ELECTRODE ARRAY DEVICE HAVING AN ADSORBED POROUS REACTION LAYER

Technical Field of the Invention

The present invention provides an electrode microarray having an adsorbed porous reaction layer for improved synthesis quality. Specifically, the present invention provides an electrode microarray having a plurality of electrodes, having an adsorbed porous reaction layer and a process for treating the microarray surface to significantly enhance nucleic acid synthesis quality and increase assay sensitivity. More specifically, the present invention provides a computer controlled electrode microarray having a plurality of platinum-containing electrodes, having an adsorbed porous reaction layer and a process of treating the microarray surface to significantly enhance the quality of synthesis of oligonucleotides, peptides, and other chemical species while increasing binding assay sensitivity.

Background of the Invention

Microarrays and particularly nucleic acid microarrays have become important analytical research tools in pharmacological and biochemical research and discovery. Microarrays are miniaturized arrays of points or locations arranged in a column and row format. Molecules, including biomolecules, are attached or synthesized *in situ* at specific attachment points, which are usually in a column and row format although other formats may be used. An advantage of microarrays is that they provide the ability to conduct hundreds, if not thousands, of experiments in parallel. Such parallelism, as compared to sequential experimentation, can be used to increase the efficiency of exploring relationships between molecular structure and biological function, where slight variations in chemical structure can have profound biochemical effects. Microarrays are available in different formats and have different surface chemistry characteristics that lead to different approaches for attaching or synthesizing molecules. Differences in microarray surface chemistry lead to differences in preparation methods for providing a surface that is receptive to attachment of a presynthesized chemical species or for synthesizing a chemical species in situ. As the name suggests, the attachment points on microarrays are of a micrometer scale, which is generally 1–100μm.

Research using microarrays has focused mainly on deoxyribonucleic acid (DNA) and ribonucleic acid (RNA) related areas, which includes genomics, cellular gene expression, single nucleotide polymorphisms (SNP), genomic DNA detection and validation, functional genomics, and proteomics (Wilgenbus and Lichter, J. *Mol. Med*. 77:761, 1999; Ashfari et al., *Cancer Res*. 59:4759, 1999; Kurian et al., *J. Pathol*. 187:267, 1999; Hacia, *Nature Genetics* 21 suppl.:42, 1999; Hacia et al., *Mol. Psychiatry* 3:483, 1998; and Johnson, *Curr. Biol*. 26:R171, 1998.) In addition to microarrays for DNA/RNA research, microarrays can be used for research related to peptides (two or more linked natural or synthetic amino acids), small molecules (such as pharmaceutical compounds), oligomers, and polymers.

Considering microarrays for DNA related research, there are numerous methods for preparing a microarray of DNA related molecules. DNA related molecules include native or cloned DNA and synthetic DNA. Synthetic relatively short single-stranded DNA or RNA strands are commonly referred to as oligonucleotides (oligos), which is synonymous with oligodeoxyribonucleotide. Microarray preparation methods include the following: (1) spotting a solution on a prepared flat surface using spotting robots; (2) *in situ* synthesis by printing reagents via ink jet or other printing technology and using regular phosphoramidite chemistry; (3) *in situ* parallel synthesis using electrochemically generated acid for deprotection and using regular phosphoramidite chemistry; (4) maskless photo-generated acid (PGA) controlled *in situ* synthesis and using regular phosphoramidite chemistry; (5) mask-directed *in situ* parallel synthesis using photo-cleavage of photolabile protecting groups (PLPG); (6) maskless *in situ* parallel synthesis using PLPG and digital photolithography; and (7) electric field attraction/repulsion for depositing oligos.

Photolithographic techniques for *in situ* olio synthesis are disclosed in Fodor et al. U.S. Patent 5,445,934 and the additional patents claiming priority thereto. Electric field attraction/repulsion microarrays are disclosed in Hollis et al. U.S. Patent 5,653,939 and Heller et al. U.S. Patent 5,929,208. An electrode microarray for *in situ* oligo synthesis using electrochemical deblocking is disclosed in Montgomery U.S. Patents 6,093,302; 6,280,595, and 6,444,111 (Montgomery I, II, and III respectively), which are incorporated by reference herein. Another and materially different electrode array (not a microarray) for *in situ* oligo synthesis on surfaces

separate and apart from electrodes using electrochemical deblocking is disclosed in Southern U.S. Patent 5,667,667. A review of oligo microarray synthesis is provided by Gao et al., *Biopolymers* **2004**, *73*, 579.

Microarrays other than DNA microarrays have been disclosed. For example, the synthetic preparation of a peptide array was originally reported in 1991 using photolithography masking techniques. This method was extended in year 2000 to include an addressable masking technique using photogenerated acids and/or in combination with photosensitizers for deblocking. Reviews of peptide microarray synthesis using photolabile deblocking are provided by Pellois et al., *J. Comb. Chem.* **2000,** 2:355 and Fodor et al., *Science*, **1991**, 251:767. Recent work using peptide arrays has utilized arrays produced by spotting pre-synthesized peptides or isolated proteins. A review of protein arrays is provided by Cahill and Nordhoff, *Adv. Biochem. Engin/Biotechnol*. **2003**, 83:177.

Preparation methods for providing a microarray surface that is receptive to attachment of a presynthesized chemical species or for synthesizing a chemical species *in situ* must provide a surface that is capable of bonding a chemical species as well as being capable of providing the chemical functionality necessary to conduct pharmacological and biochemical research and discovery. One approach is to treat a surface to provide reactive groups capable of covalently bonding to chemical species of interest. In such an approach, the reactive group is typically present as a result of a surface treatment or coating of the surface. For DNA related species, the reactive group required is a hydroxyl, unless there has been a chemical modification. For peptides, the reactive group required is an amine, unless there has been a chemical modification.

Glass is a commonly used solid substrate for microarrays and must be treated before use. A common glass treatment uses silanization chemistry to introduce a stable and uniform surface having reactive groups for attachment or *in situ* synthesis of oligos or other chemical species (Guo et al., 1994, *Nucl. Acids Res*., 22:5456-5465; LeProust et al., 2001, *Nucl. Acids Res*., 29:2171-2180; Maskos and Southern, 1992, *Nucl. Acids Res*., 20:1679-1684; Skrzypcznski et al., U.S. Patent Appl. Pub. 2004/0073017, and Southern et al. U.S Patent 6,576,426.). Glass beads for bulk synthesis must also undergo silanization (Maskos and Southern). Gold surfaces are treated with thiol linker chemistry (Kelley et al. U.S. Patent Pub. 2002/0172963).

Similarly, polymeric microarray supports, such as polypropylene, must be treated by oxidation followed by introduction of reactive groups such as terminal amines (Schepinov et al., 1997, *Nucl. Acids Res*., 25:1155-1161). Additionally, polystyrene beads are surface treated with polyethylene glycols having reactive terminal groups for bulk synthesis of peptides (Merck, Inc. Novabiochem Div. and Aldrich et al., U.S. Patent Appl. Pub. 2003/0134989). Finally, the surface of electrodes on an electrode microarray must be treated with a surface coating to provide reactive groups (Montgomery I, II, and III). For oligo synthesis, such a surface coating must be able to withstand the rigors of repeated exposure to synthesis solutions and to electrochemical deblocking solutions.

The electrochemical synthesis microarray disclosed in Montgomery I, II, and III is based upon a semiconductor chip having a plurality of microelectrodes in a column and row format. This chip design uses Complimentary Metal Oxide Semiconductor (CMOS) technology to create high-density arrays of microelectrodes with parallel addressing for selecting and controlling individual microelectrodes within the array. The electrodes are "turned on" by applying a voltage, which generates electrochemical reagents (particularly acidic protons) that alter the pH in a small, defined "virtual flask" region or volume adjacent to the electrode. In order to provide reactive groups at each electrode, the microarray is coated with a porous matrix material. Biomolecules can be synthesized at any of the electrodes, and such synthesis occurs within the porous matrix material. For the deblocking step, the pH is electrochemically decreased by applying a voltage to an electrode. The pH decreases only in the vicinity of the electrode because the ability of the acidic reagent to travel away from an electrode is limited by natural diffusion and by a buffer in solution.

In general, when a surface is treated, there is a reactive group at the terminal end of a linker that is attached to the surface during treatment. A linker is a molecule that connects a species of interest to a solid surface. For example, a linker for glass has a reactive group at one end and a silane-coupling group at the other for bonding to glass. Linkers can be of various lengths, depending on the particular chemical species used to form the linker. In addition to linkers, spacers can be attached to a linker in order to provide more distance between a solid surface and an attached chemical species. Spacers can be of a different chemistry than linkers. Linkers and

spacers for attachment of oligos are disclosed for glass supports (Guo et al., LeProus et. al., Maskos et al., Skrzypcznski and Southern) for aminated polypropylene supports (Schepinov et al.) and for polystyrene beads (Merck, Inc. Novabiochem Div. and Aldrich et al.).

For a surface coating on an electrode microarray, the surface coating itself provides reactive groups that are naturally present within the coating. Montgomery I, II, and III disclose a surface coating comprising controlled porosity glass (CPG); generic polymers, such as, teflons, nylons, polycarbonates, polystyrenes, polyacylates, polycyanoacrylates, polyvinyl alcohols, polyamides, polyimides, polysiloxanes, polysilicones, polynitriles, polyelectrolytes, hydrogels, expoxy polymers, melamines, urethanes and copolymers and mixtures of these and other polymers; biologically derived polymers, polyhyaluric acids, celluloses, and chitons; ceramics, such as, alumina, metal oxides, clays, and zeolites; surfactants; thiols; self-assembled monolayers; porous carbon; and fullerine materials. Montgomery I, II, and III further discloses that the surface coating can be attached to the electrodes by spin coating, dip coating or manual application, or any other acceptable form of coating. Montgomery I, II, and III further discloses linker molecules attached to controlled porosity glass via silicon-carbon bonds and that the linker molecules include aryl, acetylene, ethylene glycol oligomers containing from 2 to 10 monomer units, diamines, diacids, amino acids, and combinations thereof. In each instance, Montgomery discloses coating the entire surface of a microarray device and not just electrode surfaces.

Guo et al. discloses the use of a 23-atom linker for covalently attaching a DNA sequence to glass. The linker is made by reaction of the glass surface with aminopropyltrimethoxysilane to provide an amino-derivatized surface followed by coupling of the amino groups with excess p-phenylenediisothiocyanate to convert the amino groups to amino-reactive phenylisothiocyanate groups. An oligonucleotide is then covalently attached to the amino-reactive group by coupling to the amino-reactive group a 5' amino-modified oligonucleotide attached to the 5' end of a sequence of an oligonucleotide. The resulting structure is a solid surface having a linker attached thereto and the linker having an oligonucleotide attached from the 5' side to the linker. Guo et al. further disclose a spacer comprising up to a 15-deoxythymidylate chain that is between the oligonucleotide and the linker. The

spacer has a 5' amino-modified oligonucleotide to allow attachment to the amino-reactive group. The spacer is attached onto the 5' end of an oligonucleotide as a part of the oligonucleotide, and then the spacer-oligonucleotide is attached to the linker. As viewed from the glass surface, the final structure provides a glass surface having a linker having attached thereto a 5' to 3' prime spacer-oligonucleotide, where the spacer-oligonucleotide has been synthesized elsewhere and then attached to the linker. The 15-deoxythymidylate chain was found to have the highest hybridization signal compared to chains having fewer deoxythymidylate units.

Maskos and Southern disclose silane-coupled linkers for glass. The linkers are different length and are terminated with a hydroxyl for oligonucleotide synthesis on the glass. The linkers are bound to glass through a glycidoxypropyl silane linkage and have a hexaethylene glycol middle section of different lengths. The linkers range from 8 to 26 atoms in length and do not have any charge. Shchepinov et al. discloses spacer molecules for coupling oligonucleotides to aminated polypropylene. The spacer molecules are built using phosphoramidite chemistry and synthesized monomers having diols as a part of the monomeric unit. Both 3' and 5' oligonucleotides were built upon the spacers.

LeProust et al. discloses silane linkers terminating in a hydroxyl, amide, or amine group. The linkers were used to synthesize oligonucleotides (deoxythymidylate units) on glass slides to determine the efficiency/fidelity of synthesis. The linkers were nonionic. Southern et al. discloses nonionic linkers/spacers for use on control pore glass (CPG) for oligonucleotide synthesis. The linkers were attached to CPG through a terminal amine attached to a group on the CPG via silanization. Skrzypcznski et al. discloses nonionic linkers/spacer coupled to glass or sol-gel glass coating through silane linkage. The linker/spacer is proposed to have a hydrophobic part next to the glass attached to a hydrophilic part where a DNA probe is attached.

Linkers and spacers are sometimes used for peptide synthesis off of a microarray. Specifically, microscopic polystyrene (PS) beads are used as a solid support (Aldrich et al.). The beads have a polyethylene glycol (PEG) spacer attached to the beads and a linking group attached to the PEG, where the linking group has a reactive group for synthesis of peptides. After synthesis, the peptides are cleaved from the linking group and recovered. Numerous PS-PEG resins for synthesis are

available commercially from Merck Company, Novabiochem Division, as well as other sources.

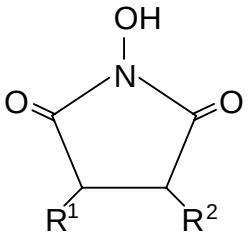
Oligo microarrays made with the electrochemical process as disclosed in Montgomery I, II, and III have had problems with oligo quality, where quality is judged by missing deoxynucleotide bases in sequences resulting from inefficient deblocking. In addition, quality problems can arise from delamination of the coating over the electrodes. Control pore glass coatings and polysaccharide agarose coatings are both prone to delamination quality problems. Such quality problems have caused the resulting oligo microarray to be less useful for sensitivity of gene expression assays (*i.e.*, finding low abundance mRNA species) and for single nucleotide polymorphisms (SNP) assays, wherein single base changes need to be detected. Peptide synthesis on electrode microarrays has also been problematic. Similar quality problems have been found for glass microarrays, where research has found inefficient reactions of the various reagents with functional groups close to glass plate surfaces (LeProust et al.).

Considering (1) the above discussion of electrode microarray quality problems for oligonucleotides, peptides, and other chemical species, and (2) the need for a surface having reactive groups on electrode microarrays, there is a need in the art to be able to improve *in situ* electrochemical synthesis quality to provide microarrays having higher quality. The present invention addresses these needs. Additionally, for electrode microarrays, there is a need for a modified surface coating incorporating a linker and spacer to improve synthesis quality and prevent fluorescence quenching.

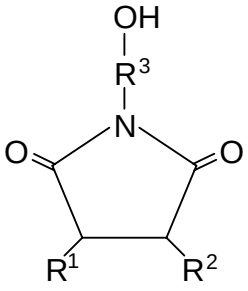
Summary of the Invention

The present invention provides an electrode microarray having an adsorbed porous reaction layer for improved synthesis quality. The microarray comprises a plurality of electrodes on a substrate, wherein the electrodes are electronically connected to a computer control system. In addition, the microarray has an adsorbed porous reaction layer on the plurality of electrodes, wherein the adsorbed porous reaction layer comprises a chemical species having at least one hydroxyl group. The chemical species is selected from the group consisting of monosaccharides, disaccharides, trisaccharides, polyethylene glycol, polyethylene glycol derivative,

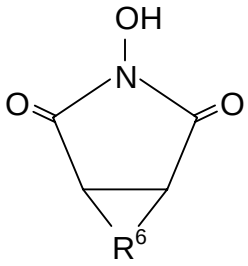
N-hydroxysuccinimide, formula I, formula II, formula III, formula IV, formula V, formula VI, and formula VII, and combinations thereof. Formula I is



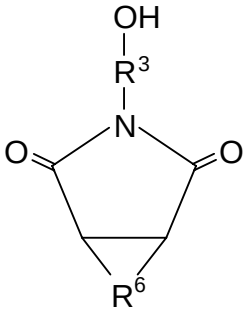
; formula II is



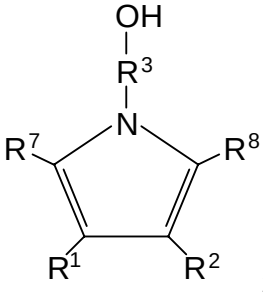
; formula III is



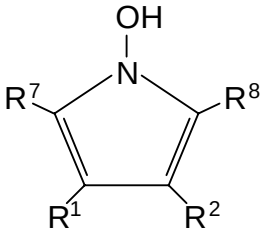
$HOR^4(OR^5)_mR^7$; formula IV is



; formula V is



; formula VI is



; and formula VII is

The subscript m is an integer from ranging from 1 to about 4. The polyethylene glycol has a molecular weight of approximately 1,000 to 20,000 daltons.

R^1, R^2, R^7, and R^8 are independently selected from the group consisting of hydrogen, and substituted and unsubstituted alkyl, alkenyl, alkynyl, cycloalkyl, cycloalkenyl, cycloalkynyl, aryl, heterocyclic ring, and polycyclic group, and halo, amide, alkoxy, acyl, acyloxy, oxycarbonyl, acyloxycarbonyl, alkoxycarbonyloxy, carboxy, amino, secondary amino, tertiary amino, hydrazino, azido, alkazoxy, cyano,

isocyano, cyanato, isocyanato, thiocyanato, fulminato, isothiocyanato, isoselenocyanato, selenocyanato, carboxyamido, acylimino, nitroso, aminooxy, carboximidoyl, hydrazonoyl, oxime, acylhydrazino, amidino, sulfide, sulfoxide, thiosulfoxide, sulfone, thiosulfone, sulfate, thiosulfate, hydroxyl, formyl, hydroxyperoxy, hydroperoxy, peroxy acid, carbamoyl, trimethyl silyl, nitro, nitroso, oxamoyl, pentazolyl, sulfamoyl, sulfenamoyl, sulfeno, sulfinamoyl, sulfino, sulfo, sulfoamino, hydrothiol, tetrazolyl, thiocarbamoyl, thiocarbazono, thiocarbodiazono, thiocarbonohydrazido, thiocarboxy, thioformyl, thioacyl, thiocyanato, thiosemicarbazido, thiosulfino, thiosulfo, thioureido, triazano, triazeno, triazinyl, trithiosulfo, sulfinimidic acid, sulfonimidic acid, sulfinohydrazonic acid, sulfonohydrazonic acid, sulfinohydroximic acid, sulfonohydroximic acid, and phosphoric acid ester.

R^3 is selected from the group consisting of heteroatom group, carbonyl, and substituted and unsubstituted alkyl, alkenyl, alkynyl, cycloalkyl, cycloalkenyl, cycloalkynyl, aryl, heterocyclic ring, and polycyclic group. R^4 and R^5 are independently selected from the group consisting of methylene, ethylene, propylene, butylene, pentylene, and hexylene. R^6 forms a ring structure with two carbons of succinimide and is selected from the group consisting of substituted and unsubstituted alkyl, alkenyl, alkynyl, cycloalkyl, cycloalkenyl, cycloalkynyl, aryl, heterocyclic ring, and polycyclic group. R^7 is selected from the group consisting of amino and hydroxyl.

The monosaccharide is selected from the group consisting of allose, altrose, arabinose, deoxyribose, erythrose, fructose, galactose, glucose, gulose, idose, lyxose, mannose, psicose, L-rhamnose, ribose, ribulose, sedoheptulose, D-sorbitol, sorbose, sylulose, tagatose, talose, threose, xylulose, and xylose. The disaccharide is selected from the group consisting of amylose, cellobiose, lactose, maltose, melibiose, palatinose, sucrose, and trehalose. The triaccharide is selected from the group consisting of raffinose and melezitose.

The polyethylene glycol derivative is selected from the group consisting of diethylene glycol, tetraethylene glycol, polyethylene glycol having primary amino groups, 2-(2-aminoethoxy) ethanol, ethanol amine, di(ethylene glycol) mono allyl ether, di(ethylene glycol) mono tosylate, tri(ethylene glycol) mono allyl ether, tri(ethylene glycol) mono tosylate, tri(ethylene glycol) mono benzyl ether,

tri(ethylene glycol) mono trityl ether, tri(ethylene glycol) mono chloro mono methyl ether, tri(ethylene glycol) mono tosyl mono allyl ether, tri(ethylene glycol) mono allyl mono methyl ether, tetra(ethlyne glycol) mono allyl ether, tetra(ethylene glycol) mono methyl ether, tetra(ethylene glycol) mono tosyl mono allyl ether, tetra(ethylene glycol) mono tosylate, tetra(ethylene glycol) mono benzyl ether, tetra(ethylene glycol) mono trityl ether, tetra(ethylene glycol) mono 1-hexenyl ether, tetra(ethylene glycol) mnon 1-heptenyl ether, tetra(ethylene glycol) mono 1-octenyl ether, tetra(ethylene glycol) mono 1-decenyl ether, tetra(ethylene glycol) mono 1-undecenyl ether, penta(ethylene glycol) mono methyl ether, penta(ethylene glycol) mono allyl mono methyl ether, penta(ethylene glycol) mono tosyl mono methyl ether, penta(ethylene glycol) mono tosyl mono allyl ether, hexa(ethylene glycol) mono allyl ether, hexa(ethylene glycol) mono methyl ether, hexa(ethylene glycol) mono benzyl ether, hexa(ethylene glycol) mono trityl ether, hexa(ethylene glycol) mono 1-hexenyl ether, hexa(ethylene glycol) mono 1-heptenyl ether, hexa(ethylene glycol) mono 1-octenyl ether, hexa(ethylene glycol) mono 1-decenyl ether, hexa(ethylene glycol) mono 1-undecenyl ether, hexa(ethylene glycol) mono 4-benzophenonyl mono 1-undecenyl ether, hepta(ethylene glycol) mono allyl ether, hepta(ethylene glycol) mono methyl ether, hepta(ethylene glycol) mono tosyl mono methyl ether, hepta(ethylene glycol) monoallyl mono methyl ether, octa(ethylene glycol) mono allyl ether, octa(ethylene glycol) mono tosylate, octa(ethylene glycol) mono tosyl mono allyl ether, undeca(ethylene glycol) mono methyl ether, undeca(ethylene glycol) mono allyl mono methyl ether, undeca(ethylene glycol) mono tosyl mono methyl ether, undeca(ethylene glycol) mono allyl ether, octadeca(ethylene glycol) mono allyl ether, octa(ethylene glycol), deca(ethylene glycol), dodeca(ethylene glycol), tetradeca(ethylene glycol), hexadeca(ethylene glycol), octadeca(ethylene glycol), benzophenone-4-hexa(ethylene glycol) allyl ether, benzophenone-4-hexa(ethylene glycol) hexenyl ether, benzophenone-4-hexa(ethylene glycol) octenyl ether, benzophenone-4-hexa(ethylene glycol) decenyl ether, benzophenone-4-hexa(ethylene glycol) undecenyl ether, 4-flourobenzophenone-4`-hexa(ethylene glycol) allyl ether, 4-flourobenzophenone-4`-hexa(ethylene glycol) undecenyl ether, 4-hydroxybenzophenone-4`-hexa(ethylene glycol) allyl ether, 4-hydroxybenzophenone-4`-hexa(ethylene glycol) undecenyl ether, 4-hydroxybenzophenone-4`-tetra(ethylene glycol) allyl ether, 4-

hydroxybenzophenone-4`-tetra(ethylene glycol) undecenyl ether, 4-morpholinobenzophenone-4`-hexa(ethylene glycol) allyl ether, 4-morpholinobenzophenone-4`-hexa(ethylene glycol) undecenyl ether, 4-morpholinobenzophenone-4`-tetra(ethylene glycol) allyl ether, and 4-morpholinobenzophenone-4`-tetra(ethylene glycol) undecenyl ether.

The present invention further provides a process for forming an electrode array having an adsorbed porous reaction layer for improved synthesis quality. The process comprises (1) providing a plurality of clean electrodes on a substrate, wherein the electrodes are electronically connected to a computer control system; and (2) adsorbing a porous reaction layer on the plurality of electrodes, wherein the porous reaction layer comprises a chemical species having at least one hydroxyl group, wherein the chemical species is selected from the group consisting of monosaccharides, disaccharides, trisaccharides, polyethylene glycol, polyethylene glycol derivative, N-hydroxysuccinimide, formula I, formula II, formula III, formula IV, formula V, and combinations thereof. The saccharides, PEG's, Formulae I-V are as provided herein.

The present invention further provides a process for adsorbing a porous reaction layer onto a plurality of electrodes, comprising (1) contacting a treatment solution to the microarray for from about 1 minute to about 2 weeks, wherein the treatment solution comprises the chemical species that adsorbs onto each electrode of the plurality of electrodes and a solvent capable of dissolving the chemical species; and (2) washing off the treatment solution while leaving a layer of chemical species adsorbed onto each electrode of the plurality of electrodes.

The present invention further provides a process for cleaning an electrode microarray comprising (1) etching the electrode microarray surface using a plasma cleaning method; and (2) cleaning the electrode microarray using a chemical cleaning method. Preferably, the plasma cleaning method comprises exposing the electrode microarray to an argon plasma sputter etch process for approximately two to six minutes, where the plasma power is 200W, the self bias voltage is 600-650V, the plasma pressure is 8 mTorr, and a 200 mm diameter electrode is used in a parallel plate plasma chamber. Preferably, the plasma cleaning method comprises exposing the electrode microarray to a sulfur hexafluoride plasma for approximately 30 to 60 minutes, where the plasma power is 300 watts, the plasma pressure is approximately

250 to 350 mTorr, and the gas flow is 124 cubic centimeters per minute in an isoptropic plasma chamber. Preferably, the plasma cleaning method comprises etching the electrode microarray in a commercial Reactive Ion Etch Plasma system (such as Oxford Plasmalab 800Plus RIE system with a 460 mm diameter electrode) using (1) an argon plasma for approximately 2 to 4 minutes and a RF plasma power of approximately 600 watts, where the pressure is approximately eight millitorr and the Ar gas flow is approximately 30 sccm; (2) an oxygen plasma for approximately 5 to 7 minutes using a power of approximately 500 watts, where the pressure is approximately 50 millitorr and the oxygen gas flow of approximately 50 sccm; or (3) an argon plasma for approximately 8 to12 minutes using a power of approximately 600 watts, where the pressure is approximately eight millitorr and the Ar gas flow is approximately 30 sccm.

Preferably, chemical cleaning method comprises an electrochemical cleaning method comprising (1) contacting a sulfuric acid solution with the electrodes of the electrode microarray, wherein the sulfuric acid solution has a concentration of approximately 0.01 to 5 molar and the electrode microarray is electronically attached to a control system; (2) pulsing a current for approximately 0.01 to 60 seconds to a first group of electrodes while a second group of electrodes is grounded; (3) pulsing a current for approximately 0.01 to 60 seconds to the second group of electrodes while the first group of electrodes is grounded; and (4) alternating between pulsing a current for approximately 0.01 to 60 seconds to the first group of electrodes while the second group of electrodes is grounded and pulsing a current for approximately 0.01 to 60 seconds to the second group of electrodes while the first group of electrodes remains grounded for a cumulative time of approximately 1 to 60 minutes. Preferably, the chemical cleaning method comprises a hydrogen peroxide cleaning method comprising contacting a hydrogen peroxide solution with the electrodes of the electrode microarray, wherein the hydrogen peroxide solution has a concentration of approximately 0.5 to 10% (by volume), contacting time is approximately 1 minute to 24 hours, and the hydrogen peroxide solution temperature is approximately 20 to 95 degrees Celsius.

Brief Description of the Drawings

Figures 1A and 1B are schematics of a cross section of two electrodes of a microarray of electrodes. In Figure 1A, an adsorbed porous reaction layer is shown as being adsorbed across the entire microarray surface. In Figure 1B, an adsorbed porous reaction layer is shown as being adsorbed predominately on only electrode surfaces. The reaction layer is shown having hydroxyl moieties as reactive groups.

Figures 2A and 2B are schematics of a cross section of two electrodes of a microarray of electrodes, wherein there is a bound linker moiety has a terminal reactive group for *in situ* synthesis.

Figure 3 is a schematic of a cross section of two electrodes of a microarray of electrodes, wherein a comparison is made between a linker/spacer having no charge to one have charge.

Figure 4 is a photograph of a magnified portion of a top view of a microarray having agarose as a reaction layer. The lighter spots are fluorescence of fluorescently labeled nucleotides that were hybridized with the array after *in situ* synthesis of DNA oligos.

Figure.5 is a photograph of a magnified portion of a top view of a microarray having sucrose as a reaction layer. The lighter spots are fluorescence of fluorescently labeled nucleotides that were hybridized with the array after *in situ* synthesis of DNA oligos.

Figure 6 is a bar chart displaying the results of a sensitivity study using sucrose as the reaction layer.

Figure 7 is a photograph of a magnified portion of a top view of a microarray having diethylene glycol as a reaction layer. The lighter spots are fluorescence of fluorescently labeled nucleotides that were hybridized with the array after *in situ* synthesis of DNA oligos.

Figure 8 is a photograph of a magnified portion of a top view of a microarray having ethylene glycol as a reaction layer. The lighter spots are fluorescence of fluorescently labeled nucleotides that were hybridized with the array after *in situ* synthesis of DNA oligos.

Figure 9 is a photograph of a magnified portion of a top view of a microarray having N-hydroxysuccinimide as a reaction layer. The lighter spots are fluorescence

of fluorescently labeled nucleotides that were hybridized with the array after *in situ* synthesis of DNA oligos.

Figure 10 is a photograph of a magnified portion of a top view of a microarray having triethylene glycol as a reaction layer. The lighter spots are fluorescence of fluorescently labeled nucleotides that were hybridized with the array after *in situ* synthesis of DNA oligos.

Figure 11 is a photograph of a magnified portion of a top view of a microarray having raffinose as a reaction layer. The lighter spots are fluorescence of fluorescently labeled nucleotides that were hybridized with the array after *in situ* synthesis of DNA oligos.

Figure 12 is a photograph of a magnified portion of a top view of a microarray having melizitose as a reaction layer. The lighter spots are fluorescence of fluorescently labeled nucleotides that were hybridized with the array after *in situ* synthesis of DNA oligos.

Figure 13 is a photograph of a magnified portion of a top view of a microarray having Splenda® as a reaction layer. The lighter spots are fluorescence of fluorescently labeled nucleotides that were hybridized with the array after *in situ* synthesis of DNA oligos.

Figure 14 is a photograph of a magnified portion of a top view of a microarray having inulin as a reaction layer. The lighter spots are fluorescence of fluorescently labeled nucleotides that were hybridized with the array after *in situ* synthesis of DNA oligos.

Figure 15 is a photograph of a magnified portion of a top view of a microarray having palatinose as a reaction layer. The lighter spots are fluorescence of fluorescently labeled nucleotides that were hybridized with the array after *in situ* synthesis of DNA oligos.

Figure 16 is a photograph of a magnified portion of a top view of a microarray having polyethylene glycol as a reaction layer. The lighter spots are fluorescence of fluorescently labeled nucleotides that were hybridized with the array after *in situ* synthesis of DNA oligos.

Figure 17 is a photograph of a magnified portion of a top view of a microarray having salicin as a reaction layer. The lighter spots are fluorescence of

fluorescently labeled nucleotides that were hybridized with the array after *in situ* synthesis of DNA oligos.

Figure 18 is a photograph of a magnified portion of a top view of a microarray having ribose as a reaction layer. The lighter spots are fluorescence of fluorescently labeled nucleotides that were hybridized with the array after *in situ* synthesis of DNA oligos.

Figure 19 is a photograph of a magnified portion of a top view of a microarray having melibiose as a reaction layer. The lighter spots are fluorescence of fluorescently labeled nucleotides that were hybridized with the array after *in situ* synthesis of DNA oligos

Figure 20A-20E are schematics of a cross-section of four electrodes of a microarray of electrodes showing the synthesis of peptides on the electrodes followed by exposure to anti-beta endorphin antibody (clone 3-E7, mouse) and Cy5 labeled donkey anti-mouse antibody. Two electrodes have an ionic linking group, and two electrodes are missing an ionic linking group.

Figure 21 is a schematic of a cross-section of two electrodes of a microarray of electrodes showing the quenching of fluorescently labeled reagent by the platinum electrode when an ionic linker is not used.

Figure 22 is a magnified and contrast-enhanced photograph of the top view of a section of an electrode microarray showing that the fluorescence of Cy5 labeled donkey anti-mouse antibody is visible when an ionic linker is used to connect the peptide to the platinum electrode overlayer.

Figure 23 is schematic of a cross-section of two electrodes of a microarray of electrodes. One electrode shows that the use of a non-ionic linker allows quenching of the Cy5 labeled donkey anti-mouse antibody because the non-ionic linker is poorly solvated. The other electrode shows that the use of an ionic linker prevents quenching of the Cy5 labeled donkey anti-mouse antibody because the ionic linker is well solvated and thus keeps the labeled antibody away from the platinum electrode.

Figure 24 is a magnified photograph of the top view of a section of an electrode microarray showing the decrease in fluorescence quenching as the length of the linker/spacer is increased from 0 to 15 deoxythymidylate units. The linker/spacer was synthesized *in situ*. The fluorescence is from Texas Red labeled

streptavidin bound to a biotin that is covalently attached to the end of the linker/spacer.

Figure 25 is a photograph of a magnified portion of a top view of a microarray having 1-(3-hydroxylpropyl) pyrrole as a reaction layer. The lighter spots are fluorescence of fluorescently labeled nucleotides that were hybridized with the array after *in situ* synthesis of DNA oligos.

Figure 26 is a photograph of a magnified portion of a top view of a microarray having 1-hexylpyrrole as a reaction layer. The lighter spots are fluorescence of fluorescently labeled nucleotides that were hybridized with the array after *in situ* synthesis of DNA oligos.

Figure 27 is a photograph of a magnified portion of a top view of a microarray having a combination reaction layer, wherein the combination comprises sucrose and fructose. The lighter spots are fluorescence of fluorescently labeled nucleotides that were hybridized with the array after *in situ* synthesis of DNA oligos. The oligomers have a length of 35 to 70 mers.

Figure 28 is a photograph of a magnified portin of a top view of a microarray having a combination reaction layer, wherein the combination comprises sucrose and fructose. The lighter spots are fluorescence of fluorescently labeled nucleotides that were hybridized with the array after *in situ* synthesis of DNA oligos. The oligomers have a length of 35 mers.

Figure 29 is a photograph of a magnified portin of a top view of a microarray having a combination reaction layer, wherein the combination comprises sucrose and fructose. The lighter spots are fluorescence of fluorescently labeled nucleotides that were hybridized with the array after *in situ* synthesis of DNA oligos. The oligomers have an average length of 40 mers.

Figure 30 is a photograph of a magnified portin of a top view of a microarray having a combination reaction layer, wherein the combination comprises sucrose and fructose. The lighter spots are fluorescence of fluorescently labeled nucleotides that were hybridized with the array after *in situ* synthesis of DNA oligos. The oligomers have a length of 45 mers.

Figure 31 is a photograph of a magnified portin of a top view of a microarray having a combination reaction layer, wherein the combination comprises sucrose and fructose. The lighter spots are fluorescence of fluorescently labeled nucleotides that

were hybridized with the array after *in situ* synthesis of DNA oligos. The oligomers have a length of 50 mers.

Figure 32 is a photograph of a magnified portin of a top view of a microarray having a combination reaction layer, wherein the combination comprises sucrose and fructose. The lighter spots are fluorescence of fluorescently labeled nucleotides that were hybridized with the array after *in situ* synthesis of DNA oligos. The oligomers have a length of 55 mers.

Figure 33 is a photograph of a magnified portin of a top view of a microarray having a combination reaction layer, wherein the combination comprises sucrose and fructose. The lighter spots are fluorescence of fluorescently labeled nucleotides that were hybridized with the array after *in situ* synthesis of DNA oligos. The oligomers have a length of 60 mers.

Figure 34 is a photograph of a magnified portin of a top view of a microarray having a combination reaction layer, wherein the combination comprises sucrose and fructose. The lighter spots are fluorescence of fluorescently labeled nucleotides that were hybridized with the array after *in situ* synthesis of DNA oligos. The oligomers have a length of 65 mers.

Figure 35 is a photograph of a magnified portin of a top view of a microarray having a combination reaction layer, wherein the combination comprises sucrose and fructose. The lighter spots are fluorescence of fluorescently labeled nucleotides that were hybridized with the array after *in situ* synthesis of DNA oligos. The oligomers have a length of 70 mers.

Detailed Description of the Invention

For the most part, nomenclature for chemical groups as used herein follows the recommendations of "The International Union for Pure and Applied Chemistry", Principles of Chemical Nomenclature: a Guide to IUPAC Recommendations, Leigh, G.J.; Favre, H.A. and Metanomski, W.V., Blackwell Science, 1998, the disclosure of which is incorporated by reference herein. Formation of substituted structures is limited by atom valence requirements.

"Oligomer" means a molecule of intermediate relative molecular mass, the structure of which essentially comprises a small plurality of units derived, actually or conceptually, from molecules of lower relative molecular mass. A molecule is

regarded as having an intermediate relative molecular mass if it has properties which do vary significantly with the removal of one or a few of the units. If a part or the whole of the molecule has an intermediate relative molecular mass and essentially comprises a small plurality of units derived, actually or conceptually, from molecules of lower relative molecular mass, it may be described as oligomeric, or by oligomer used adjectivally. Oligomers are typically comprised of a monomer.

The term “co-oligomer” means an oligomer derived from more than one species of monomer. The term oligomer includes co-oligomers. As examples of oligomers, a single stranded DNA molecule consisting of deoxyadenylate (A), deoxyguanylate (G), deoxycytidylate (C), and deoxythymidylate (T) units in the following sequence, AGCTGCTATA is a co-oligomer, and a single stranded DNA molecule consisting of 10-T units is an oligomer; however, both are referred to as oligomers.

The term “monomer” means a molecule that can undergo polymerization thereby contributing constitutional units to the essential structure of a macromolecule such as an oligomer, co-oligomer, polymer, or co-polymer. Examples of monomers include A, C, G, T, adenylate, guanylate, cytidylate, uridylate, amino acids, vinyl chloride, and other vinyls.

The term “polymer” means a substance composed of macromolecules, which is a molecule of high relative molecular mass, the structure of which essentially comprises the multiple repetition of units derived, actually or conceptually, from molecules of low relative molecular mass. In many cases, especially for synthetic polymers, a molecule can be regarded as having a high relative molecular mass if the addition or removal of one or a few of the units has a negligible effect on the molecular properties. This statement fails in the case of certain macromolecules for which the properties may be critically dependent on fine details of the molecular structure. If a part or the whole of the molecule has a high relative molecular mass and essentially comprises the multiple repetition of units derived, actually or conceptually, from molecules of low relative molecular mass, it may be described as either macromolecular or polymeric, or by polymer used adjectivally.

The term “copolymer” means a polymer derived from more than one species of monomer. Copolymers that are obtained by copolymerization of two monomer species are sometimes termed bipolymers, those obtained from three monomers

terpolymers, those obtained from four monomers quaterpolymers, etc. The term polymer includes co-polymers.

The term "polyethylene glycol" (PEG) means an organic chemical having a chain consisting of the common repeating ethylene glycol unit $[--CH_2--CH_2--O--]_n$. PEG's are typically long chain organic polymers that are flexible, hydrophilic, enzymatically stable, and biologically inert, but they do not have an ionic charge in water. In general, PEG can be divided into two categories. First, there is polymeric PEG having a molecular weight ranging from 1000 to greater than 20,000. Second, there are PEG-like chains having a molecular weight that is less than 1000. Polymeric PEG has been used in bioconjugates, and numerous reviews have described the attachment of this linker moiety to various molecules. PEG has been used as a linker, where the short PEG-like linkers can be classified into two types, the homo-$[X--(CH_2--CH_2--O)_n]--X$ and heterobifunctional $[X--(CH_2--CH_2--O)_n]--Y$ spacers.

The term "PEG derivative" means an ethylene glycol derivative having the common repeating unit of PEG. Examples of PEG derivatives include, but are not limited to, diethylene glycol (DEG), tetraethylene glycol (TEG), polyethylene glycol having primary amino groups, di(ethylene glycol) mono allyl ether, di(ethylene glycol) mono tosylate, tri(ethylene glycol) mono allyl ether, tri(ethylene glycol) mono tosylate, tri(ethylene glycol) mono benzyl ether, tri(ethylene glycol) mono trityl ether, tri(ethylene glycol) mono chloro mono methyl ether, tri(ethylene glycol) mono tosyl mono allyl ether, tri(ethylene glycol) mono allyl mono methyl ether, tetra(ethlyne glycol) mono allyl ether, tetra(ethylene glycol) mono methyl ether, tetra(ethylene glycol) mono tosyl mono allyl ether, tetra(ethylene glycol) mono tosylate, tetra(ethylene glycol) mono benzyl ether, tetra(ethylene glycol) mono trityl ether, tetra(ethylene glycol) mono 1-hexenyl ether, tetra(ethylene glycol) mnon 1-heptenyl ether, tetra(ethylene glycol) mono 1-octenyl ether, tetra(ethylene glycol) mono 1-decenyl ether, tetra(ethylene glycol) mono 1-undecenyl ether, penta(ethylene glycol) mono methyl ether, penta(ethylene glycol) mono allyl mono methyl ether, penta(ethylene glycol) mono tosyl mono methyl ether, penta(ethylene glycol) mono tosyl mono allyl ether, hexa(ethylene glycol) mono allyl ether, hexa(ethylene glycol) mono methyl ether, hexa(ethylene glycol) mono benzyl ether, hexa(ethylene glycol) mono trityl ether, hexa(ethylene glycol) mono 1-hexenyl ether, hexa(ethylene glycol)

mono 1-heptenyl ether, hexa(ethylene glycol) mono 1-octenyl ether, hexa(ethylene glycol) mono 1-decenyl ether, hexa(ethylene glycol) mono 1-undecenyl ether, hexa(ethylene glycol) mono 4-benzophenonyl mono 1-undecenyl ether, hepta(ethylene glycol) mono allyl ether, hepta(ethylene glycol) mono methyl ether, hepta(ethylene glycol) mono tosyl mono methyl ether, hepta(ethylene glycol) monoallyl mono methyl ether, octa(ethylene glycol) mono allyl ether, octa(ethylene glycol) mono tosylate, octa(ethylene glycol) mono tosyl mono allyl ether, undeca(ethylene glycol) mono methyl ether, undeca(ethylene glycol) mono allyl mono methyl ether, undeca(ethylene glycol) mono tosyl mono methyl ether, undeca(ethylene glycol) mono allyl ether, octadeca(ethylene glycol) mono allyl ether, octa(ethylene glycol), deca(ethylene glycol), dodeca(ethylene glycol), tetradeca(ethylene glycol), hexadeca(ethylene glycol), octadeca(ethylene glycol), benzophenone-4-hexa(ethylene glycol) allyl ether, benzophenone-4-hexa(ethylene glycol) hexenyl ether, benzophenone-4-hexa(ethylene glycol) octenyl ether, benzophenone-4-hexa(ethylene glycol) decenyl ether, benzophenone-4-hexa(ethylene glycol) undecenyl ether, 4-flourobenzophenone-4`-hexa(ethylene glycol) allyl ether, 4-flourobenzophenone-4`-hexa(ethylene glycol) undecenyl ether, 4-hydroxybenzophenone-4`-hexa(ethylene glycol) allyl ether, 4-hydroxybenzophenone-4`-hexa(ethylene glycol) undecenyl ether, 4-hydroxybenzophenone-4`-tetra(ethylene glycol) allyl ether, 4-hydroxybenzophenone-4`-tetra(ethylene glycol) undecenyl ether, 4-morpholinobenzophenone-4`-hexa(ethylene glycol) allyl ether, 4-morpholinobenzophenone-4`-hexa(ethylene glycol) undecenyl ether, 4-morpholinobenzophenone-4`-tetra(ethylene glycol) allyl ether , and 4-morpholinobenzophenone-4`-tetra(ethylene glycol) undecenyl ether.

The term “polyethylene glycol having primary amino groups” refers to polyethylene glycol having substituted primary amino groups in place of the hydroxyl groups. Substitution can be up to 98% in commercial products ranging in molecular weight from 5,000 to 20,000 Da.

The term “alkyl” means a straight or branched chain alkyl group containing up to approximately 20 but preferably up to 8 carbon atoms. Examples of alkyl groups include but are not limited to the following: methyl, ethyl, n-propyl, isopropyl, n-butyl, isobutyl, *sec*-butyl, *tert*-butyl, n-pentyl, isopentyl, neopentyl, *tert*-

pentyl, isohexyl, n-hexyl, n-heptyl, and n-octyl. A substituted alkyl has one or more hydrogen atoms substituted by other groups or a carbon replaced by a divalent, trivalent, or tetravalent group or atom. Although alkyls by definition have a single radical, as used herein, alkyl includes groups that have more than one radical to meet valence requirements for substitution.

The term "alkenyl" means a straight or branched chain alkyl group having at least one carbon-carbon double bond, and containing up to approximately 20 but preferably up to 8 carbon atoms. Examples of alkenyl groups include, but are not limited to, vinyl, 1-propenyl, 2-butenyl, 1,3-butadienyl, 2-pentenyl, 2,4-hexadienyl, 4-(ethyl)-1,3-hexadienyl, and 2-(methyl)-3-(propyl)-1,3-butadienyl. A substituted alkenyl has one or more hydrogen atoms substituted by other groups or a carbon replaced by a divalent, trivalent, or tetravalent group or atom. Although alkenyls by definition have a single radical, as used herein, alkenyl includes groups that have more than one radical to meet valence requirements for substitution.

The term "alkynyl" means a straight or branched chain alkyl group having a single radical, having at least one carbon-carbon triple bond, and containing up to approximately 20 but preferably up to 8 carbon atoms. Examples of alkynyl groups include, but are not limited to, the ethynyl, 1-propynyl, 2-propynyl, 1-butynyl, 2-butynyl, 3-butynyl, 4-pentynyl, 5-hexynyl, 6-heptynyl, 7-octynyl, 1-methyl-2-butynyl, 2-methyl-3-pentynyl, 4-ethyl-2-pentynyl, and 5,5-methyl-1,3-hexynyl. A substituted alkynyl has one or more hydrogen atoms substituted by other groups or a carbon replaced by a divalent, trivalent, or tetravalent group or atom. Although alkynyls by definition have a single radical, as used herein, alkynyl includes groups that have more than one radical to meet valence requirements for substitution.

The term "cycloalkyl" means an alkyl group forming at least one ring, wherein the ring has approximately 3 to 14 carbon atoms. Examples of cycloalkyl groups include but are not limited to the following: cyclopropyl, cyclobutyl, cyclopentyl, and cyclohexyl. A substituted cycloalkyl has one or more hydrogen atoms substituted by other groups or a carbon replaced by a divalent, trivalent, or tetravalent group or atom. Although cycloalkyls by definition have a single radical, as used herein, cycloalkyl includes groups that have more than one radical to meet valence requirements for substitution.

The term “cycloalkenyl” means an alkenyl group forming at least one ring and having at least one carbon-carbon double bond within the ring, wherein the ring has approximately 3 to 14 carbon atoms. Examples of cycloalkenyl groups include, but are not limited to, cyclopropenyl, cyclobutenyl, cyclopentenyl, 1,3-cyclopentadienyl, and cyclohexenyl. A substituted cycloalkenyl has one or more hydrogens substituted by other groups or a carbon replaced by a divalent, trivalent, or tetravalent group or atom. Although cycloalkenyls by definition have a single radical, as used herein, cycloalkenyl includes groups that have more than one radical to meet valence requirements for substitution.

The term “cycloalkynyl” means an alkynyl group forming at least one ring and having at least one carbon-carbon triple bond, wherein the ring contains up to approximately 14 carbon atoms. A group forming a ring having at least one triple bond and having at least one double bond is a cycloalkynyl group. An example of a cycloalkynyl group includes, but is not limited to, cyclooctyne. A substituted cycloalkynyl has one or more hydrogen atoms substituted by other groups. Although cycloalkynyls by definition have a single radical, as used herein, cycloalkynyl includes groups that have more than one radical to meet valence requirements for substitution.

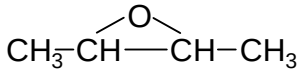
The term “aryl” means an aromatic carbon ring group having a single radical and having approximately 4 to 20 carbon atoms. Examples of aryl groups include, but are not limited to, phenyl, naphthyl, and anthryl. A substituted aryl has one or more hydrogen atoms substituted by other groups. Although aryls by definition have a single radical, as used herein, aryl includes groups that have more than one radical to meet valence requirements for substitution. An aryl group can be a part of a fused ring structure such as N-hydroxysuccinimide bonded to phenyl (benzene) to form N-hydroxyphthalimide.

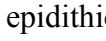
The term “hetero” when used in the context of chemical groups, or “heteroatom” means an atom other than carbon or hydrogen. Preferred examples of heteroatoms include oxygen, nitrogen, phosphorous, sulfur, boron, silicon, and selenium.

The term “heterocyclic ring” means a ring structure having at least one ring moiety having at least one heteroatom forming a part of the ring, wherein the heterocyclic ring has approximately 4 to 20 atoms connected to form the ring

structure. An example of a heterocyclic ring having 6 atoms is pyridine with a single hereroatom. Additional examples of heterocyclic ring structures having a single radical include, but are not limited to, acridine, carbazole, chromene, imidazole, furan, indole, quinoline, and phosphinoline. Examples of heterocyclic ring structures include, but are not limited to, aziridine, 1,3-dithiolane, 1,3-diazetidine, and 1,4,2-oxazaphospholidine. Examples of heterocyclic ring structures having a single radical include, but are not limited to, fused aromatic and non-aromatic structures: 2*H*-furo[3,2-*b*]pyran, 5H-pyrido[2,3-*d*]-*o*-oxazine, 1*H*-pyrazolo[4,3-*d*]oxazole, 4*H*-imidazo[4,5-*d*]thiazole, selenazolo[5,4-*f*]benzothiazole, and cyclopenta[*b*]pyran. Heterocyclic rings can have one or more radicals to meet valence requirements for substitution.

The term "polycyclic" or "polycyclic group" means a carbon ring structure having more than one ring, wherein the polycyclic group has approximately 4 to 20 carbons forming the ring structure and has a single radical. Examples of polycyclic groups include, but are not limited to, bicyclo[1.1.0]butane, bicyclo[5.2.0]nonane, and tricycle[5.3.1.1]dodecane. Polycyclic groups can have one or more radicals to meet valence requirements for substitution.

The term "halo" or "halogen" means fluorine, chlorine, bromine, or iodine. The term "heteroatom group" means one heteroatom or more than one heteroatoms bound together and having two free valences for forming a covalent bridge between two atoms. For example, the oxy radical, –O– can form a bridge between two methyls to form CH_3–O–CH_3 (dimethyl ether) or can form a bridge between two carbons to form an epoxy such as cis or trans 2,3-epoxybutane, . As used herein and in contrast to the normal usage, the term heteroatom group will be used to mean the replacement of groups in an alkyl, alkenyl, alkynyl, cycloalkyl, cycloalkenyl, and cycloalkynyl and not the formation of cyclic bridges, such as an epoxy, unless the term cyclic bridge is used with the term heteroatom group to denote the normal usage.

Examples of heteroatom groups, using the nomenclature for hetero bridges (such as an epoxy bridge), include but are not limited to the following: azimino (), azo (), biimino (), epidioxy (), epidithio (), epithio (), epithioximino (), epoxy (), epoxyimino (), epoxynitrilo (), epoxythio (),

epoxythioxy (), furano (), imino (), and nitrilo (). Examples of heteroatom groups using the nomenclature for forming acyclic bridges include but are not limited to the following: epoxy (), epithio (), episeleno (), epidioxy (), epidithio (), lambda^4-sulfano (), epoxythio (), epoxythioxy (), epoxyimino (), epimino (), diazano (), diazeno (), triaz[1]eno (), phosphano (), stannano (), epoxymethano (), epoxyethano (), epoxyprop[1]eno ().

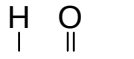
The term “bridge” means a connection between one part of a ring structure to another part of the ring structure by a hydrocarbon bridge. Examples of bridges include but are not limited to the following: methano, ethano, etheno, propano, butano, 2-buteno, and benzeno.

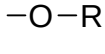
The term “hetero bridge” means a connection between one part of a ring structure to another part of the ring structure by one or more heteroatom groups, or a ring formed by a heterobridge connecting one part of a linear structure to another part of the linear structure, thus forming a ring.

The term “oxy” means the divalent radical –O–.

The term “oxo” means the divalent radical =O.

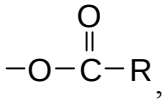
The term “carbonyl” means the group , wherein the carbon has two radicals for bonding.

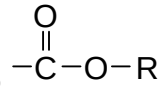
The term “amide” or “acylamino” means the group , wherein the nitrogen has one single radical for bonding and R is hydrogen or an unsubstituted or substituted alkyl, alkenyl, alkynyl, cycloalkyl, cycloalkenyl, cycloalkynyl, aryl, heterocyclic ring, or polycyclic group.

The term “alkoxy” means the group , wherein the oxygen has a single radical and R is hydrogen or an unsubstituted or substituted alkyl, alkenyl, alkynyl, cycloalkyl, cycloalkenyl, cycloalkynyl, aryl, heterocyclic ring, or polycyclic group. Examples of alkoxy groups where the R is an alkyl include but are not limited to the following: methoxy, ethoxy, propoxy, butoxy, pentoxy, hexoxy, heptoxy, octoxy, 1,1-dimethylethoxy, 1,1-dimethylpropoxy, 1,1-dimethylbutoxy, 1,1-

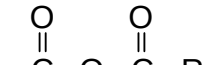
dimethylpentoxy, 1-ethyl-1-methylbutoxy, 2,2-dimethylpropoxy, 2,2-dimethylbutoxy, 1-methyl-1-ethylpropoxy, 1,1-diethylpropoxy, 1,1,2-trimethylpropoxy, 1,1,2-trimethylbutoxy, 1,1,2,2-tetramethylpropoxy. Examples of alkoxy groups where the R is an alkenyl group include but are not limited to the following: ethenyloxy, 1-propenyloxy, 2-propenyloxy, 1-butenyloxy, 2-butenyloxy, 3-butenyloxy, 1-methyl-prop-2-enyloxy, 1,1-dimethyl-prop-2-enyloxy, 1,1,2-trimethyl-prop-2-enyloxy, and 1,1-dimethyl-but-2-enyloxy, 2-ethyl-1,3-dimethyl-but-1-enyloxy. Examples of alkyloxy groups where the R is an alkynyl include but are not limited to the following: ethynyloxy, 1-propynyloxy, 2-propynyloxy, 1-butynyloxy, 2-butynyloxy, 3-butynyloxy, 1-methyl-prop-2-ynyloxy, 1,1-dimethyl-prop-2-ynyloxy, and 1,1-dimethyl-but-2-ynyloxy, 3-ethyl-3-methyl-but-1-ynyloxy. Examples of alkoxy groups where the R is an aryl group include but are not limited to the following: phenoxy, 2-naphthyloxy, and 1-anthyloxy.

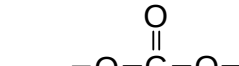
The term “acyl” means the group , wherein the carbon has a single radical and R is hydrogen or an unsubstituted or substituted alkyl, alkenyl, alkynyl, cycloalkyl, cycloalkenyl, cycloalkynyl, aryl, heterocyclic ring, or polycyclic group. Examples of acyl groups include but are not limited to the following: acetyl, propionyl, butyryl, isobutyryl, valeryl, isovaleryl, acryloyl, propioloyl, mathacryloyl, crotonoyl, isocrotonoyl, benzoyl, and naphthoyl.

The term “acyloxy” means the group , wherein the oxygen has a single radical and R is hydrogen or an unsubstituted or substituted alkyl, alkenyl, alkynyl, cycloalkyl, cycloalkenyl, cycloalkynyl, aryl, heterocyclic ring, or polycyclic group. Examples of acyloxy groups include but are not limited to the following: acetoxy, ethylcarbonyloxy, 2-propenylcarbonyloxy, pentylcarbonyloxy, 1-hexynylcarbonyloxy, benzoyloxy, cyclohexylcarbonyloxy, 2-naphthoyloxy, 3-cyclodecenylcarbonyloxy.

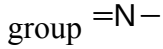
The term “oxycarbonyl” means the group , wherein the carbon has a single radical and R is hydrogen or an unsubstituted or substituted alkyl, alkenyl, alkynyl, cycloalkyl, cycloalkenyl, cycloalkynyl, aryl, heterocyclic ring, or polycyclic group. Examples of oxycarbonyl groups include but are not limited to the

following: methoxycarbonyl, ethoxycarbonyl, isopropyloxycarbonyl, phenoxycarbonyl, and cyclohexyloxycarbonyl.

The term “acyloxycarbonyl” means the group , wherein the carbon has a single radical and R is hydrogen or an unsubstituted or substituted alkyl, alkenyl, alkynyl, cycloalkyl, cycloalkenyl, cycloalkynyl, aryl, heterocyclic ring, or polycyclic group.

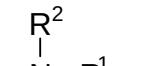
The term “alkoxycarbonyloxy” means the group , wherein the oxygen has a single radical and R is hydrogen or an unsubstituted or substituted alkyl, alkenyl, alkynyl, cycloalkyl, cycloalkenyl, cycloalkynyl, aryl, heterocyclic ring, or polycyclic group.

The term “carboxy” means the group –C(O)OH, wherein the carbon has a single radical.

The term “imino” or “nitrene” means the group , wherein the nitrogen has two radicals and R is hydrogen or an unsubstituted or substituted alkyl, alkenyl, alkynyl, cycloalkyl, cycloalkenyl, cycloalkynyl, aryl, heterocyclic ring, or polycyclic group.

The term “amino” means the group —NH2, where the nitrogen has a single radical.

The term “secondary amino” means the group —NH—R, wherein the nitrogen has a single radical and R is hydrogen or an unsubstituted or substituted alkyl, alkenyl, alkynyl, cycloalkyl, cycloalkenyl, cycloalkynyl, aryl, heterocyclic ring, or polycyclic group.

The term “tertiary amino” means the group , wherein the nitrogen has a single radical and R_1 and R_2 are independently selected from the group consisting of unsubstituted and substituted alkyl, alkenyl, alkynyl, cycloalkyl, cycloalkenyl, cycloalkynyl, aryl, heterocyclic ring, and polycyclic group.

The term “hydrazi” means the group –NH–NH–, wherein the nitrogens have single radicals bound to the same atom. The term “hydrazo” means the group –NH–NH–, wherein the nitrogens have single radicals bound to the different atoms.

The term “hydrazino” means the group NH_2–NH–, wherein the nitrogen has a single radical.

The term “hydrazono” means the group NH_2–N=, wherein the nitrogen has two radicals.

The term “hydroxyimino” means the group HO–N=, wherein the nitrogen has two radicals.

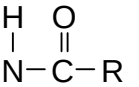
The term “alkoxyimino” means the group R–O–N=, wherein the nitrogen has two radicals and R is an unsubstituted or substituted alkyl, alkenyl, alkynyl, cycloalkyl, cycloalkenyl, cycloalkynyl, aryl, heterocyclic ring, or polycyclic group.

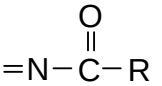
The term “azido” means the group N_3–, wherein the nitrogen has one radical.

The term “azoxy” means the group –N(O)=N–, wherein the nitrogens have one radical.

The term “alkazoxy” means the group R–N(O)=N–, wherein the nitrogen has one radical and R is hydrogen or an unsubstituted or substituted alkyl, alkenyl, alkynyl, cycloalkyl, cycloalkenyl, cycloalkynyl, aryl, heterocyclic ring, or polycyclic group. Azoxybenzene is an example compound.

The term “cyano” means the group –CN. The term “isocyano” means the group –NC. The term “cyanato” means the group –OCN. The term “isocyanato” means the group –NCO. The term “fulminato” means the group –ONC. The term “thiocyanato” means the group –SCN. The term “isothiocyanato” means the group –NCS. The term “selenocyanato” means the group –SeCN. The term “isoselenocyanato” means the group –NCSe.

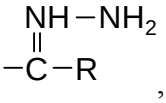
The term “carboxyamido” or “acylamino” means the group , wherein the nitrogen has a single radical and R is hydrogen or an unsubstituted or substituted alkyl, alkenyl, alkynyl, cycloalkyl, cycloalkenyl, cycloalkynyl, aryl, heterocyclic ring, or polycyclic group.

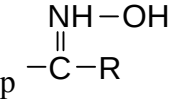
The term “acylimino” means the group , wherein the nitrogen has two radicals and R is hydrogen or an unsubstituted or substituted alkyl, alkenyl, alkynyl, cycloalkyl, cycloalkenyl, cycloalkynyl, aryl, heterocyclic ring, or polycyclic group.

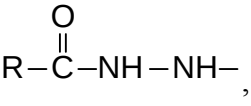
The term “nitroso” means the group O=N–, wherein the nitrogen has a single radical.

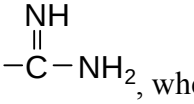
The term “aminooxy” means the group –O-NH_2, wherein the oxygen has a single radical.

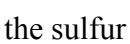
The term “carxoimidioy” means the group , wherein the carbon has a single radical and R is hydrogen or an unsubstituted or substituted alkyl, alkenyl, alkynyl, cycloalkyl, cycloalkenyl, cycloalkynyl, aryl, heterocyclic ring, or polycyclic group.

The term “hydrazonoyl” means the group , wherein the carbon has a single radical and R is hydrogen or an unsubstituted or substituted alkyl, alkenyl, alkynyl, cycloalkyl, cycloalkenyl, cycloalkynyl, aryl, heterocyclic ring, or polycyclic group.

The term “hydroximoyl” or “oxime” means the group , wherein the carbon has a single radical and R is hydrogen or an unsubstituted or substituted alkyl, alkenyl, alkynyl, cycloalkyl, cycloalkenyl, cycloalkynyl, aryl, heterocyclic ring, or polycyclic group.

The term “hydrazino” means the group , wherein the nitrogen has a single radical and R is hydrogen or an unsubstituted or substituted alkyl, alkenyl, alkynyl, cycloalkyl, cycloalkenyl, cycloalkynyl, aryl, heterocyclic ring, or polycyclic group.

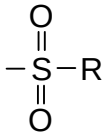
The term “amidino” means the group , wherein the carbon has a single radical.

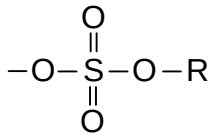
The term “sulfide” means the group , wherein the sulfur has a single radical and R is hydrogen or an unsubstituted or substituted alkyl, alkenyl, alkynyl, cycloalkyl, cycloalkenyl, cycloalkynyl, aryl, heterocyclic ring, or polycyclic group.

The term “thiol” means the group –S–, wherein the sulfur has two radicals. Hydrothiol means –SH.

The term “thioacyl” means the group –C(S)–R, wherein the carbon has a single radical and R is hydrogen or an unsubstituted or substituted alkyl, alkenyl, alkynyl, cycloalkyl, cycloalkenyl, cycloalkynyl, aryl, heterocyclic ring, or polycyclic group.

The term “sulfoxide” means the group , wherein the sulfur has a single radical and R is hydrogen or an unsubstituted or substituted alkyl, alkenyl, alkynyl, cycloalkyl, cycloalkenyl, cycloalkynyl, aryl, heterocyclic ring, or polycyclic group. The term “thiosulfoxide” means the substitution of sulfur for oxygen in sulfoxide; the term includes substitution for an oxygen-bound between the sulfur and the R group when the first carbon of the R group has been substituted by an oxy group and when the sulfoxide is bound to a sulfur atom on another group.

The term “sulfone” means the group , wherein the sulfur has a single radical and R is hydrogen or an unsubstituted or substituted alkyl, alkenyl, alkynyl, cycloalkyl, cycloalkenyl, cycloalkynyl, aryl, heterocyclic ring, or polycyclic group. The term “thiosulfone” means substitution of sulfur for oxygen in one or two locations in sulfone; the term includes substitution for an oxyen bound between the sulfur and the R group when the first carbon of the R group has been substituted by an oxy group and when the sulfone is bound to a sulfur atom on another group.

The term “sulfate” means the group , wherein the oxygen has a single radical and R is hydrogen or an unsubstituted or substituted alkyl, alkenyl, alkynyl, cycloalkyl, cycloalkenyl, cycloalkynyl, aryl, heterocyclic ring, or polycyclic group. The term “thiosulfate” means substitution of sulfur for oxygen in one, two, three, or four locations in sulfate.

The term “phosphoric acid ester” means the group $R^1R^2PO_4$–, wherein the oxygen has a single radical and R^1 is selected from the group consisting of hydrogen and unsubstituted and substituted alkyl, alkenyl, alkynyl, cycloalkyl, cycloalkenyl, cycloalkynyl, aryl, heterocyclic ring, and polycyclic group, and R^2 is selected from

the group consisting of unsubstituted and substituted alkyl, alkenyl, alkynyl, cycloalkyl, cycloalkenyl, cycloalkynyl, aryl, heterocyclic ring, and polycyclic group.

The term "substituted" or "substitution," in the context of chemical species, means independently selected from the group consisting of (1) the replacement of a hydrogen on at least one carbon by a monovalent radical, (2) the replacement of two hydrogens on at least one carbon by a divalent radical, (3) the replacement of three hydrogens on at least one terminal carbon (methyl group) by a trivalent radical, (4) the replacement of at least one carbon and the associated hydrogens (*e.g.*, methylene group) by a divalent, trivalent, or tetravalent radical, and (5) combinations thereof. Meeting valence requirements restricts substitution. Substitution occurs on alkyl, alkenyl, alkynyl, cycloalkyl, cycloalkenyl, cycloalkynyl, aryl, heterocyclic ring, and polycyclic groups, providing substituted alkyl, substituted alkenyl, substituted alkynyl, substituted cycloalkyl, substituted cycloalkenyl, substituted cycloalkynyl, substituted aryl group, substituted heterocyclic ring, and substituted polycyclic groups.

The groups that are substituted on an alkyl, alkenyl, alkynyl, cycloalkyl, cycloalkenyl, cycloalkynyl, aryl, heterocyclic ring, and polycyclic groups are independently selected from the group consisting of alkyl, alkenyl, alkynyl, cycloalkyl, cycloalkenyl, cycloalkynyl, aryl, heterocyclic ring, polycyclic group, halo, heteroatom group, oxy, oxo, carbonyl, amide, alkoxy, acyl, acyloxy, oxycarbonyl, acyloxycarbonyl, alkoxycarbonyloxy, carboxy, imino, amino, secondary amino, tertiary amino, hydrazi, hydrazino, hydrazono, hydroxyimino, azido, azoxy, alkazoxy, cyano, isocyano, cyanato, isocyanato, thiocyanato, fulminato, isothiocyanato, isoselenocyanato, selenocyanato, carboxyamido, acylimino, nitroso, aminooxy, carboximidoyl, hydrazonoyl, oxime, acylhydrazino, amidino, sulfide, thiol, sulfoxide, thiosulfoxide, sulfone, thiosulfone, sulfate, thiosulfate, hydroxyl, formyl, hydroxyperoxy, hydroperoxy, peroxy acid, carbamoyl, trimethyl silyl, nitrilo, nitro, aci-nitro, nitroso, semicarbazono, oxamoyl, pentazolyl, seleno, thiooxi, sulfamoyl, sulfenamoyl, sulfeno, sulfinamoyl, sulfino, sulfinyl, sulfo, sulfoamino, sulfonato, sulfonyl, sulfonyldioxy, hydrothiol, tetrazolyl, thiocarbamoyl, thiocarbazono, thiocarbodiazono, thiocarbonohydrazido, thiocarbonyl, thiocarboxy, thiocyanato, thioformyl, thioacyl, thiosemicarbazido, thiosulfino, thiosulfo, thioureido, thioxo, triazano, triazeno, triazinyl, trithio, trithiosulfo, sulfinimidic acid,

sulfonimidic acid, sulfinohydrazonic acid, sulfonohydrazonic acid, sulfinohydroximic acid, sulfonohydroximic acid, and phosphoric acid ester, and combinations thereof.

As an example of a substitution, replacement of one hydrogen or ethane by a hydroxyl provides ethanol, and replacement of two hydogens by an oxo on the middle carbon of propane provides acetone (dimethyl ketone.) As a further example, replacement the middle carbon (the methenyl group) of propane by the oxy radical (–O–) provides dimethyl ether (CH_3–O–CH_3.) As a futher example, replacement of one hydrogen on a benzene by a phenyl group provides biphenyl.

As provided above, heteroatom groups can be substituted inside an alkyl, alkenyl, or alkylnyl group for a methylene group (:CH_2) thus forming a linear or branched substituted structure rather than a ring or can be substituted for a methylene inside of a cycloalkyl, cycloalkenyl, or cycloalkynyl ring thus forming a heterocyclic ring. As a further example, nitrilo (—N—) can be substituted on benzene for one of the carbons and associated hydrogen to provide pyridine, or and oxy radical can be substituted to provide pyran.

The term "unsubstituted" means that no hydrogen or carbon has been replaced on an alkyl, alkenyl, alkynyl, cycloalkyl, cycloalkenyl, cycloalkynyl, or aryl group.

The term "linker" means a molecule having one end attached or capable of attaching to a solid surface and the other end having a reactive group that is attached or capable of attaching to a chemical species of interest such as a small molecule, an oligomer, or a polymer. A linker may already be bound to a solid surface and/or may already have a chemical species of interest bound to its reactive group. A linker may have a protective group attached to its reactive group, where the protective group is chemically or electrochemically removable. A linker may comprise more than one molecule, where the molecules are covalently joined *in situ* to form the linker having the desired reactive group projecting away from a solid surface.

The term "spacer" means a molecule having one end attached or capable of attaching to the reactive group of a linker and the other end having a reactive group that is attached or capable of attaching to a chemical species of interest such as a small molecule, an oligomer, or a polymer. A spacer may already be bound to a linker and/or may already have a chemical species of interest bound to its reactive

group. A spacer may have a protective group attached to its reactive group, where the protective group is chemically or electrochemically removable. A spacer may be formed *in situ* on a linker. A spacer may be formed and then attached to a linker already attached to a solid surface. A spacer may be externally synthesized on a chemical species of interest followed by attachment to a linker already attached to a solid surface. A chemical species of interest may be attached to a spacer that is attached to a linker, where the entire structure is then attached to a solid surface at a reactive sight on the solid surface. The purpose of a spacer is to extend the distance between a molecule of interest and a solid surface.

The term "combination linker and spacer" means a linker having both the properties of a linker and a spacer. A combination linker and spacer may be synthesized *in situ* or synthesized externally and attached to a solid surface.

The term "coating" means a thin layer of material that is chemically and/or physically bound to a solid surface. A coating may be attached to a solid surface by mechanical interlocking as well as by van der Waals forces (dispersion forces and dipole forces), electron donor-acceptor interactions, metallic coordination/complexation, covalent bonding, or a combination of the aforementioned. A coating can provide a reactive group for direct attachment of a chemical species of interest, attachment of a linker, or attachment of a combination linker and spacer. A coating can be polymerized and/or cross-linked *in situ*.

The term "reactive" or "reaction" as used in reactive or reaction coating or reactive or reaction layer means that there is a chemical species or bound group within the layer that is capable of forming a covalent bond for attachment of a linker, spacer, or other chemical species to the layer or coating.

The term "porous" as used in porous reactive layer or coating means that there are non-uniformities within the layer or coating to allow molecular species to diffuse into and through the layer or coating.

The term "adsorption" or "adsorbed" means a chemical attachment by van der Waals forces (dispersion forces and dipole forces), electron donor-acceptor interactions, or metallic coordination/complexation, or a combination of the aforementioned forces. After adsorption, a species may covalently bind to a surface, depending on the surface, the species, and the environmental conditions.

The term “microarray” refers to, in general, planer surface having specific spots that are usually arranged in a column and row format, wherein each spot can be used for some type of chemical or biochemical analysis, synthesis, or method. The spots on a microarray are typically smaller than 100 micrometers. The term “electrode microarray” refers to a microarray of electrodes, wherein the electrodes are the specific spots on the microarray.

The term “synthesis quality” refers to, in general, the average degree of similarity between a desired or designed chemical or biochemical species and the species actually synthesized. The term can refer to other issues in a synthesis such as the effect of a layer or coating on the synthesis quality achieved.

The term “solvation” means a chemical process in which solvent molecules and molecules or ions of a solute combine to form a compound, wherein the compound is generally a loosely bound complex held together by van der Waals forces (dispersion forces and dipole forces), acid-base interactions (electron donor acceptor interactions), ionic interaction, or metal complex interactions but not covalent bonds. In water, the pH of the water can affect solvation of dissociable species such as acids and bases. In addition, the concentration of salts as well as the charge on salts can affect solvation.

The term “agarose” means any commercially available agarose. Agarose is a polysaccharide biopolymer and is usually obtained from seaweed. Agarose has a relatively large number of hydroxyl groups, which provide for high water solubility. Agarose is available commercially in a wide ranger of molecular weights and properties.

The term “controlled pore glass” means any commercially available controlled pore glass material suitable for coating purposes. In general, controlled pore glass (CPG) is an inorganic glass material having a high surface area owing to a large amount of void space.

The term “monosaccharide” means one sugar molecule unlinked to any other sugars. Examples of monosaccharides include allose, altrose, arabinose, deoxyribose, erythrose, fructose (D-Levulose), galactose, glucose, gulose, idose, lyxose, mannose, psicose, ribose, ribulose, sedoheptulose, D-sorbitol, sorbose, sylulose, L-rhamnose (6-Deoxy-L-mannose), tagatose, talose, threose, xylulose, and xylose.

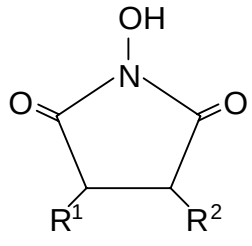
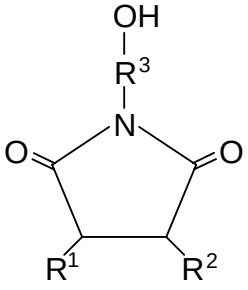
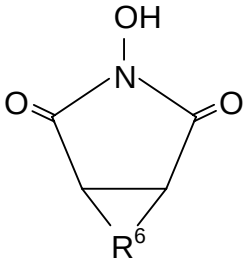
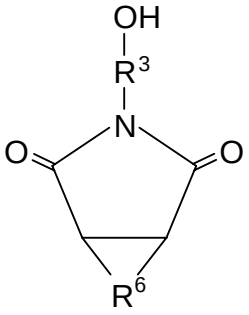
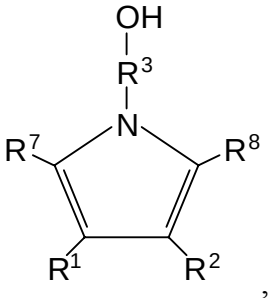
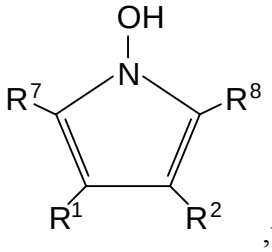
The term “disaccharide” means two sugars linked together to form one molecule. Examples of disaccharides include amylose, cellobiose (4-β-D-glucopyranosyl-D-glucopyranose), lactose, maltose (4-O-α-D-glucopyranosyl-D-glucose), melibiose (6-O-α-D-Galactopyranosyl-D-glucose), palatinose (6-O-α-D-Glucopyranosyl-D-fructose), sucrose, and trehalose (a-D-Glucopyranosyl-α-D-glucopyranoside).

The term “trisaccharide” means three sugars linked together to form one molecule. Examples of a trisaccharides include raffinose (6-O-α-D-Galactopyranosyl-D-glucopyranosyl-β-D-fructofuranoside) and melezitose (O-α-D-glucopyranosyl-(1→3)-β-D-fructofuranosyl-a-D-glucopyranoside).

The term “polysaccharide” means more than three sugars linked together to form one molecule, but more accurately means a sugar-based polymer or oligomer. Examples of polysaccharides include inulin, dextran (polymer composed of glucose subunits), starches, and cellulose.

Specific Embodiments

In an embodiment of the present invention, an electrode microarray having an adsorbed porous reaction layer for improved synthesis quality is provided. The microarray has a plurality of electrodes attached to a substrate, wherein the electrodes are electronically connected to a computer control system that allows selection of any electrode individually or more than one electrode as group of electrodes. Figures 1A and 1B are schematics of a cross section of two electrodes **108**, **110** of such a microarray **106** having a plurality of electrodes. In one embodiment of the present invention, an adsorbed layer **104A** shown in Figure 1A covers the electrodes and the substrate that the electrodes are attached thereto. The adsorbed layer **104A** has hydroxyl reactive groups **102**. The reactive groups **102** can be groups other than hydroxyl including but not limited to amine, carboxylic acid, aldehyde, thiol, alkene, alkyne, nitrile, azido, or phosphorous-based compound. In another embodiment shown in Figure 1B, the adsorbed layer **104B** can be substantially on the electrodes but substantially not on the substrate **106**. In either embodiment, the adsorbed layer can be chemically blocked and selectively electrochemically deblocked to control the locations of chemical reactions to specific electrodes while preventing chemical reactions on non-selected electrodes and on non-electrode areas.

The adsorbed porous reaction layer on the plurality of electrodes comprises a chemical species having at least one hydroxyl group, wherein the chemical species is selected from the group consisting of monosaccharides, disaccharides, trisaccharides, polyethylene glycol, polyethylene glycol derivative, N-hydroxysuccinimide, formula I, formula II, formula III, formula IV, formula V, formula VI, and formula VII, and combinations thereof, wherein formula I is , formula II is , formula III is $HOR^4(OR^5)_mR^7$, formula IV is , formula V is , formula VI is , and formula VII is , wherein m is an integer from 1 to 4.

R^1, R^2, R^7, and R^8 are independently selected from the group consisting of hydrogen, and substituted and unsubstituted alkyl, alkenyl, alkynyl, cycloalkyl,

cycloalkenyl, cycloalkynyl, aryl, heterocyclic ring, and polycyclic group, and halo, amide, alkoxy, acyl, acyloxy, oxycarbonyl, acyloxycarbonyl, alkoxycarbonyloxy, carboxy, amino, secondary amino, tertiary amino, hydrazino, azido, alkazoxy, cyano, isocyano, cyanato, isocyanato, thiocyanato, fulminato, isothiocyanato, isoselenocyanato, selenocyanato, carboxyamido, acylimino, nitroso, aminooxy, carboximidoyl, hydrazonoyl, oxime, acylhydrazino, amidino, sulfide, sulfoxide, thiosulfoxide, sulfone, thiosulfone, sulfate, thiosulfate, hydroxyl, formyl, hydroxyperoxy, hydroperoxy, peroxy acid, carbamoyl, trimethyl silyl, nitro, nitroso, oxamoyl, pentazolyl, sulfamoyl, sulfenamoyl, sulfeno, sulfinamoyl, sulfino, sulfo, sulfoamino, hydrothiol, tetrazolyl, thiocarbamoyl, thiocarbazono, thiocarbodiazono, thiocarbonohydrazido, thiocarboxy, thioformyl, thioacyl, thiocyanato, thiosemicarbazido, thiosulfino, thiosulfo, thioureido, triazano, triazeno, triazinyl, trithiosulfo, sulfinimidic acid, sulfonimidic acid, sulfinohydrazonic acid, sulfonohydrazonic acid, sulfinohydroximic acid, sulfonohydroximic acid, and phosphoric acid ester;

R^3 is preferably selected from the group consisting of heteroatom group, carbonyl, and substituted and unsubstituted alkyl, alkenyl, alkynyl, cycloalkyl, cycloalkenyl, cycloalkynyl, aryl, heterocyclic ring, and polycyclic group

R^4 and R^5 are preferably independently selected from the group consisting of methylene, ethylene, propylene, butylene, pentylene, and hexylene.

R^6 forms a ring structure with two carbons of succinimide and is selected from the group consisting of substituted and unsubstituted alkyl, alkenyl, alkynyl, cycloalkyl, cycloalkenyl, cycloalkynyl, aryl, heterocyclic ring, and polycyclic group. R^7 is selected from the group consisting of amino and hydroxyl.

Preferably, the monosaccharide is selected from the group consisting of allose, altrose, arabinose, deoxyribose, erythrose, fructose (D-Levulose), galactose, glucose, gulose, idose, lyxose, mannose, psicose, L-rhamnose (6-Deoxy-L-mannose), ribose, ribulose, sedoheptulose, D-sorbitol, sorbose, sylulose, tagatose, talose, threose, xylulose, and xylose. Preferably, the disaccharide is selected from the group consisting of amylose, cellobiose (4-β-D-glucopyranosyl-D-glucopyranose), lactose, maltose (4-O-α-D-glucopyranosyl-D-glucose), melibiose (6-O-α-D-Galactopyranosyl-D-glucose), palatinose (6-O-α-D-Glucopyranosyl-D-fructose), sucrose, and trehalose (α-D-Glucopyranosyl-a-D-glucopyranoside). Preferably the

triaccharide is selected from the group consisting of raffinose (6-O-α-D-Galactopyranosyl-D-glucopyranosyl-β-D-fructofuranoside) and melezitose (O-α-D-glucopyranosyl-(1→3)-β-D-fructofuranosyl-α-D-glucopyranoside).

Preferably the polyethylene glycol has a molecular weight between approximately 1,000 and approximately 20,000, more preferably between approximately 5000 and approximately 15,000, and most preferably between approximately 7,000 and approximately 10,000.

Preferably, the polyethylene glycol derivative is selected from the group consisting of diethylene glycol, tetraethylene glycol, polyethylene glycol having primary amino groups, 2-(2-aminoethoxy) ethanol, ethanol amine, di(ethylene glycol) mono allyl ether, di(ethylene glycol) mono tosylate, tri(ethylene glycol) mono allyl ether, tri(ethylene glycol) mono tosylate, tri(ethylene glycol) mono benzyl ether, tri(ethylene glycol) mono trityl ether, tri(ethylene glycol) mono chloro mono methyl ether, tri(ethylene glycol) mono tosyl mono allyl ether, tri(ethylene glycol) mono allyl mono methyl ether, tetra(ethlyne glycol) mono allyl ether, tetra(ethylene glycol) mono methyl ether, tetra(ethylene glycol) mono tosyl mono allyl ether, tetra(ethylene glycol) mono tosylate, tetra(ethylene glycol) mono benzyl ether, tetra(ethylene glycol) mono trityl ether, tetra(ethylene glycol) mono 1-hexenyl ether, tetra(ethylene glycol) mnon 1-heptenyl ether, tetra(ethylene glycol) mono 1-octenyl ether, tetra(ethylene glycol) mono 1-decenyl ether, tetra(ethylene glycol) mono 1-undecenyl ether, penta(ethylene glycol) mono methyl ether, penta(ethylene glycol) mono allyl mono methyl ether, penta(ethylene glycol) mono tosyl mono methyl ether, penta(ethylene glycol) mono tosyl mono allyl ether, hexa(ethylene glycol) mono allyl ether, hexa(ethylene glycol) mono methyl ether, hexa(ethylene glycol) mono benzyl ether, hexa(ethylene glycol) mono trityl ether, hexa(ethylene glycol) mono 1-hexenyl ether, hexa(ethylene glycol) mono 1-heptenyl ether, hexa(ethylene glycol) mono 1-octenyl ether, hexa(ethylene glycol) mono 1-decenyl ether, hexa(ethylene glycol) mono 1-undecenyl ether, hexa(ethylene glycol) mono 4-benzophenonyl mono 1-undecenyl ether, hepta(ethylene glycol) mono allyl ether, hepta(ethylene glycol) mono methyl ether, hepta(ethylene glycol) mono tosyl mono methyl ether, hepta(ethylene glycol) monoallyl mono methyl ether, octa(ethylene glycol) mono allyl ether, octa(ethylene glycol) mono tosylate, octa(ethylene glycol) mono tosyl mono allyl ether, undeca(ethylene glycol) mono methyl ether,

undeca(ethylene glycol) mono allyl mono methyl ether, undeca(ethylene glycol) mono tosyl mono methyl ether, undeca(ethylene glycol) mono allyl ether, octadeca(ethylene glycol) mono allyl ether, octa(ethylene glycol), deca(ethylene glycol), dodeca(ethylene glycol), tetradeca(ethylene glycol), hexadeca(ethylene glycol), octadeca(ethylene glycol), benzophenone-4-hexa(ethylene glycol) allyl ether, benzophenone-4-hexa(ethylene glycol) hexenyl ether, benzophenone-4-hexa(ethylene glycol) octenyl ether, benzophenone-4-hexa(ethylene glycol) decenyl ether, benzophenone-4-hexa(ethylene glycol) undecenyl ether, 4-flourobenzophenone-4`-hexa(ethylene glycol) allyl ether, 4-flourobenzophenone-4`-hexa(ethylene glycol) undecenyl ether, 4-hydroxybenzophenone-4`-hexa(ethylene glycol) allyl ether, 4-hydroxybenzophenone-4`-hexa(ethylene glycol) undecenyl ether, 4-hydroxybenzophenone-4`-tetra(ethylene glycol) allyl ether, 4-hydroxybenzophenone-4`-tetra(ethylene glycol) undecenyl ether, 4-morpholinobenzophenone-4`-hexa(ethylene glycol) allyl ether, 4-morpholinobenzophenone-4`-hexa(ethylene glycol) undecenyl ether, 4-morpholinobenzophenone-4`-tetra(ethylene glycol) allyl ether , and 4-morpholinobenzophenone-4`-tetra(ethylene glycol) undecenyl ether.

More preferably, the adsorbed porous reaction layer chemical species having at least one hydroxyl group is selected from the group consisting of sucrose, palatinose, fructose, glucose, lactose, DEG, TEG, and PEG having a molecular weight of approximately 8,000. Most preferably, the adsorbed porous reaction layer chemical species having at least one hydroxyl group is sucrose.

In an embodiment of the present invention, a method is provided for cleaning the electrode microarray prior to adsorption of the porous reaction layer onto the microarray. In one preferred embodiment for cleaning the microarray, the microarray is cleaned using a plasma cleaning method and then cleaned using an electrochemical cleaning method. In another preferred embodiment for cleaning the microarray, the microarray is cleaned using a plasma cleaning method and then cleaned using a hydrogen peroxide cleaning method.

In one embodiment of the present invention, the plurality of electrodes on the electrode microarray is selected from the group consisting of platinum, gold, semiconductor, indium tin oxide, and carbon, and combinations thereof. Platinum is the preferred embodiment. In one embodiment, the plasma cleaning method

comprises exposing the electrode microarray to an inert gas to physically clean (sputter etch) the surface of the electrode array. The inert gas is preferably Argon, and preferably, the sputter etch process is performed for approximately two to six minutes, wherein the plasma power is 200W, the self bias voltage is 600-650V, the plasma pressure is 8 mTorr, and a 200 mm diameter electrode is used in a parallel plate plasma chamber. In another embodiment, the plasma cleaning method comprises exposing the electrode microarray to a chemically reactive gas to clean the surface of the electrode array through a chemical reactive process. The reactive gas is prefereably oxygen, sulfur hexafluoride, trimfluoromethane, carbon tetrafluoride or other chemically reactive gas species.

In a preferred embodiment the plasma process is performed in an Oxford Instruments Plasmalab 800 Plus RIE system having an electrode diameter of 460mm, wherein the plasma cleaning method comprises a three-step plasma treatment. In step one, the microarray is etched using argon plasma for approximately three minutes using a RF plasma power of approximately 600 watts, a set pressure of approximately eight millitorr and and an Ar gas flow of approximately 30 sccm. In step two, the microarray is etched using oxygen plasma for approximately six minutes using an RF plasma power of approximately 500 watts, a set pressure of approximately 50 millitorr and an oxygen gas flow of approximately 50 sccm. For the final step, the microarray is etched using argon plasma for approximately ten minutes using an RF plasma power of approximately 600 watts, a set pressure of approximately eight millitorr and an Ar gas flow of approximately 30sccm. Without being bound by the degree of etching, the amount of material removed by etching is estimated to be approximately equivalent to between 300 to 400 ångstrom of a plasma enhanced chemical vapor deposited (PECVD) silicon nitride film.

Preferably, the plasma cleaning method comprises exposing the electrode microarray to a sulfur hexafluoride plasma for approximately 30 to 60 minutes, where the plasma power is 300 watts, the plasma pressure is approximately 250 to 350 mTorr, and the gas flow is 124 cubic centimeters per minute in an isoptropic plasma chamber. Preferably, the plasma cleaning method comprises etching the electrode microarray in a commercial Reactive Ion Etch Plasma system (such as Oxford Plasmalab 800Plus RIE system with a 460 mm diameter electrode) using (1) an argon plasma for approximately 2 to 4 minutes and a RF plasma power of

approximately 600 watts, where the pressure is approximately eight millitorr and the Ar gas flow is approximately 30 sccm; (2) an oxygen plasma for approximately 5 to 7 minutes using a power of approximately 500 watts, where the pressure is approximately 50 millitorr and the oxygen gas flow of approximately 50 sccm; or (3) an argon plasma for approximately 8 to12 minutes using a power of approximately 600 watts, where the pressure is approximately eight millitorr and the Ar gas flow is approximately 30 sccm.

In a preferred embodiment, the electrochemical cleaning method comprises placing the electrode microarray into a solution of sulfuric acid and then pulsing columns of electrodes having an alternating pattern of pulsed/active electrodes and ground electrodes. After the first pulse, the active electrodes become the ground electrodes and the ground electrodes become the active electrodes. For each subsequent pulse, the electrode columns alternate between being the active column and being the ground column. The electrode columns alternate between active and ground for the duration of the cleaning time. The concentration of sulfuric acid is between approximately 0.01 and 5 molar, more preferably between approximately 0.1 and 1.5 molar, and most preferably between approximately 0.4 and 0.6 molar. The duration of the cleaning time is between approximately 1 and 60 minutes, more preferably between approximately 5 and 15 minutes, and most preferably between approximately 8 and 12 minutes. The pulse time (active electrode column time) is between approximately 0.01 and 60 seconds, more preferably between approximately 0.05 and 0.5 seconds, and most preferably between approximately 0.08-0.12 seconds. The cleaning is done preferably between approximately 0 °C and 50 °C and most preferably between approximately room temperature and 30 °C. After exposure to the sulfuric acid and electrical pulsing, the microarray is washed using distilled water. In one preferred embodiment, the concentration of sulfuric acid is 0.5 molar, the cleaning time is 10 minutes, the pulse time is 0.1 seconds, and the temperature is room temperature.

In a preferred embodiment, the hydrogen peroxide cleaning method comprises placing the electrode microarray into a solution containing hydrogen peroxide. The concentration of hydrogen peroxide is between approximately 0.5 and 10 percent hydrogen peroxide, more preferably between approximately 1 and 5 percent hydrogen peroxide, and most preferably between approximately 2 and 4

percent hydrogen peroxide. The temperature of the solution is preferably between approximately room temperature and 95 °C, more preferably between approximately 35 °C and 80 °C, and most preferably between approximately 60 °C and 70 °C. The time of treatment is preferably between approximately 1 minute and 24 hours, more preferably between approximately 30 minutes and 12 hours, and most preferably between approximately 45 minutes and 2 hours. In the most preferred embodiment, the concentration of hydrogen peroxide is 3 percent; the treatment time is one hour; and the temperature of the solution is 65 °C. Afterward exposure to the hydrogen peroxide solution, the microarray is rinsed using distilled water.

In one embodiment of the present invention, an adsorption method is provided for the attachment of the adsorbed porous reaction layer chemical species to a clean electrode microarray. The electrode microarray is placed into a solution containing a chemical species that forms the reaction layer. Without being bound by theory, the chemical species has a natural affinity for the clean microarray thus adsorbs onto the surface thereof. The treatment time is between approximately 1 minute and 1 month, more preferably between approximately 30 minutes to 1 week, and most preferably between approximately 1 hour and 24 hours. The solvent used for making the solution is preferably water. Other solvents are suitable, including alcohols, acetonitrile, dimethyl formamide and methylene chloride as well as other common laboratory solvents or the uncommon equivalent of such solvents. Other unusual solvents may be suitable. Any solvent that dissolves the chemical species is suitable. The concentration of the chemical species in solution is between approximately 0.001 and 5 molar, more preferably between approximately 0.1 and 2 molar, and most preferably between approximately 0.2 and 0.5 molar. The temperature of the solution during treatment is preferably between approximately 0 and 90 °C. In one preferred embodiment, the solution is an aqueous solution of 0.25 molar sucrose; the treatment time is one hour; and the temperature is room temperature. In another preferred embodiment, the solution is an aqueous solution of 0.25 molar sucrose; the treatment time is 48 hours; and the temperature is 37 °C. After treatment, the microarray is rinsed using the solvent used for the treatment solution. After rinsing, the microarray is allowed to air dry.

In another embodiment of the present invention, an electrode microarray having an adsorbed porous reaction layer having a combination linker and spacer

(linker/spacer) attached thereto for improved synthesis quality is provided. The microarray has a plurality of electrodes attached to a substrate, wherein the electrodes are electronically connected to a computer control system that allows selection of any electrode individually or more than one electrode as group of electrodes. In one embodiment, the linker/spacer is synthesized *in situ* on the adsorbed porous reaction layer. In a preferred embodiment, the linker/spacer is synthesized *in situ* on an adsorbed porous reaction layer comprising sucrose.

Embodiments of the present invention are provided in Figures 2A and 2B, which are schematics of a cross section of two electrodes **208**, **210** of an electrode microarray **206** having a plurality of electrodes. In one embodiment, shown in Figure 2A, the microarray **206** has an adsorbed porous reaction layer **204A** having reacted hydroxyl groups **202** (shown after reaction as an ether linkage) attached to the entire surface of the microarray **206**. A blocking group (P) **212** is shown attached to the reaction layer **204A** at non-electrode locations. The blocking group **212** prevents synthesis at non-electrode locations. In another embodiment, shown in Figure 2B, the microarray **205** has an adsorbed porous reaction layer **204B** having reacted hydroxyl groups **202**(shown after reaction as an ether linkage)**,** wherein the reaction layer is substantially attached only to electrodes **208**, **210**. In both embodiments, the electrodes **208**, **210** have a linker/spacer **214** attached thereto to the reaction layer **204A**, **204B**. The linker/spacer **214** is attached through an ether linkage **202**. The linker/spacer has a terminal reactive group **216** for *in situ* synthesis.

In one embodiment of the present invention, the linker/spacer is an oligomer synthesized *in situ* and having a substantial charge in aqueous solution. In a preferred embodiment, the linker/spacer is a sequence of DNA synthesized *in situ*. Figure 3 shows a cross section of two electrodes **308**, **310** of an electrode microarray **306** having a plurality of electrodes. An adsorbed porous reaction layer **304** is shown attached to the microarray **306**. Electrode **310** shows a DNA linker/spacer **316** having a negative charge **318** in an aqueous solution **320** having cations, wherein the linker/spacer is attached to an adsorbed porous reaction layer **304** through an ether linkage **302** and has a linked group **312** attached at the end of the linker/spacer **316** protruding into the aqueous solution **320**. In a preferred embodiment, the linker/spacer comprises a 15-unit deoxythymidylate DNA chain synthesized *in situ*.

Electrode **308** shows a non-ionic linker/spacer **314** attached thereto via an ether linkage **302** and having a linked group **312** terminally attached.

Without being bound by theory, the non-ionic linker/spacer **314** likely allows the linked group **312** to approach the microarray **306** because the non-ionic linker/spacer **314** is less well solvated owing to the lack of ionic charge. Without being bound by theory, the charge on the linker/spacer **316** likely improves solvation in aqueous media **320** by preventing the linker/spacer **316** from folding on itself because of charge repulsion. Charge repulsion prevents the linker/spacer **316** from interacting with other adjacent charged linker/spacers on the same electrode. Additionally, solvation structures are likely formed in the aqueous media thus minimizing side chain contact of the charged linker/spacer with the solid surface. Without being bound by theory, a well solvated linker/spacer is expected to allow a subsequent group placed in a solution to have better access to the reactive group on the end of the linker/spacer while at the same time preventing quenching of fluorescence from a fluorescently labeled marker attached to a subsequent group or a chain of subsequent groups.

The following examples are provided merely to explain, illustrate, and clarify the present invention and not to limit the scope or application of the present invention. One of skill in the art would readily recognize similar embodiments and applications of the present invention that fall within the scope of the present invention.

Example 1

This example illustrates microarrays of nucleotides prepared using selected adsorbed porous reaction layers on the different microarrays. Each microarray was cleaned using the plasma cleaning method and the electrochemical cleaning method or using the plasma cleaning method and the hydrogen peroxide cleaning method, each as disclosed herein. After cleaning, each microarray was exposed to a solution containing a chemical for forming an adsorbed porous reaction layer as disclosed herein. The chemicals used for the experiments included agarose, sucrose, diethylene glycol, ethylene glycol, N-hydroxysuccinimide, triethylene glycol, raffinose, melizitose, Splenda®, inulin, polyethylene glycol having a molecular weight of 8000, salicin, ribose, and melibiose.

After each microarray was prepared , after cleaning with a porous reaction layer, different nucleotides of either 15 mer, shown in Figures 11 though 19, 25, and 26, or 35 mer, shown in Figures 5 through 10, were synthesized *in situ* on each microarray using an electrochemical synthesis method. After synthesis, the 35 mer nucleotide microarrays were hybridized to a complex background having a spiked-in control transcript. The complex background sample was prepared from fluorescently labeled placental DNA. The spiked-in control was a labeled phage lambda nucleic acid. Various amounts of spiked-in control transcripts were combined with the complex background. The 15 mer microarrays were hybridized to labeled 15 mer DNA oligonucleotides. The 15 mer oligonucleotides were prepared from phage lambda nucleic acid. After hybridization to the spiked control transcripts in the complex background or the 15mer labeled oligonucleotide, each microarray was imaged to view the amount of fluorescence and the quality of the fluorescence on the microelectrodes of the microarrays. Quality was considered "good" when there was a fluorescent circle on an electrode having a relatively uniform amount of fluorescence and having a sharp loss of fluorescence at the edge of the circle. In addition, another quality parameter was where there was minimal fluorescence at locations other than electrodes.

In Figures 27 through 35, sucrose was blended with other saccharides to form an adsorbed porous reaction layer. The solution having the blend contained 50mM of sucrose, 100mM of fructose, and 100mM of glucose. Oligonucleotides were synthesized with lengths of 35, 40, 45, 50, 55, 60, 65, and 70 mers on different quadrants of the microarray. Figure 27 shows a section of a microarray having each of the different length of DNA mers. Figures 28 through 35 show a larger magnification of each of the quandrants in Figure 27. Synthesis quality was assessed by hybridization of a labeled random 9 mer (sequence: NNN NNN NNN, where N=A, G, C, or T). Without being bound by theory, a blend of monosaccharides and disaccharides used to form the adsorbed porous reaction layer is hypothesized to decrease the amount of DNA that is synthesized at each electrode. Furthermore, without being bound by theory, as the length of the oligo is increased, thus increasing the quantity of DNA made per spot, the DNA may be susceptible to sheer forces and may be coming off the electrode when sucrose is used by itself. Glucose and fructose provided lower density of DNA synthesis at each electrode. Thus,

blending sucrose with glucose and fructose is thought to reduce the amount of DNA per electrode. Using a blend as provided in the present invention, the amount, as well as the spacing, between the DNA synthesized at each electrode is better controlled.

Figures 4 through 19, 25, 26, and 27 are magnified photographs of a top view of a portion of each microarray having a different adsorbed porous reaction layer. In Figure 4, the reaction layer was agarose. Electrode **402** shows non-uniform fluorescence that indicated the synthesis was of low quality. The low quality may have been a result of a separation of the agarose away from the electrode. The synthesis was performed in a checkerboard pattern of on and off electrodes where electrode **404** was an electrode that was off. This result indicated that agarose is not that suitable for use as a reaction layer.

In Figure 5, the reaction layer was sucrose. Electrode **502** shows good uniformity across the electrodes of the fluorescence, which indicated a high quality synthesis and a stable reaction layer. At electrode **504**, there is some amount of spotting; however, on the whole, sucrose worked well as a reaction layer.

Figure 6 shows the results of a sensitivity study on a sucrose reaction layer. Hybridization was done with and without transcript spike. Controls were done to ensure that the microarray was performing the synthesis as designed. Comparing the results of spiked to non-spiked samples, the microarray showed a sensitivity of approximately one picomolar when sucrose is used as the porous reaction layer.

In Figure 7, the reaction layer is diethylene glycol. Electrodes **704**, **706**, **708** show uniformity problems and loss of sharpness at the edge of the electrodes. Moreover, there were considerable random spotting **702**. In Figure 8, the reaction layer is ethylene glycol. Electrodes **802** and **804** showed some indication of synthesis; however, the overall quality was very low owing to the lack of synthesis and considerable amount of random spotting. In Figure 9, the reaction layer is N-hydroxysuccinamide. Electrode **904** showed acceptable uniformity and sharpness at the edge of the electrode. However, electrodes **902** and **906** showed some random spotting. In Figure 10, the reaction layer is triethylene glycol. Electrode **1002** showed good quality. Electrode **1004** showed some spotting. Electrode **1006** showed some halo effect where the middle part of the electrode showed a loss of fluorescence, which may indicate a loss of reaction layer.

In Figure 11, the reaction layer is raffinose. Although synthesis occurred, electrodes **1102**, **1104**, and **1106** showed a fair amount of non-uniformity and random spotting. In Figure 12, the reaction layer is melizitose. There was little, if any, indication of synthesis at electrode **1202**. There was some random spotting. In Figure 13, the reaction layer is Splenda®, a modified sucrose. Uniformity was fairly good as shown at electrodes **1302** and **1304**. Electrode **1306** showed some non-uniformity and random spotting. In Figure 14, the reaction layer is inulin, a fructose oligomer. Electrodes **1402** and **1404** indicated spotting synthesis. There was considerable random spotting as indicated by feature **1406**.

In Figure 15, the reaction layer is palatinose. Electrodes **1502** and **1504** showed good uniformity and edge sharpness. Feature **1506** showed that there is some random spotting. In Figure 16, the reaction layer is polyethylene glycol having a molecular weight of approximately 8000 daltons. Electrodes **1602** and **1604** showed very good uniformity and edge sharpness. Additionally, there was minimal random spotting. In Figure 17, the reaction layer is salicin. Electrodes **1702** and **1704** showed very spotty and non-uniform synthesis. In Figure 18, the reaction layer is ribose. Electrodes **1802** and **1804** showed minimal spotty synthesis. There was some random spotting. In Figure 19, the reaction layer is melibiose. Electrodes **1902** and **1904** showed non-uniform synthesis.

In Figure 25, the reaction layer is 1-(3-hydroxylpropyl) pyrrole. The electrodes showed a fairly uniform synthesis, indicating 1-(3-hydroxylpropyl) pyrrole as a good candidate for uses as an adsorbed porous reaction layer. In Figure 26, the reaction layer is 1-hexylpyrrole. The electrodes showed a fairly uniform synthesis, indicating 1-hexylpyrrole as a good candidate for uses as an adsorbed porous reaction layer. Figure 27 is a photograph of a magnified portion of a top view of a microarray having a combination reaction layer, wherein the combination comprises sucrose, fructose, and glucose. The lighter spots are fluorescence of fluorescently labeled nucleotides that were hybridized with the array after *in situ* synthesis of DNA oligos. The oligomers had a length of 35 to 70 mers. Figures 28 through 35 show each quandrant of Figure 27.

Example 2

This example illustrates a peptide array with and without a combination linker and spacer that was synthesized on an electrode microarray of platinum electrodes having an absorbed porous reaction layer comprising sucrose. The combination linker and spacer was a 16 T unit synthesized *in situ*. After synthesis of the combination linker and spacer, the peptide array was synthesized *in situ* thereon. Fluorescent reagent was used to image the peptides, but the only image that could be seen was on the electrodes having the combination linker and spacer.

The electrode microarray used was a commercial microarray made by CombiMatrix Corporation (CUSTOMARRAY) (Dill et al., *Anal. Chim. Acta* **2001**, 444:69, and Montgomery I, II, and III). The microarray consisted of a semiconductor silicon chip with an array of 1024 individually serially addressable 92-micrometer diameter platinum electrodes in a 16x64 pattern. Prior to using the microarray, the electrodes were coated with sucrose to allow covalent bonding of chemical species to the electrode via the adsorbed sucrose. The sucrose was adsorbed by exposing the platinum electrodes to a solution of sucrose in water followed by a water rinse to remove excess sucrose. The electrodes were set to a specified voltage via connection to a personal computer having appropriate control software. The software allowed control of each electrode on the microarray for electrochemical deblocking in the sequential synthesis of small molecules, oligomers, and polymers, including oligos and peptides.

On four electrodes (Figure 22), a 15-unit deoxythymidylate strand was synthesized using standard phosphoramidite chemistry. For the electrochemical deblocking steps, 1.8 volts was applied for 60 seconds using an acetonitrile/methanol deblocking solution. Following the deblocking of the 15^{th} deoxythymidylate, a deoxythymidylate having a 5' aminoethoxyethyl modifier was attached to electrodes having the 15 deoxythymidylate units and attached to electrodes <u>not</u> having the 15 deoxythymidylate units (Figure 22). A modified deoxythymidylate can be obtained from Glen Research, Inc. The microarray was then fully deprotected using standard chemical deblocking instead of electrochemical deblocking.

Chemical deblocking was accomplished by exposing the microarray to a one to one solution of ethylene diamine and ethanol for one hour at 65 °C and then exposing to Deblock T® (Burdick and Jackson) for 30 minutes at room temperature.

Leucine (L) was coupled to eight electrodes. The microarray was exposed to a solution containing t-BOC protected L (120 milligrams, 0.52 millimoles), O-benzotriazol-1-yl-N,N,N',N'-tetramethyluronium hexafluorophosphate (190 milligrams, 0.50 millimoles)(HBTU), N-hydroxybenztriazole (67 milligrams, 0.50 millimoles)(HOBT), and diisopropylethylamine (261 microliter, 1.50 millimoles)(DIPEA) dissolved into one milliliter of N,N-dimethylformamide (DMF).

Following coupling of the leucine, the microarray was washed successively with DMF (one milliliter) and then methylene chloride (one milliliter). Following washing, the leucine-coupling step was repeated to ensure complete coverage of the electrodes with the t-BOC protected leucine. Following the second L couple step, the microarray was washed successively with DMF (one milliliter), methylene chloride (one milliliter), and then with ethanol to remove any residual DMF or methylene chloride. The microarray was then allowed to air dry.

Following drying, the microarray was covered with a solution of 1,2-diphenylhydrazine (200 milligrams, 1.1 millimoles) and tetrabutylammonium hexafluorophosphate (400 milligrams, 1.0 millimoles) dissolved in methylene chloride (10 milliliters). Using a computer control system, the eight selected electrodes were powered to make such electrodes the active electrodes to deblock the L on only the active electrodes. Deblocking removed the t-BOC protecting group from the L on the active electrodes. The active electrodes were held at 3.0 volts verses a platinum counter electrode for 60 seconds. After deblocking, the deblock solution was removed from the microarray. The microarray was rinsed with ethanol to remove any residual electrochemical deblocking solution and then allowed to air dry.

The synthesis process was repeated using a step pattern with t-BOC-phenylalanine-OH (F) (Figure 22). Following this step, electrochemical deblocking was done. The synthesis process iterated through two rounds of boc-glycine-OH (G) followed by Boc-tyrosine (t-butyl)-OH (Y) to construct a peptide having LFGGY as its sequence as viewed by moving away from the solid surface. The peptide sequence is more commonly written as YGGFL.

Once the microarray was constructed, instead of using electrochemical deblocking, the entire microarray was subjected to standard chemical deblocking using 40% trifluoroacetic acid (TFA) in methylene chloride (30 minutes) followed

by 90% aqueous TFA (30 minutes). Following deblocking, the microarray was rinsed with ethanol and then blocked with acylated bovine serum albumin (ABSA) to eliminate background binding of antibody. The solution used for blocking contained two milligrams per milliliter of ABSA in 2XPBS and 0.05% TWEEN 20™. The blocking reaction was allowed to proceed for 30 minutes. After blocking, the microarray was incubated with primary anti-beta-endorphin antibody. The antibody used was Clone 3-E7 (monoclonal, mouse) and was diluted by 1/1000 using 2XPBS having 0.05% TWEEN 20™ therein. The 2XPBS and TWEEN 20™ were purchased from Chemicon International, Inc. The anti-beta-endorphin antibody will selectively adsorb on the electrodes having the peptide sequence YGGFL synthesized thereon. Following incubation, the microarray was exposed to Cy5™ labeled donkey anti-mouse antibody, which will selectively adsorb onto the anti-beta-endorphin antibody. The Cy5™ labeled donkey anti-mouse antibody was purchased from Integrated DNA Technologies. Finally, the microarray was imaged on an Array Works® Imager to locate the electrodes having Cy5™ labeled donkey anti-mouse.

Figures 20A-20E are schematics of a cross-section of a microarray **2006** of four electrodes **2008**, **2009**, **2010**, **2010** of a microarray of electrodes. A sequence of steps is shown for the synthesis of the combination linker and spacer **2016**, **2018**, **2020A**, **2020B** on two electrodes **2010**, **2011** followed by peptide synthesis 2024 and labeling **2030**, **2032**, **2034**. Figure 20A is a schematic of the electrode microarray **2006** before synthesis. A coating **2004** is shown covering the microarray. The coating **2004** only covered the platinum electrodes **2008**, **2009**, **2010**, **2011**. The coating **2004** is shown having hydroxyl groups as the reactive groups **2002A**. Other reactive groups may be used. For this experiment, the coating **2004** was an adsorbed layer of sucrose; therefore, the reactive groups were hydroxyl groups. Step **2012** was a sequence of steps for the attachment of the combination linker and spacer to two electrodes **2010**, **2011** in Figure 20B. Two electrodes **2008**, **2009** are shown without the combination linker and spacer but having the reactive group changed to an amine **2020A** by attachment of a modified T **2014**, **2018** according to the above procedure. Step **2022** was the first step in building the peptide **2024** by adding L to the reactive amine groups **2020B** as shown in Figure 20C. Step **2026** was multiple steps for building the peptide chain **2024** as shown in Figure 20D on all four electrodes **2008**, **2009**, **2010**, **2011**. Step **2028** is two steps for the adsorption of Clone 3-E7 antibody

2030 followed by adsorption of the Cy5™ labeled donkey anti-mouse **2032**, **2034** according to the above procedure as shown in Figure 20E. The Cy5™ labeled donkey anti-mouse **2034** on two electrodes **2008**, **2009** is shown as shaded to indicate that the fluorescence is quenched by the platinum electrodes because the distance between the electrodes and the label is insufficient to prevent quenching. In contrast, Cy5™ labeled donkey anti-mouse **2032** on two electrodes **2010**, **2011** is shown as not shaded to indicate that the fluorescence is visible because the combination linker and spacer provides sufficient distance between the label and the electrodes to prevent quenching. Although only one synthesis unit is shown per electrode, there were actually many units at each electrode; however, for illustration purposes, only one unit is shown.

Figure 21 is a schematic of two electrodes from Figure 20E shown with and without the combination linker and spacer. Figure 21 shows a cross section of the electrode microarray **2106** showing two electrodes **2108**, **2110** and having a coating **2104** having reactive hydroxyl groups **2102**. The coating **2104** is sucrose and was present only on the platinum electrodes. Figure 21 shows the effect of the combination linker and spacer **2116** on the distance between the Cy5 labeled donkey anti-mouse antibody **2132**, **2134** and the platinum electrodes **2108**, **2110** and the accompanying effect on preventing quenching. The fluorescence from the label **2134** on electrode **2108** was quenched whereas the fluorescence from the label **2132** on electrode **2110** was not quenched due to the further distance between the electrode **2110** and the label **2132**. Additionally, the T units **2114**, **2116** are shown have a negative charge **2136**, which improveed solvation in aqueous media **2140** having ions **2138**. The negative counter ions are not shown. The ions shown are merely representative of any type of ion that may have been present in solution. The hydronium ion is shown to represent acidic species as a result of the dissociation of the phosphate OH groups on the T units.

Figure 22 is a magnified photograph of the eight electrodes used in this example. The four electrodes **2202** did not have the combination linker and spacer and hence did not show any visible fluorescence from the Cy5 labeled donkey anti-mouse antibody because of platinum quenching. The four electrodes **2204** did have the combination linker and spacer and hence did show the fluorescence from the Cy5 labeled donkey anti-mouse antibody.

Example 3

An electrode microarray was prepared according to the procedures in Example 1 but with a series of linker/spacers of different lengths from 0 to 15 T units. In addition, after the first amino acid, leucine, was attached, no subsequent amino acids were attached. Instead, biotin was attached to the leucine at the locations having the different lengths of linker/spacers. Following attachment of the biotin, the microarray was covered by a solution of Texas Red labeled streptavidin, which selectively complexes to biotin. Image analysis was done on the microarray to view the electrodes having the Texas Red labeled strepavidin.

Figure 24 is magnified photograph of a top view of a portion of the microarray **2400** showing rows **2402**, **2404**, **2406**, **2408**, **2410**, **2412**, and **2414**. Moving from left to right, the length of the combination linker and spacer was zero on the first electrode in rows **2402**, **2408**, and **2412**. Moving from right to left, the length of the linker/spacer was zero on the first electrode in rows **2403**, **2410**, and **2414**. Row **2406** did not have any synthesis thereon. For rows **2402**, **2408**, and **2412**, the length of the linker/spacer increased by one T unit moving from left to right. For rows **2403**, **2410**, and **2414**, the length of the combination linker and spacer increased by one T unit moving from right to left. To allow *in situ* synthesis, the cells without a T unit had one modified T unit having the amine group according to example 1 and Figure 21, electrode **2108**. Figure 24 shows that as the length of the combination linker and spacer increases, the fluorescence increases. At approximately 6 to 8 T units, the fluorescence began to increase substantially until reaching the last cell having 15 T units having the strongest fluorescence. Thus, increasing the length of the linker/spacer can eliminate the quenching effect of the platinum electrode.

Example 4

Figure 23 is a schematic of a cross section of two cells **2308**, **2310** of an electrode microarray **2306** having a plurality of platinum electrodes serially and individually addressable. A coating **2304** having hydroxyl reactive groups **2302** is shown. The coating **2304** was a sucrose layer adsorbed onto the platinum electrodes and was only present on the electrodes. Electrode **2308** is shown with a non-ionic

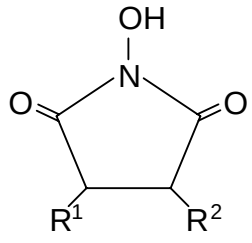
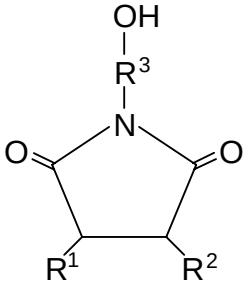
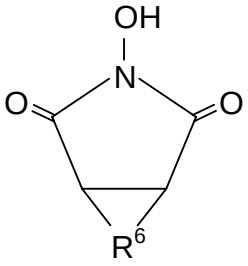
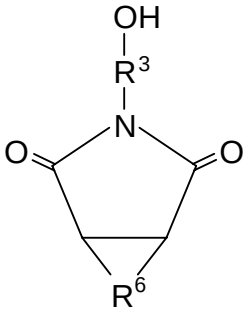
combination linker and spacer **2314**, and electrode **2310** is shown having a combination linker and spacer **2316** in accordance with the present invention. The nonionic linker **2314** was attached before or after synthesis of the combination linker and spacer **2316** in accordance with the present invention. The peptide **2324** was synthesized *in situ* on electrodes **2308** and **2310**. The fluorescent labeling procedure of examples 1 and 2 was used to label the peptides **2330**, **2332**, **2334** at electrodes **2308** and **2310**.

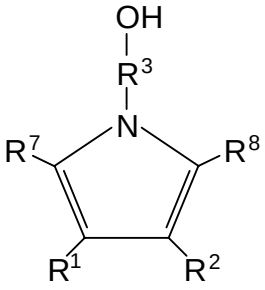
The nonionic combination linker and spacer **2314** was a PEG compound or other nonionic compound. Although PEG is water soluble, it is not as well solvated as the multiple ionic combination linker and spacer **2316** of the present invention because negative charges **2318** contributed substantially to solvation. The lack of charge on a PEG (or other nonionic) can allow the PEG to fold upon itself, to approach the electrode surface, or to approach nearby PEG chains on the same electrode with the result that the fluorescence on electrode **2308** is expected to be less than **2310** due to platinum quenching and due to less access of the labeling species to the peptide. It is expected that synthesis efficiency will be higher using the multiple ionic combination linker and spacer **2316** of the present invention because of better access to the reactive group **420A**, **420B** on the end of the combination linker and spacer **2316**.

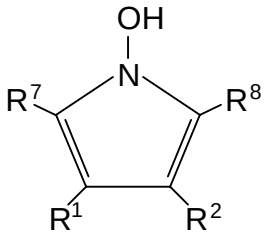
We claim:

1. An electrode array having an adsorbed porous reaction layer for synthesis comprising:

(a) a plurality of electrodes on a substrate, wherein each of the plurality of electrodes is electronically connected to a computer control system and wherein each electrode of the plurality of electrodes has a surface; and

(b) a porous reaction layer adsorbed onto the surface of each electrode of the plurality of electrodes, wherein the porous reaction layer comprises a chemical species or mixture of chemical specie, wherein the chemical species is selected from the group consisting of monosaccharides, disaccharides, trisaccharides, polyethylene glycol, polyethylene glycol derivative, N-hydroxysuccinimide, formula I, formula II, formula III, formula IV, formula V, formula VI, formula VII, and combinations thereof, wherein formula I is , formula II is , formula III is $HOR^4(OR^5)_mR^7$, formula IV is , formula V is , formula VI is



, and formula VII is 

, wherein in each formula

m is an integer from 1 to 4;

R^1, R^2, R^7, and R^8 are independently selected from the group consisting of hydrogen, and substituted and unsubstituted alkyl, alkenyl, alkynyl, cycloalkyl, cycloalkenyl, cycloalkynyl, aryl, heterocyclic ring, and polycyclic group, and halo, amide, alkoxy, acyl, acyloxy, oxycarbonyl, acyloxycarbonyl, alkoxycarbonyloxy, carboxy, amino, secondary amino, tertiary amino, hydrazino, azido, alkazoxy, cyano, isocyano, cyanato, isocyanato, thiocyanato, fulminato, isothiocyanato, isoselenocyanato, selenocyanato, carboxyamido, acylimino, nitroso, aminooxy, carboximidoyl, hydrazonoyl, oxime, acylhydrazino, amidino, sulfide, sulfoxide, thiosulfoxide, sulfone, thiosulfone, sulfate, thiosulfate, hydroxyl, formyl, hydroxyperoxy, hydroperoxy, peroxy acid, carbamoyl, trimethyl silyl, nitro, nitroso, oxamoyl, pentazolyl, sulfamoyl, sulfenamoyl, sulfeno, sulfinamoyl, sulfino, sulfo, sulfoamino, hydrothiol, tetrazolyl, thiocarbamoyl, thiocarbazono, thiocarbodiazono, thiocarbonohydrazido, thiocarboxy, thioformyl, thioacyl, thiocyanato, thiosemicarbazido, thiosulfino, thiosulfo, thioureido, triazano, triazeno, triazinyl, trithiosulfo, sulfinimidic acid, sulfonimidic acid, sulfinohydrazonic acid, sulfonohydrazonic acid, sulfinohydroximic acid, sulfonohydroximic acid, and phosphoric acid ester;

R^3 is selected from the group consisting of heteroatom group, carbonyl, and substituted and unsubstituted alkyl, alkenyl, alkynyl, cycloalkyl, cycloalkenyl, cycloalkynyl, aryl, heterocyclic ring, and polycyclic group;

R^4 and R^5 are independently selected from the group consisting of methylene, ethylene, propylene, butylene, pentylene, and hexylene;

R^6 forming a ring structure with two carbons of succinimide and is selected from the group consisting of substituted and unsubstituted alkyl, alkenyl, alkynyl,

cycloalkyl, cycloalkenyl, cycloalkynyl, aryl, heterocyclic ring, and polycyclic group; and

R^7 is selected from the group consisting of amino and hydroxyl.

2. The electrode array of claim 1, wherein the monosaccharide is selected from the group consisting of allose, altrose, arabinose, deoxyribose, erythrose, fructose, galactose, glucose, gulose, idose, lyxose, mannose, psicose, L-rhamnose, ribose, ribulose, sedoheptulose, D-sorbitol, sorbose, sylulose, tagatose, talose, threose, xylulose, and xylose.

3. The electrode array of claim 1, wherein the disaccharide is selected from the group consisting of amylose, cellobiose, lactose, maltose, melibiose, palatinose, sucrose, and trehalose

The electrode microarray of claim 1, wherein the triaccharide is selected from the group consisting of raffinose and melezitose.

4. The electrode array of claim 1, wherein the polyethylene glycol derivative is selected from the group consisting of diethylene glycol, tetraethylene glycol, polyethylene glycol having primary amino groups, 2-(2-aminoethoxy) ethanol, ethanol amine, di(ethylene glycol) mono allyl ether, di(ethylene glycol) mono tosylate, tri(ethylene glycol) mono allyl ether, tri(ethylene glycol) mono tosylate, tri(ethylene glycol) mono benzyl ether, tri(ethylene glycol) mono trityl ether, tri(ethylene glycol) mono chloro mono methyl ether, tri(ethylene glycol) mono tosyl mono allyl ether, tri(ethylene glycol) mono allyl mono methyl ether, tetra(ethlyne glycol) mono allyl ether, tetra(ethylene glycol) mono methyl ether, tetra(ethylene glycol) mono tosyl mono allyl ether, tetra(ethylene glycol) mono tosylate, tetra(ethylene glycol) mono benzyl ether, tetra(ethylene glycol) mono trityl ether, tetra(ethylene glycol) mono 1-hexenyl ether, tetra(ethylene glycol) mnon 1-heptenyl ether, tetra(ethylene glycol) mono 1-octenyl ether, tetra(ethylene glycol) mono 1-decenyl ether, tetra(ethylene glycol) mono 1-undecenyl ether, penta(ethylene glycol) mono methyl ether, penta(ethylene glycol) mono allyl mono methyl ether, penta(ethylene glycol) mono tosyl mono methyl ether, penta(ethylene glycol) mono tosyl mono allyl ether, hexa(ethylene glycol) mono allyl ether, hexa(ethylene glycol) mono methyl ether, hexa(ethylene glycol) mono benzyl ether, hexa(ethylene glycol) mono trityl ether, hexa(ethylene glycol) mono 1-hexenyl ether, hexa(ethylene glycol) mono 1-heptenyl ether, hexa(ethylene glycol) mono 1-octenyl ether, hexa(ethylene

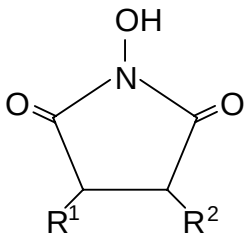
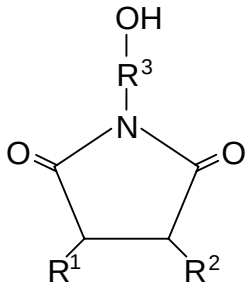
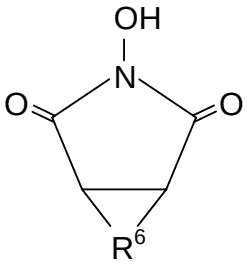
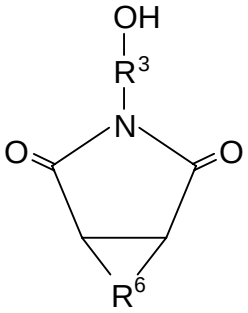
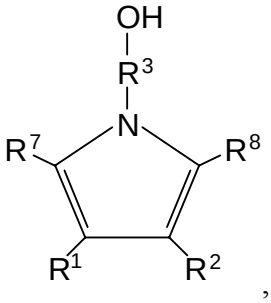
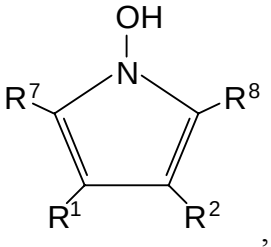
glycol) mono 1-decenyl ether, hexa(ethylene glycol) mono 1-undecenyl ether, hexa(ethylene glycol) mono 4-benzophenonyl mono 1-undecenyl ether, hepta(ethylene glycol) mono allyl ether, hepta(ethylene glycol) mono methyl ether, hepta(ethylene glycol) mono tosyl mono methyl ether, hepta(ethylene glycol) monoallyl mono methyl ether, octa(ethylene glycol) mono allyl ether, octa(ethylene glycol) mono tosylate, octa(ethylene glycol) mono tosyl mono allyl ether, undeca(ethylene glycol) mono methyl ether, undeca(ethylene glycol) mono allyl mono methyl ether, undeca(ethylene glycol) mono tosyl mono methyl ether, undeca(ethylene glycol) mono allyl ether, octadeca(ethylene glycol) mono allyl ether, octa(ethylene glycol), deca(ethylene glycol), dodeca(ethylene glycol), tetradeca(ethylene glycol), hexadeca(ethylene glycol), octadeca(ethylene glycol), benzophenone-4-hexa(ethylene glycol) allyl ether, benzophenone-4-hexa(ethylene glycol) hexenyl ether, benzophenone-4-hexa(ethylene glycol) octenyl ether, benzophenone-4-hexa(ethylene glycol) decenyl ether, benzophenone-4-hexa(ethylene glycol) undecenyl ether, 4-flourobenzophenone-4`-hexa(ethylene glycol) allyl ether, 4-flourobenzophenone-4`-hexa(ethylene glycol) undecenyl ether, 4-hydroxybenzophenone-4`-hexa(ethylene glycol) allyl ether, 4-hydroxybenzophenone-4`-hexa(ethylene glycol) undecenyl ether, 4-hydroxybenzophenone-4`-tetra(ethylene glycol) allyl ether, 4-hydroxybenzophenone-4`-tetra(ethylene glycol) undecenyl ether, 4-morpholinobenzophenone-4`-hexa(ethylene glycol) allyl ether, 4-morpholinobenzophenone-4`-hexa(ethylene glycol) undecenyl ether, 4-morpholinobenzophenone-4`-tetra(ethylene glycol) allyl ether, and 4-morpholinobenzophenone-4`-tetra(ethylene glycol) undecenyl ether.

5. The electrode array of claim 1, wherein the polyethylene glycol has a molecular weight of approximately 1,000 to 20,000.

6. The electrode array of claim 1, wherein the electrodes surface is made from a material is selected from the group consisting of platinum, gold, semiconductor, indium tin oxide, and carbon and combinations thereof.

7. A process for forming an electrode array device having a plurality of electrodes wherein each electrode has a surface, and a porous reaction layer adsorbed to the surface for improved synthesis quality comprising:

(a) providing a plurality of electrodes on a substrate, wherein each of the plurality of electrodes is electronically connected to a computer control system and wherein each electrode of the plurality of electrodes has a surface; and

(b) adsorbing a porous reaction layer on the surface of each electrode of the plurality of electrodes, wherein the porous reaction layer comprises a chemical species, wherein the chemical species is selected from the group consisting of monosaccharides, disaccharides, trisaccharides, polyethylene glycol, polyethylene glycol derivative, N-hydroxysuccinimide, formula I, formula II, formula III, formula IV, formula V, formula VI, formula VII, and combinations thereof, wherein formula I is , formula II is , formula III is , formula IV is $HOR^4(OR^5)_mR^7$, formula V is , formula VI is , and formula VII is , wherein in each formula

m is an integer from 1 to 4;

R^1, R^2, R^7, and R^8 are independently selected from the group consisting of hydrogen, and substituted and unsubstituted alkyl, alkenyl, alkynyl, cycloalkyl, cycloalkenyl, cycloalkynyl, aryl, heterocyclic ring, and polycyclic group, and halo, amide, alkoxy, acyl, acyloxy, oxycarbonyl, acyloxycarbonyl, alkoxycarbonyloxy, carboxy, amino, secondary amino, tertiary amino, hydrazino, azido, alkazoxy, cyano, isocyano, cyanato, isocyanato, thiocyanato, fulminato, isothiocyanato, isoselenocyanato, selenocyanato, carboxyamido, acylimino, nitroso, aminooxy, carboximidoyl, hydrazonoyl, oxime, acylhydrazino, amidino, sulfide, sulfoxide, thiosulfoxide, sulfone, thiosulfone, sulfate, thiosulfate, hydroxyl, formyl, hydroxyperoxy, hydroperoxy, peroxy acid, carbamoyl, trimethyl silyl, nitro, nitroso, oxamoyl, pentazolyl, sulfamoyl, sulfenamoyl, sulfeno, sulfinamoyl, sulfino, sulfo, sulfoamino, hydrothiol, tetrazolyl, thiocarbamoyl, thiocarbazono, thiocarbodiazono, thiocarbonohydrazido, thiocarboxy, thioformyl, thioacyl, thiocyanato, thiosemicarbazido, thiosulfino, thiosulfo, thioureido, triazano, triazeno, triazinyl, trithiosulfo, sulfinimidic acid, sulfonimidic acid, sulfinohydrazonic acid, sulfonohydrazonic acid, sulfinohydroximic acid, sulfonohydroximic acid, and phosphoric acid ester;

R^3 is selected from the group consisting of heteroatom group, carbonyl, and substituted and unsubstituted alkyl, alkenyl, alkynyl, cycloalkyl, cycloalkenyl, cycloalkynyl, aryl, heterocyclic ring, and polycyclic group;

R^4 and R^5 are independently selected from the group consisting of methylene, ethylene, propylene, butylene, pentylene, and hexylene;

R^6 forms a ring structure with two carbons of succinimide and is selected from the group consisting of substituted and unsubstituted alkyl, alkenyl, alkynyl, cycloalkyl, cycloalkenyl, cycloalkynyl, aryl, heterocyclic ring, and polycyclic group; and

R^7 is selected from the group consisting of amino and hydroxyl.

8. The process of claim 7, wherein the monosaccharide is selected from the group consisting of allose, altrose, arabinose, deoxyribose, erythrose, fructose, galactose, glucose, gulose, idose, lyxose, mannose, psicose, L-rhamnose, ribose, ribulose, sedoheptulose, D-sorbitol, sorbose, sylulose, tagatose, talose, threose, xylulose, and xylose.

9. The process of claim 7, wherein the disaccharide is selected from the group consisting of amylose, cellobiose, lactose, maltose, melibiose, palatinose, sucrose, and trehalose

10. The process of claim 7, wherein the triaccharide is selected from the group consisting of raffinose and melezitose.

11. The process of claim 7, wherein the polyethylene glycol derivative is selected from the group consisting of diethylene glycol, tetraethylene glycol, polyethylene glycol having primary amino groups, 2-(2-aminoethoxy) ethanol, ethanol amine, di(ethylene glycol) mono allyl ether, di((ethylene glycol) mono tosylate, tri(ethylene glycol) mono allyl ether, tri(ethylene glycol) mono tosylate, tri(ethylene glycol) mono benzyl ether, tri(ethylene glycol) mono trityl ether, tri(ethylene glycol) mono chloro mono methyl ether, tri(ethylene glycol) mono tosyl mono allyl ether, tri(ethylene glycol) mono allyl mono methyl ether, tetra(ethlyne glycol) mono allyl ether, tetra(ethylene glycol) mono methyl ether, tetra(ethylene glycol) mono tosyl mono allyl ether, tetra(ethylene glycol) mono tosylate, tetra(ethylene glycol) mono benzyl ether, tetra(ethylene glycol) mono trityl ether, tetra(ethylene glycol) mono 1-hexenyl ether, tetra(ethylene glycol) mnon 1-heptenyl ether, tetra(ethylene glycol) mono 1-octenyl ether, tetra(ethylene glycol) mono 1-decenyl ether, tetra(ethylene glycol) mono 1-undecenyl ether, penta(ethylene glycol) mono methyl ether, penta(ethylene glycol) mono allyl mono methyl ether, penta(ethylene glycol) mono tosyl mono methyl ether, penta(ethylene glycol) mono tosyl mono allyl ether, hexa(ethylene glycol) mono allyl ether, hexa(ethylene glycol) mono methyl ether, hexa(ethylene glycol) mono benzyl ether, hexa(ethylene glycol) mono trityl ether, hexa(ethylene glycol) mono 1-hexenyl ether, hexa(ethylene glycol) mono 1-heptenyl ether, hexa(ethylene glycol) mono 1-octenyl ether, hexa(ethylene glycol) mono 1-decenyl ether, hexa(ethylene glycol) mono 1-undecenyl ether, hexa(ethylene glycol) mono 4-benzophenonyl mono 1-undecenyl ether, hepta(ethylene glycol) mono allyl ether, hepta(ethylene glycol) mono methyl ether, hepta(ethylene glycol) mono tosyl mono methyl ether, hepta(ethylene glycol) monoallyl mono methyl ether, octa(ethylene glycol) mono allyl ether, octa(ethylene glycol) mono tosylate, octa(ethylene glycol) mono tosyl mono allyl ether, undeca(ethylene glycol) mono methyl ether, undeca(ethylene glycol) mono allyl mono methyl ether, undeca(ethylene glycol) mono tosyl mono methyl ether,

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12. The process of claim 7, wherein the polyethylene glycol has a molecular weight from approximately 1,000 to 20,000.

13. The process of claim 7, wherein the step of adsorbing the porous reaction layer further comprises:

(b_1) contacting a treatment solution to the microarray for from about 1 minute to about 1 month, wherein the treatment solution comprises the chemical species and a solvent capable of dissolving the chemical species, wherein the chemical species has a concentration of approximately 0.001 to 5 molar, wherein the temperature of the treatment solution is approximately 0 to 90 degrees celcius.

14. The process of claim 7, wherein the surface of each electrode of the plurality of electrodes is selected from the group consisting of platinum, gold, semiconductor, indium tin oxide, and carbon and combinations thereof.

15. The process of claim 7, wherein the step of providing the plurality of electrodes further comprises:

(a_1) etching the electrode surfaces using a plasma cleaning method; and

(a_2) cleaning the electrode surfaces using a chemical cleaning method.

16. The process of claim 15, wherein the plasma cleaning method further comprises:

($a_{1.1}$) exposing the electrode microarray to an argon plasma plasma for approximately two to six minutes.

16. The process of claim 15, wherein the plasma cleaning method further comprises:

($a_{1.1}$) exposing the electrode microarray to a sulfur hexafluoride plasma plasma for approximately two to six minutes.

17. The process of claim 15, wherein the plasma cleaning method comprises:

($a_{1.1}$) etching the electrode microarray using an argon plasma for from about 2 to about 4 minutes using a power of approximately 600 watts and a pressure of approximately eight millitorr;

($a_{1.2}$) etching the electrode microarray using an oxygen plasma for from about 5 to about 7 minutes using a power of approximately 500 watts and a pressure of approximately 50 millitorr; and

($a_{1.3}$) etching the electrode microarray using an argon plasma for from about 8 to about 12 minutes using a power of approximately 600 watts and a pressure of approximately eight millitorr.

18. The process of claim 15, wherein the chemical cleaning method further comprises an electrochemical cleaning method, wherein the electrochemical cleaning method comprises:

($a_{2.1}$) contacting a sulfuric acid solution with the surface of the electrodes, wherein the sulfuric acid solution has a concentration of approximately 0.01 to 5 molar;

($a_{2.2}$) pulsing a current for approximately 0.01 to 60 seconds to a first group of electrodes while a second group of electrodes is grounded, wherein each electrode is in the first group of electrodes or the second group of electrodes;

($a_{2.3}$) pulsing a current for approximately 0.01 to 60 seconds to the second group of electrodes while the first group of electrodes is grounded; and

($a_{2.4}$) alternating between pulsing a current for approximately 0.01 to 60 seconds to the first group of electrodes while the second group of electrodes is grounded and pulsing a current for approximately 0.01 to 60 seconds to the second

group of electrodes while the first group of electrodes remains grounded for a cumulative time of approximately 1 to 60 minutes.

19. The process of claim 15, wherein the chemical cleaning method further comprises a hydrogen peroxide cleaning method comprising:

($a_{2.1}$) contacting a hydrogen peroxide solution with the surface of the electrodes, wherein the hydrogen peroxide solution has a concentration of approximately 0.5 to 10 percent (by volume), wherein the contacting time is from about 1 minute to about 24 hours, and the hydrogen peroxide solution temperature is approximately 20 to 95 degrees Celsius.

20. A process for cleaning an electrode microarray comprising:

(a) etching the electrode microarray using a plasma cleaning method; and

(b) cleaning the electrode microarray using a chemical cleaning method.

21. The process of claim 20, wherein the plasma cleaning method comprises:

(a_1) etching the surface of the electrodes using an argon plasma for from about 2 to about minutes using a power of approximately 600 watts and a pressure of approximately eight millitorr;

(a_2) etching the surface of the electrodes using an oxygen plasma for from about 5 to about 7 minutes using a power of approximately 500 watts and a pressure of approximately 50 millitorr; and

(a_3) etching the surface of the electrodes using an argon plasma for from about 8 to about 12 minutes using a power of approximately 600 watts and a pressure of approximately eight millitorr;

22. The process of claim 20, wherein the chemical cleaning method comprises:

(b_1) contacting a sulfuric acid solution with the surface of the electrodes, wherein the sulfuric acid solution has a concentration of approximately 0.01 to 5 molar and the electrodes are electronically attached to a control system;

(b_2) pulsing a current for from about 0.01 to about 60 seconds to a first group of electrodes while a second group of electrodes is grounded, wherein the first group and the second group constitute a plurality of electrodes;

(b_3) pulsing a current for from about 0.01 to about 60 seconds to the second group of electrodes while the first group of electrodes is grounded; and

(b_4) alternating between pulsing a current for from about 0.01 to about 60 seconds to the first group of electrodes while the second group of electrodes is grounded and pulsing a current for from about 0.01 to about 60 seconds to the second group of electrodes while the first group of electrodes remains grounded for a cumulative time of from about 1 to about 60 minutes.

23. The process of claim 20, wherein the chemical cleaning method comprises a hydrogen peroxide cleaning method, wherein the hydrogen peroxide cleaning method comprises contacting a hydrogen peroxide solution with the surface of the electrodes, wherein the hydrogen peroxide solution has a concentration of from about 0.5 to about 10 percent (by volume), wherein contacting time is from about 1 minute to about 24 hours, and wherein the hydrogen peroxide solution temperature is from about 20 to about 95 degrees Celsius.