a neutral surface charge.

41. The method of any one of claims 1-37, wherein the particle panel comprises a first distinct particle type and a second distinct particle type, wherein the first distinct particle type and the second distinct particle type are nanoparticles, wherein the first distinct particle type has a surface charge less than -20 mV and the second distinct particle type has a surface charge greater than -20 mV.

42. The method of any one of claims 1-37, wherein the particle panel comprises a first distinct particle type and a second distinct particle type, wherein the first distinct particle type and the second distinct particle type are microparticles, wherein the first distinct particle type has a negative surface charge, and wherein the second distinct particle type has a positive surface charge.

43. The method of any one of claims 1-37, wherein the particle panel comprises a subset of negatively charged nanoparticles, wherein each particle of the subset differ by at least one surface chemical group.

44. The method of any one of claims 1-37, wherein the particle panel comprises a first distinct particle type, a second particle, and a third distinct particle type, wherein the first distinct particle type, the second distinct particle type, and the third distinct particle type comprise iron oxide cores, polymer shells, and are less than about 500 nm in diameter and wherein the first distinct particle type comprises a negative charge, the second distinct particle type comprises a positive charge, and the third distinct particle type comprises a neutral charge, wherein the diameter is a mean diameter as measured by dynamic light scattering.

45. The method of claim 44, wherein the first distinct particle type comprises a silica coating, the second distinct particle type comprises a poly(N-(3-(dimethylamino)propyl)

methacrylamide) (PDMAAPMA), and the third distinct particle type comprises a poly(oligo(ethylene glycol) methyl ether methacrylate) (POEGMA) coating.

46. The method of any one of claims 1-45, wherein at least one distinct particle type of the particle panel is a nanoparticle.

47. The method of any one of claims 1-46, wherein at least one distinct particle type of the particle panel is a microparticle.

48. The method of any one of claims 1-47, wherein at least one distinct particle type of the particle panel is a superparamagnetic iron oxide particle.

49. The method of any one of claims 1-48, wherein each particle of the particle panel comprise an iron oxide material.

50. The method of any one of claims 1-49, wherein at least one distinct particle type of the particle panel has an iron oxide core.

51. The method of any one of claims 1-49, wherein at least one distinct particle type of the particle panel has iron oxide crystals embedded in a polystyrene core.

52. The method of any one of claims 1-47, wherein each distinct particle type of the particle panel is a superparamagnetic iron oxide particle.

53. The method of any one of claims 1-52, wherein each distinct particle type of the particle panel comprises an iron oxide core.

54. The method of any one of claims 1-52, wherein each one distinct particle type of the particle panel has iron oxide crystals embedded in a polystyrene core.

55. The method of any one of claims 1-55, wherein at least one distinct particle type of particle panel comprises a carboxylated polymer, an aminated polymer, a zwitterionic polymer, or any combination thereof.

56. The method of any one of claims 1-56, wherein at least one particle type of the particle panel comprises an iron oxide core with a silica shell coating.

57. The method of any one of claims 1-56, wherein at least one particle type of the particle panel comprises an iron oxide core with a poly(N-(3-(dimethylamino)propyl) methacrylamide) (PDMAPMA) coating.

58. The method of any one of claims 1-56, wherein at least one particle type of the particle panel comprises an iron oxide core with a poly(oligo(ethylene glycol) methyl ether methacrylate) (POEGMA) coating.

59. The method of any one of claims 1-58, wherein at least one distinct particle type of the particle panel comprises a negative surface charge.

60. The method of any one of claims 1-58, wherein at least one distinct particle type of the particle panel comprises a positive surface charge.

61. The method of any one of claims 1-58, wherein at least one distinct particle type of the particle panel comprises a neutral surface charge.

62. The method of any one of claims 1-61, wherein the particle panel comprises one or more distinct particle types selected from **TABLE 10**.

63. The method of any one of claims 1-62, wherein the particle panel comprises two or more distinct particle types, three or more distinct particle types, four or more distinct particle types, five or more distinct particle types, six or more distinct particle types, seven or more distinct particle types, eight or more distinct particle types, nine or more distinct particle types, or all ten distinct particle types selected from **TABLE 10**.

64. The method of any one of claims 1-63, wherein the particle panel comprises one or more distinct particle types selected from **TABLE 12**.

65. The method of any one of claims 1-64, wherein the particle panel comprises two or more distinct particle types, three or more distinct particle types, four or more distinct particle types, five or more distinct particle types, six or more distinct particle types, seven or more distinct particle types, eight or more distinct particle types, nine or more distinct particle types, or all ten distinct particle types selected from **TABLE 12**.

66. A composition comprising three or more distinct magnetic particle types that differ by two or more physicochemical properties, wherein a subset of the three or more distinct

magnetic particle types share a physicochemical property of the two or more physicochemical properties and wherein such particle types of the subset bind different proteins.

67. The composition of claim 66, wherein the three or more distinct magnetic particle types adsorb proteins from a sample over a dynamic range of at least 7, at least 8, at least 9, or at least 10.

68. The composition of any one of claims 66-67, the three or more distinct magnetic particle types are capable of adsorbing from 1 to 20,000 proteins groups from a sample.

69. The composition of any one of claims 66-68, the three or more distinct magnetic particle types are capable of adsorbing from 1,000 to 10,000 protein groups from a sample.

70. The composition of any one of claims 66-69, the three or more distinct magnetic particle types are capable of adsorbing from 1,000 to 5,000 protein groups from a sample.

71. The composition of any one of claims 66-70, the three or more distinct magnetic particle types are capable of adsorbing from 1,200 to 2,200 protein groups from a sample.

72. The composition of any one of claims 69-71, wherein the protein group comprises a peptide sequence having a minimum length of 7 amino acid residues.

73. The composition of any one of claims 66-72, the three or more distinct magnetic particle types are capable of adsorbing from 1 to 20,000 proteins from a sample.

74. The composition of any one of claims 66-73, the three or more distinct magnetic particle types are capable of adsorbing from 1,000 to 10,000 proteins from a sample.

75. The composition of any one of claims 66-74, the three or more distinct magnetic particle types are capable of adsorbing from 1,800 to 5,000 proteins from a sample.

76. The composition of any one of claims 66-75, wherein the composition comprises at least 4 distinct magnetic particle types, at least 5 distinct magnetic particle types, at least 6 distinct magnetic particle types, at least 7 distinct magnetic particle types, at least 8 distinct magnetic particle types, at least 9 distinct magnetic particle types, at least 10 distinct magnetic particle types, at least 11 distinct magnetic particle types, at least 12 distinct magnetic particle types, at least 13 distinct magnetic particle types, at least 14 distinct magnetic particle types, at least 15 distinct magnetic particle types, at least 20 distinct magnetic particle types, or at least 30 distinct magnetic particle types.

77. The composition of claim 76, wherein the composition comprises at least 10 distinct magnetic particle types.

78. The composition of any one of claims 66-77, wherein the composition comprises a first distinct particle type and a second distinct particle type, wherein the first distinct particle type and the second distinct particle type share at least two physicochemical properties and differ by at least two physicochemical properties, such that the first distinct particle type and the second distinct particle type are different.

79. The composition of any one of claims 66-78, wherein the composition comprises a first distinct particle type and a second distinct particle type, wherein the first distinct particle type and the second distinct particle type share at least two physicochemical properties and differ by at least one physicochemical property, such that the first distinct particle type and the second distinct particle type are different.

80. The composition of any one of claims 66-79, wherein the physicochemical property comprises size, charge, core material, shell material, porosity, or surface hydrophobicity.

81. The composition of claim 80, wherein the size is diameter or radius, as measured by dynamic light scattering, SEM, TEM, or any combination thereof.

82. The composition of any one of claims 66-81, wherein the composition comprises a first distinct particle type and a second distinct particle type, wherein the first distinct particle type and the second distinct particle type comprise a carboxylate material, wherein the first distinct particle is a microparticle, and wherein the second distinct particle type is a nanoparticle.

83. The composition of any one of claims 66-81, wherein the particle panel comprises a first distinct particle type and a second distinct particle type, wherein the first distinct particle type and the second distinct particle type comprise a surface charge of from 0 mV and -50 mV, wherein the first distinct particle type has a diameter of less than 200 nm, and wherein the second distinct particle type has a diameter of greater than 200 nm

84. The composition of any one of claims 66-81, wherein the particle panel comprises a first distinct particle type and a second distinct particle type, wherein the first distinct particle type and the second distinct particle type comprise a diameter of 100 to 400 nm, wherein the first distinct particle type has a positive surface charge, and wherein the second distinct particle type has a neutral surface charge.

85. The composition of any one of claims 66-81, wherein the particle panel comprises a first distinct particle type and a second distinct particle type, wherein the first distinct particle type and the second distinct particle type are nanoparticles, wherein the first distinct particle type has a surface charge less than -20 mV and the second distinct particle type has a surface charge greater than -20 mV

86. The composition of any one of claims 66-81, wherein the particle panel comprises a first distinct particle type and a second distinct particle type, wherein the first distinct particle type and the second distinct particle type are microparticles, wherein the first distinct particle type has a negative surface charge, and wherein the second distinct particle type has a positive surface charge.

87. The composition of any one of claims 66-81, wherein the composition comprises a subset of negatively charged nanoparticles, wherein each particle type of the subset differ by at least one surface chemical group.

88. The composition of any one of claims 66-81, wherein the composition comprises a first distinct particle type, a second distinct particle type, and a third distinct particle type, wherein the first distinct particle type, the second distinct particle type, and the third distinct particle type comprise iron oxide cores, polymer shells, and are less than about 500 nm in diameter and wherein the first distinct particle type comprises a negative charge, the second distinct particle type comprises a positive charge, and the third distinct particle type comprises a neutral charge, wherein the diameter is a mean diameter as measured by dynamic light scattering.

89. The composition of claim 88, wherein the first distinct particle type comprises a silica coating, the second distinct particle type comprises a poly(N-(3-(dimethylamino)propyl) methacrylamide) (PDMAAPMA), and the third distinct particle type comprises a poly(oligo(ethylene glycol) methyl ether methacrylate) (POEGMA) coating.

90. The composition of any one of claims 66-89, wherein the three or more distinct magnetic particle types comprise a nanoparticle.

91. The composition of any one of claims 66-90, wherein the three or more distinct magnetic particle types comprises a microparticle.

92. The composition of any one of claims 66-91, wherein at least one distinct particle type of the three or more distinct magnetic particle types is a superparamagnetic iron oxide particle.

93. The composition of any one of claims 66-92, wherein at least one distinct particle type of the three or more distinct magnetic particle types comprise an iron oxide material.

94. The composition of any one of claims 66-93, wherein at least one distinct particle type of the three or more distinct magnetic particle types has an iron oxide core.

95. The composition of any one of claims 66-94, wherein at least one distinct particle type of the three or more distinct magnetic particle types has iron oxide crystals embedded in a polystyrene core.

96. The composition of any one of claims 66-95, wherein each distinct particle type of the three or more distinct magnetic particle types is a superparamagnetic iron oxide particle.

97. The composition of any one of claims 66-96, wherein each distinct particle type of the three or more distinct magnetic particle types comprise an iron oxide core.

98. The composition of any one of claims 66-97, wherein each one distinct particle type of the three or more distinct magnetic particle types has iron oxide crystals embedded in a polystyrene core.

99. The composition of any one of claims 66-98, wherein at least one particle type of the three or more distinct magnetic particle types comprises a polymer coating.

100. The composition of any one of claims 66-99, wherein the three or more distinct magnetic particle types comprise a carboxylated polymer, an aminated polymer, a zwitterionic polymer, or any combination thereof.

101. The composition of any one of claims 66-100, wherein at least one particle type of the three or more distinct magnetic particle types comprises an iron oxide core with a silica shell coating.

102. The composition of any one of claims 66-100, wherein at least one particle type of the three or more distinct magnetic particle types comprises an iron oxide core with a poly(N-(3-(dimethylamino)propyl) methacrylamide) (PDMAEMA) coating.

103. The composition of any one of claims 66-100, wherein at least one particle type of the three or more distinct magnetic particle types comprises an iron oxide core with a poly(oligo(ethylene glycol) methyl ether methacrylate) (POEGMA) coating.

104. The composition of any one of claims 66-103, wherein at least one particle type of the three or more distinct magnetic particle types comprises a negative surface charge.

105. The composition of any one of claims 66-103, wherein at least one particle type of the three or more distinct magnetic particle types comprises a positive surface charge.

106. The composition of any one of claims 66-103, wherein at least one particle type of the three or more distinct magnetic particle types comprises a neutral surface charge.

107. The composition of any one of claims 66-106, wherein the three or more distinct magnetic particle types comprise one or more particle types of **TABLE 10**.

108. The composition of any one of claims 66-107, wherein the particle panel comprises two or more distinct particle types, three or more distinct particle types, four or more distinct particle types, five or more distinct particle types, six or more distinct particle types, seven or more distinct particle types, eight or more distinct particle types, nine or more distinct particle types, or all ten distinct particle types selected from **TABLE 10**.

109. The composition of any one of claims 66-108, wherein the three or more distinct magnetic particle types comprise one or more particle types of **TABLE 12**.

110. The composition of any one of claims 66-109, wherein the particle panel comprises two or more distinct particle types, three or more distinct particle types, four or more distinct particle types, five or more distinct particle types, six or more distinct particle types, seven or more distinct particle types, eight or more distinct particle types, nine or more distinct particle types, or all ten distinct particle types selected from **TABLE 12**.

111. The method of any one of claims 1-64 or the composition of any one of claims 67-110, wherein the sample is a biological sample.

112. The method of claim 111, wherein the biological sample is plasma, serum, CSF, urine, tear, cell lysates, tissue lysates, cell homogenates, tissue homogenates, nipple aspirates, fecal samples, synovial fluid and whole blood, or saliva.

113. The method of any one of claims 1-64 or the composition of any one of claims 67-110, wherein the sample is a non-biological sample.

114. The method of claim 113, wherein the non-biological sample is water, milk, solvents, or a homogenized sample.