

BLOOD SAMPLE MANAGEMENT USING OPEN CELL FOAM

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims priority to United States Provisional Application Serial No. 62/063,536, entitled “Blood Sample Management Using Open Cell Foam” filed October 14, 2014, and United States Provisional Application Serial No. 62/207,618, entitled “Blood Sample Management Using Open Cell Foam” filed August 20, 2015, the entire disclosures of each of which are herein incorporated by reference.

BACKGROUND OF THE INVENTION

1. Field of the Disclosure

[0002] The present disclosure relates generally to a blood transfer device. More particularly, the present disclosure relates to a blood transfer device, a blood transfer and testing system, a lancet and blood transfer device, and a method of loading an anticoagulant.

2. Description of the Related Art

[0003] Blood sampling is a common health care procedure involving the withdrawal of at least a drop of blood from a patient. Blood samples are commonly taken from hospitalized, homecare, and emergency room patients either by finger stick, heel stick, or venipuncture. Once collected, blood samples may be analyzed to obtain medically useful information including, for example, chemical composition, hematology, and coagulation.

[0004] Blood tests determine the physiological and biochemical states of the patient, such as disease, mineral content, drug effectiveness, and organ function. Blood tests may be performed in a clinical laboratory or at the point-of-care near the patient.

SUMMARY OF THE INVENTION

[0005] The present disclosure provides a specimen mixing and transfer device adapted to receive a sample. The specimen mixing and transfer device includes a housing, a material including pores that is disposed within the housing, and a dry anticoagulant powder within the pores of the material. In one embodiment, the material is a sponge material. In other embodiments, the material is an open cell foam. In one embodiment, the open cell foam is treated with an anticoagulant to form a dry anticoagulant powder finely distributed throughout the pores of the material. A blood sample may be received within the specimen mixing and transfer device. The blood sample is exposed to and mixes with the anticoagulant powder while passing through the material.

[0006] A specimen mixing and transfer device of the present disclosure offers uniform and passive blood mixing with an anticoagulant under flow-through conditions. A specimen mixing and transfer device of the present disclosure could catch blood clots or other contaminants within the microstructure of the material and prevent them from being dispensed into a diagnostic sample port. A specimen mixing and transfer device of the present disclosure enables a simple, low-cost design for passive flow-through blood stabilization. A specimen mixing and transfer device of the present disclosure enables precisely controlled loading of an anticoagulant into the material by soaking it with an anticoagulant and water solution and then drying the material to form a finely distributed dry anticoagulant powder throughout the pores of the material.

[0007] A specimen mixing and transfer device of the present disclosure may provide an effective passive blood mixing solution for applications wherein blood flows through a line. Such a specimen mixing and transfer device is useful for small blood volumes, e.g., less than 50 μL or less than 500 μL , and/or where inertial, e.g., gravity based, forces are ineffective for bulk manual mixing by flipping back and forth a blood collection container such as is required for vacuum tubes.

[0008] In accordance with an embodiment of the present invention, a specimen mixing and transfer device adapted to receive a sample includes a housing having a first end, a second end, and a sidewall extending therebetween; a material including pores and disposed within the housing; and a dry anticoagulant powder within the pores of the material.

[0009] In one configuration, the sample is a blood sample. In another configuration, the housing is adapted to receive the blood sample therein via the first end. In yet another configuration, with the blood sample received within the housing, the blood sample passes through the material thereby effectively mixing the blood sample with the dry anticoagulant powder. In one configuration, the blood sample dissolves and mixes with the dry anticoagulant powder while passing through the material. In another configuration, the material is an open cell foam. In yet another configuration, the material is a sponge. In one configuration, the first end includes an inlet. In another configuration, the second end includes an outlet. In yet another configuration, the housing defines a mixing chamber having a material including pores disposed within the mixing chamber. In one configuration, the housing includes an inlet channel in fluid communication with the inlet and the mixing chamber and an outlet channel in fluid communication with the mixing chamber and the outlet. In another configuration, the housing includes a dispensing chamber between the mixing chamber and the outlet.

[0010] In accordance with another embodiment of the present invention, a specimen mixing and transfer device adapted to receive a sample includes a housing having a first end, a second end, and a sidewall extending therebetween; a dry anticoagulant powder disposed within the housing; and a mixing element disposed within the housing.

[0011] In one configuration, the sample is a blood sample. In another configuration, the housing is adapted to receive the blood sample therein via the first end. In yet another configuration, with the blood sample received within the housing, the mixing element interferes with a flow of the blood sample to promote mixing of the blood sample with the dry anticoagulant powder. In one configuration, the dry anticoagulant powder is deposited on an interior surface of the housing. In another configuration, the mixing element comprises a plurality of posts. In one configuration, the first end includes an inlet. In another configuration, the second end includes an outlet. In yet another configuration, the housing defines a mixing chamber having a dry anticoagulant powder disposed within the mixing chamber. In one configuration, the housing includes an inlet channel in fluid communication with the inlet and the mixing chamber and an outlet channel in fluid communication with the mixing chamber and the outlet. In another configuration, the housing includes a dispensing chamber between the mixing chamber and the outlet. In yet another configuration, the housing includes two diverted flow channels between the inlet channel and the outlet channel.

[0012] In accordance with yet another embodiment of the present invention, a method of loading an anticoagulant to a material having pores includes soaking the material in a liquid solution of the anticoagulant and water; evaporating the water of the liquid solution; and forming a dry anticoagulant powder within the pores of the material.

[0013] In one configuration, the material is a sponge. In another configuration, the material is an open cell foam.

BRIEF DESCRIPTION OF THE DRAWINGS

[0014] The above-mentioned and other features and advantages of this disclosure, and the manner of attaining them, will become more apparent and the disclosure itself will be better understood by reference to the following descriptions of embodiments of the disclosure taken in conjunction with the accompanying drawings, wherein:

[0015] **Fig. 1** is a partial cross-sectional view of a specimen mixing and transfer device in accordance with an embodiment of the present invention.

[0016] **Fig. 2** is a microscopic view of the microstructure of an open cell foam material having a dry anticoagulant powder distributed throughout its microstructure in accordance with an embodiment of the present invention.

[0017] **Fig. 3** is a partial cross-sectional view of a specimen mixing and transfer device in accordance with another embodiment of the present invention.

[0018] **Fig. 4** is a perspective view of a specimen mixing and transfer device in accordance with an embodiment of the present invention.

[0019] **Fig. 5** is a partial cross-sectional view of a specimen mixing and transfer device in accordance with an embodiment of the present invention.

[0020] **Fig. 6** is a partial cross-sectional view taken along line 6-6 of **Fig. 5** in accordance with an embodiment of the present invention.

[0021] **Fig. 7** is a perspective view of a specimen mixing and transfer device in accordance with another embodiment of the present invention.

[0022] **Fig. 8** is a partial cross-sectional view of a specimen mixing and transfer device in accordance with another embodiment of the present invention.

[0023] **Fig. 9** is a partial cross-sectional view taken along line 9-9 of **Fig. 8** in accordance with an embodiment of the present invention.

[0024] **Fig. 10** is a perspective view of alternate embodiments of a specimen mixing and transfer device in accordance with another embodiment of the present invention.

[0025] **Fig. 11A** is a perspective view of a syringe assembly in accordance with an embodiment of the present invention.

[0026] **Fig. 11B** is a close-up partial perspective view of the syringe assembly of **Fig. 11A** in accordance with an embodiment of the present invention.

[0027] **Fig. 11C** is a perspective view of a syringe assembly in accordance with an embodiment of the present invention.

[0028] **Fig. 12** is a perspective view of an open cell foam material in accordance with an embodiment of the present invention.

[0029] **Fig. 13** is a microscopic view of the microstructure of an open cell foam material having a dry anticoagulant powder distributed throughout its microstructure in accordance with an embodiment of the present invention.

[0030] **Fig. 14** is a microscopic view of the microstructure of an untreated foam material.

[0031] **Fig. 15** is a perspective view of a syringe assembly in accordance with an embodiment of the present invention.

[0032] **Fig. 16** is a graph demonstrating the anticoagulant uptake by a blood sample flowing through an open cell foam material having a dry anticoagulant powder distributed throughout its microstructure in accordance with an embodiment of the present invention.

[0033] **Fig. 17** is a perspective view of a blood transfer system in accordance with an embodiment of the present invention.

[0034] **Fig. 18** is a perspective view of a blood transfer system in accordance with an embodiment of the present invention.

[0035] **Fig. 19** is a perspective view of a blood transfer system in accordance with an embodiment of the present invention.

[0036] **Fig. 20** is a perspective view of a blood transfer system in accordance with an embodiment of the present invention.

[0037] Corresponding reference characters indicate corresponding parts throughout the several views. The exemplifications set out herein illustrate exemplary embodiments of the disclosure, and such exemplifications are not to be construed as limiting the scope of the disclosure in any manner.

DETAILED DESCRIPTION

[0038] The following description is provided to enable those skilled in the art to make and use the described embodiments contemplated for carrying out the invention. Various modifications, equivalents, variations, and alternatives, however, will remain readily apparent to those skilled in the art. Any and all such modifications, variations, equivalents, and alternatives are intended to fall within the spirit and scope of the present invention.

[0039] For purposes of the description hereinafter, the terms “upper”, “lower”, “right”, “left”, “vertical”, “horizontal”, “top”, “bottom”, “lateral”, “longitudinal”, and derivatives thereof shall relate to the invention as it is oriented in the drawing figures. However, it is to be understood that the invention may assume various alternative variations, except where expressly specified to the contrary. It is also to be understood that the specific devices illustrated in the attached drawings, and described in the following specification, are simply exemplary embodiments of the invention. Hence, specific dimensions and other physical characteristics related to the embodiments disclosed herein are not to be considered as limiting.

[0040] **Figs. 1-3** illustrate exemplary embodiments of a specimen mixing and transfer device of the present disclosure. The specimen mixing and transfer device **10** is adapted to receive a sample **12**. In one embodiment, the specimen mixing and transfer device **10** includes a housing

14, a material **16** including pores **18** that is disposed within the housing **14**, and a dry anticoagulant powder **20** within the pores **18** of the material **16**.

[0041] With a sample **12** received within the specimen mixing and transfer device **10**, a portion of the specimen mixing and transfer device **10** acts as a flow-through chamber for the effective mixing of a sample **12** with the dry anticoagulant powder **20** within the material **16**. In other embodiments, the material **16** may contain other dry substances. The effective mixing is achieved by passing the sample **12** through the material **16** having the dry anticoagulant powder **20** distributed throughout its microstructure.

[0042] A specimen mixing and transfer device **10** of the present disclosure offers uniform and passive blood mixing with an anticoagulant under flow-through conditions. A specimen mixing and transfer device **10** of the present disclosure may catch blood clots or other contaminants within the microstructure of the material **16** and prevent them from being dispensed into a diagnostic sample port. A specimen mixing and transfer device **10** of the present disclosure enables a simple, low cost design for passive flow-through blood stabilization. A specimen mixing and transfer device **10** of the present disclosure enables precisely controlled loading of an anticoagulant into the material **16** by soaking it with an anticoagulant and water solution and then drying the material **16** to form a finely distributed dry anticoagulant powder **20** throughout the pores **18** of the material **16**.

[0043] A specimen mixing and transfer device **10** of the present disclosure may provide an effective passive blood mixing solution for applications wherein blood flows through a line. Such a specimen mixing and transfer device **10** is useful for small blood volumes, e.g., less than 50 μL or less than 500 μL , and/or where inertial, e.g., gravity based, forces are ineffective for bulk manual mixing by flipping back and forth a blood collection container such as is required for vacuum tubes.

[0044] **Fig. 1** illustrates an exemplary embodiment of a specimen mixing and transfer device **10** of the present disclosure. Referring to **Fig. 1**, in one embodiment, a specimen mixing and transfer device **10** includes a housing **14**, a material **16** including pores **18** that are disposed within the housing **14**, and a dry anticoagulant powder **20** within the pores **18** of the material **16**. The housing **14** includes a first end **22**, a second end **24**, and a sidewall **26** extending between the first end **22** and the second end **24**. In one embodiment, the first end **22** includes an inlet **28** and the second end **24** includes an outlet **30**.

[0045] Referring to **Fig. 1**, in one embodiment, the housing **14** of the specimen mixing and transfer device **10** includes an inlet channel **32** and an outlet channel **34**. The inlet channel **32** and the outlet channel **34** are in fluid communication via a flow channel or mixing chamber **36**.

For example, the inlet channel **32** is in fluid communication with the inlet **28** and the mixing chamber **36**; and the outlet channel **34** is in fluid communication with the mixing chamber **36** and the outlet **30**. In one embodiment, the material **16** is disposed within the mixing chamber **36** of the housing **14**.

[0046] In one embodiment, the material **16** is a sponge material. In other embodiments, the material **16** is an open cell foam. In one embodiment, the open cell foam is treated with an anticoagulant, as described in detail below, to form a dry anticoagulant powder **20** finely distributed throughout the pores **18** of the material **16**. A sample **12** may be received within the specimen mixing and transfer device **10**. In some embodiments, the sample **12** gets soaked into the material **16** based on capillary principles. In some embodiments, the sample **12** may be a blood sample. The blood sample is exposed to and mixes with the anticoagulant powder **20** while passing through the intricate microstructure of the material **16**. In this manner, the specimen mixing and transfer device **10** produces a stabilized sample. In some embodiments, the stabilized sample may be transferred to a diagnostic instrument such as a blood testing device, a point-of-care testing device, or similar analytical device.

[0047] In one embodiment, the material **16** is an open cell foam. For example, the material **16** is a soft deformable open cell foam that is inert to blood. In one embodiment, the open cell foam may be a melamine foam, such as Basotect® foam commercially available from BASF. In another embodiment, the open cell foam may consist of a formaldehyde-melamine-sodium bisulfite copolymer. The open cell foam may be a flexible, hydrophilic open cell foam that is resistant to heat and many organic solvents. In one embodiment, the open cell foam may be a sponge material.

[0048] A method of loading an anticoagulant to a material **16** having pores **18** will now be discussed. In one embodiment, the method includes soaking the material **16** in a liquid solution of the anticoagulant and water; evaporating the water of the liquid solution; and forming a dry anticoagulant powder **20** within the pores **18** of the material **16**.

[0049] The method of the present disclosure enables precisely controlled loading of an anticoagulant into the material **16** by soaking it with an anticoagulant and water solution and then drying the material **16** to form a finely distributed dry anticoagulant powder **20** throughout the pores **18** of the material **16**, as shown in Fig. 2.

[0050] Anticoagulants such as Heparin or EDTA (Ethylene Diamine Tetra Acetic Acid), as well as other blood stabilization agents, could be introduced into the material **16** as a liquid solution by soaking the material **16** in the liquid solution of a desired concentration. After evaporating the liquid phase, e.g., evaporating the water from a water and Heparin solution, a

dry anticoagulant powder **20** is formed and finely distributed throughout the internal structure of the material **16**, as shown in **Fig. 2**. For example, the dry anticoagulant powder **20** is formed and finely distributed throughout the pores **18** of the material **16**. In a similar manner, the material **16** could be treated to provide a hydrophobic, hydrophilic, or reactive internal pore surface.

[0051] In one configuration, a key advantage of providing an open cell foam as the material **16** is that a known amount of anticoagulant may be loaded into the pores **18** of the foam material. A desired concentration of an anticoagulant may be dissolved in water or other suitable solvent and then introduced into the pores **18** of the open cell foam material **16** in liquid form. In one embodiment, the anticoagulant may be loaded into the pores **18** by dipping the open cell foam material **16** into a solution of anticoagulant and water or solvent and subsequently allowing the open cell foam material **16** to dry. The open cell foam material **16** may be allowed to dry in ambient air or in a heated oven. After drying, the anticoagulant may be distributed throughout the internal microstructure of the open cell foam material **16** in the form of a dry powder.

[0052] It is noted that suitable hydrophilic foam material having interconnected cell pores may be loaded with anticoagulant, as described above, and used as described herein for flow-through blood stabilization.

[0053] One key advantage of using a melamine-based open cell foam material is that melamine foams have a generally low analyte bias. As discussed herein, analyte bias is the difference in a measured value of an analyte as compared to a blood control value. Generally, analyte bias occurs when analytes adhere to a surface of a material, when analytes are leached from a material, via introduction of other components which may interfere with a measurement, or upon activation of a biological process. Additional open cell foam materials which are suitable for use as described herein include organic thermoplastic and thermosetting polymers and co-polymers, including but not limited to polyolefins, polyimides, polyamides, such as polyethylene terephthalate (PET), polypropylene (PP), polyethylene (PE), and the like. The material may be in fibrous structure, such as woven or random fiber form, or irregular 3D structure.

[0054] In order to avoid or minimize potential analyte bias associated with the housing **14** of the transfer device **10**, the material of the housing **14** may be treated. In one embodiment, the housing **14** may be treated with an additive coating which acts to block analytes from sticking to a surface. Additive coatings may include, but are not limited to, 1.) proteins, such as bovine serum albumin (BSA), casein, or non-fat milk, 2.) surfactants such as polysorbate 20

(Tween 20) and organosilicone (L-720), 3.) polymers and copolymers such as polyethylene glycol (PEG), polyvinyl alcohol (PVA), and polyvinylpyrrolidone (PVP), 4.) carbohydrates such as dextran and glycosamino glycans, such as heparin, and 5.) cell membrane mimicking polymers such as Lipidure.

[0055] Alternatively, the housing **14** may be treated with a chemical surface modification. Chemical surface modifications can include, but are not limited to, 1.) gas plasma treatment, 2.) chemical bonding or polyethylene glycol (PEG) or other polymers to achieve a desired hydrophobicity or hydrophilicity, 3.) chemical modification of the surface to include hydrophilic compositions such as ethylene glycol, or hydrophobic groups, such as long carbon chains, and 4.) vapor deposition of a substance, such as parylene. It is appreciated herein that combinations of any of the above materials may be used to achieve the desired properties to minimize analyte bias for a specific analyte or group of analytes.

[0056] In one embodiment, the mixing chamber **36** includes the material **16** having a dry anticoagulant powder **20** therein. For example, referring to **Figs. 1 and 3**, the material **16** is disposed within the mixing chamber **36** of the specimen mixing and transfer device **10**. The anticoagulant can be loaded into the material **16** having pores **18** as described above.

[0057] Referring to **Fig. 1**, the housing **14** of the specimen mixing and transfer device **10** is adapted to receive a sample **12** therein via the first end **22**. For example, the housing **14** of the specimen mixing and transfer device **10** is adapted to receive a sample **12** therein via the inlet **28**. After the sample **12** enters the specimen mixing and transfer device **10** via the inlet **28**, the sample **12** flows through the inlet channel **32** to the mixing chamber **36**.

[0058] With the sample **12** received within the mixing chamber **36**, the mixing chamber **36** acts as a flow-through chamber for the effective mixing of a sample **12** with the dry anticoagulant powder **20** within the material **16**. In other embodiments, the material **16** may contain other dry substances. The effective mixing is achieved by passing the sample **12** through the material **16** having the dry anticoagulant powder **20** distributed throughout its microstructure. The sample **12** dissolves and mixes with the dry anticoagulant powder **20** while passing through the material **16**.

[0059] Referring to **Fig. 2**, a view of the microstructure of the material **16** having a dry anticoagulant powder **20** distributed throughout its microstructure, e.g., its pores **18**, is illustrated.

[0060] Referring to **Fig. 3**, in one embodiment, the housing **14** of the specimen mixing and transfer device **10** includes a dispensing chamber or holding chamber **38**. The dispensing chamber **38** may be adjacent the outlet **30** of the specimen mixing and transfer device **10**. For

example, the dispensing chamber **38** may be disposed between the mixing chamber **36** and the outlet **30**.

[0061] After the blood sample is exposed to and mixes with the anticoagulant powder **20** while passing through the intricate microstructure of the material **16**, a stabilized sample flows from the material **16** to the dispensing chamber **38** via the outlet channel **34**. The stabilized sample can remain within the dispensing chamber **38** until it is desired to transfer the stabilized sample from the specimen mixing and transfer device **10**. For example, the stabilized sample may be transferred to a diagnostic instrument such as a blood testing device, a point-of-care testing device, or similar analytical device.

[0062] **Figs. 4-10** illustrate other exemplary embodiments of a specimen mixing and transfer device of the present disclosure. Referring to **Figs. 4-10**, a specimen mixing and transfer device of the present disclosure may also be effective with small blood volumes that are typically associated with laminar flow conditions that require flow obstacles to promote mixing with a dry anticoagulant deposited on the walls of the flow-through structure.

[0063] **Figs. 4-6** illustrate another exemplary embodiment of a specimen mixing and transfer device of the present disclosure. The specimen mixing and transfer device **100** is adapted to receive a sample **112**. In some embodiments, the sample **112** may be a blood sample. In one embodiment, the specimen mixing and transfer device **100** includes a housing **114**, a dry anticoagulant powder **120** disposed within the housing **114**, and a mixing element **115** disposed within the housing **114**.

[0064] The housing **114** includes a first end **122**, a second end **124**, and a sidewall **126** extending between the first end **122** and the second end **124**. In one embodiment, the first end **122** includes an inlet **128** and the second end **124** includes an outlet **130**.

[0065] Referring to **Fig. 5**, in one embodiment, the housing **114** of the specimen mixing and transfer device **100** includes an inlet channel **132** and an outlet channel **134**. The inlet channel **132** and the outlet channel **134** are in fluid communication via a flow channel or mixing chamber **136**. For example, the inlet channel **132** is in fluid communication with the inlet **128** and the mixing chamber **136**; and the outlet channel **134** is in fluid communication with the mixing chamber **136** and the outlet **130**. In one embodiment, the dry anticoagulant powder **120** is disposed within the mixing chamber **136** of the housing **114**.

[0066] In one embodiment, the inlet channel **132** and the outlet channel **134** are in fluid communication via a first flow channel **140** and a second flow channel **142**. For example, the inlet channel **132** may branch off into two separate flow channels, e.g., the first flow channel **140** and the second flow channel **142**. The two separate flow channels, e.g., the first flow

channel **140** and the second flow channel **142**, may both flow into the outlet channel **134** as shown in **Fig. 5**.

[0067] The first flow channel **140** includes walls **144** and the second flow channel **142** includes walls **146**. In one embodiment, a first portion of the dry anticoagulant powder **120** is deposited on walls **144** and a second portion of the dry anticoagulant powder **120** is deposited on walls **146**. For example, in one embodiment, a first portion of the dry anticoagulant powder **120** is deposited on an interior surface **148** of the housing **114**, e.g., an interior surface of wall **144**, and a second portion of the dry anticoagulant powder **120** is deposited on an interior surface **148** of the housing **114**, e.g., an interior surface of wall **146**.

[0068] Referring to **Fig. 5**, in one embodiment, the housing **114** of the specimen mixing and transfer device **100** includes a dispensing chamber or holding chamber **138**. The dispensing chamber **138** may be adjacent to the outlet **130** of the specimen mixing and transfer device **100**. For example, the dispensing chamber **138** may be disposed between the mixing chamber **136** and the outlet **130**. In one embodiment, the dispensing chamber **138** may be positioned between the flow channels **140**, **142** and the outlet **130**.

[0069] In one embodiment, the specimen mixing and transfer device **100** includes a mixing element **115** disposed within the housing **114**. For example, a portion of the mixing chamber **136** may also include obstacles or mixing promoters **150** that interfere with the flow path of the blood sample thereby promoting mixing between the blood sample and the dry anticoagulant powder **120**. In some embodiments, a portion of the first flow channel **140** and a portion of the second flow channel **142** may include obstacles or mixing promoters **150** that interfere with the flow path of the blood sample thereby promoting mixing between the blood sample and the dry anticoagulant powder **120**.

[0070] Referring to **Figs. 4-6**, the specimen mixing and transfer device **100** is adapted to receive a sample **112** therein via the first end **122**. For example, the housing **114** of the specimen mixing and transfer device **100** is adapted to receive a sample **112** therein via the inlet **128**. The sample **112** flows into the inlet **128** and to the inlet channel **132**. In some embodiments, the sample **112** may be a blood sample.

[0071] With the blood sample received within the inlet channel **132**, a first portion **152** of the blood sample flows to the first flow channel **140** and a second portion **154** of the blood sample flows to the second flow channel **142**. The first flow channel **140** provides a first flow path for the first portion **152** of the blood sample and the second flow channel **142** provides a second flow path for the second portion **154** of the blood sample.

[0072] With the first portion **152** of the blood sample received within the first flow channel **140**, the first portion **152** of the blood sample mixes with a first portion of the dry anticoagulant powder **120** deposited on the walls **144** of the first flow channel **140**. The first flow channel **140** may also include obstacles or mixing promoters **150** that interfere with the flow path of the blood sample thereby promoting mixing between the blood sample and the first portion of the dry anticoagulant powder **120**. After mixing, the first portion **152** of the blood sample and the first portion of the dry anticoagulant powder **120**, i.e., a stabilized blood sample, travel to the outlet channel **134**.

[0073] With the second portion **154** of the blood sample received within the second flow channel **142**, the second portion **154** of the blood sample mixes with a second portion of the dry anticoagulant powder **120** deposited on the walls **146** of the second flow channel **142**. The second flow channel **142** may also include obstacles or mixing promoters **150** that interfere with the flow path of the blood sample thereby promoting mixing between the blood sample and the second portion of the dry anticoagulant powder **120**. After mixing, the second portion **154** of the blood sample and the second portion of the dry anticoagulant powder **120**, i.e., a stabilized blood sample, travel to the outlet channel **134**.

[0074] In other embodiments, other portions of the specimen mixing and transfer device **100** may also include obstacles or mixing promoters **150** that interfere with the flow path of the blood sample thereby promoting mixing between the blood sample and the dry anticoagulant powder **120**.

[0075] **Figs. 7-10** illustrate other exemplary embodiments of a specimen mixing and transfer device of the present disclosure. Referring to **Figs. 7 and 8**, the specimen mixing and transfer device **200** is adapted to receive a sample **212**. In some embodiments, the sample **212** may be a blood sample. In one embodiment, the specimen mixing and transfer device **200** includes a housing **214**, a dry anticoagulant powder **220** disposed within the housing **214**, and a mixing element **215** disposed within the housing **214**.

[0076] The housing **214** includes a first end **222**, a second end **224**, and a sidewall **226** extending between the first end **222** and the second end **224**. In one embodiment, the first end **222** includes an inlet **228** and the second end **224** includes an outlet **230**.

[0077] Referring to **Fig. 8**, in one embodiment, the housing **214** of the specimen mixing and transfer device **200** includes an inlet channel **232** and an outlet channel **234**. The inlet channel **232** and the outlet channel **234** are in fluid communication via a flow channel or mixing chamber **236**. For example, the inlet channel **232** is in fluid communication with the inlet **228** and the mixing chamber **236**; and the outlet channel **234** is in fluid communication with the

mixing chamber **236** and the outlet **230**. In one embodiment, the dry anticoagulant powder **220** is disposed within the mixing chamber **236** of the housing **214**. In one embodiment, the dry anticoagulant powder **220** is deposited on an interior surface **260** of the housing **214**.

[0078] Referring to **Fig. 8**, in one embodiment, the housing **214** of the specimen mixing and transfer device **200** includes a dispensing chamber or holding chamber **238**. The dispensing chamber **238** may be adjacent to the outlet **230** of the specimen mixing and transfer device **200**. For example, the dispensing chamber **238** may be disposed between the mixing chamber **236** and the outlet **230**.

[0079] In one embodiment, the specimen mixing and transfer device **200** includes a mixing element **215** disposed within the housing **214**. In one embodiment, the mixing element **215** includes a plurality of posts **270**. For example, the mixing chamber **236** may include a plurality of posts **270** that interfere with the flow path of the blood sample thereby promoting mixing between the blood sample and the dry anticoagulant powder **220**.

[0080] Referring to **Figs. 7 and 8**, the specimen mixing and transfer device **200** is adapted to receive a sample **212** therein via the first end **222**. For example, the housing **214** of the specimen mixing and transfer device **200** is adapted to receive a sample **212** therein via the inlet **228**. The sample **212** flows into the inlet **228** and to the inlet channel **232**. In some embodiments, the sample **212** may be a blood sample.

[0081] With the blood sample received within the inlet channel **232**, the blood sample flows into the mixing chamber **236**. As the blood sample flows into the mixing chamber **236**, the blood sample mixes with the dry anticoagulant powder **220** deposited on an interior surface **260** of the housing **214**. The mixing chamber **236** may include the plurality of posts **270** that interfere with the flow path of the blood sample thereby promoting mixing between the blood sample and the dry anticoagulant powder **220**. After mixing, the blood sample and the dry anticoagulant powder **220**, i.e., a stabilized blood sample, travel to the outlet channel **234**.

[0082] In other embodiments, other portions of the specimen mixing and transfer device **200** may also include mixing elements **215** that interfere with the flow path of the blood sample thereby promoting mixing between the blood sample and the dry anticoagulant powder **220**.

[0083] Referring to **Fig. 10**, alternate embodiments of a specimen mixing and transfer device of the present disclosure are illustrated.

[0084] **Figs. 11A-16** illustrate another exemplary embodiment of a material of the present disclosure. The material **502** includes pores **505** and has a dry anticoagulant powder **504** within the pores **505** of the material **502**, as described above. In one embodiment, the material **502** is a sponge material. In other embodiments, the material **502** is an open cell foam. In one

embodiment, the open cell foam is treated with an anticoagulant, as described in detail above, to form a dry anticoagulant powder **504** finely distributed throughout the pores **505** of the material **502**.

[0085] In one embodiment, the material **502** is an open cell foam. For example, the material **502** is a soft deformable open cell foam that is inert to blood. In one embodiment, the open cell foam may be a melamine foam, such as Basotect® foam commercially available from BASF. In another embodiment, the open cell foam may consist of a formaldehyde-melamine-sodium bisulfite copolymer. The open cell foam may be a flexible, hydrophilic open cell foam that is resistant to heat and many organic solvents. In one embodiment, the open cell foam may be a sponge material.

[0086] Referring to **Figs. 11A-16**, the material **502** can be utilized with a syringe assembly **500**. The syringe assembly **500** may include an open cell foam material **502** having a dry anticoagulant powder **504** therein. The open cell foam material **502** is disposed within the syringe assembly **500**. The anticoagulant can be loaded into the open cell foam material **502** having pores **505**, as described above.

[0087] In one embodiment, the syringe assembly **500** includes a syringe barrel **506** having a first end **508**, a second end **510**, and a sidewall **512** extending therebetween and defining an interior **514**. Referring to **Figs. 11A-11C and 15**, the open cell foam material **502** is disposed within the interior **514** of the syringe barrel **506**.

[0088] In one embodiment, the syringe assembly **500** includes a plunger rod **516** and a stopper **518**. The plunger rod **516** includes a first end **520** and a second end **522**. The stopper **518** is engaged with the second end **522** of the plunger rod **516** and is slidably disposed within the interior **514** of the syringe barrel **506**. The stopper **518** is sized relative to the interior **514** of the syringe barrel **506** to provide sealing engagement with the sidewall **512** of the syringe barrel **506**.

[0089] The open cell foam material **502** is placed in the syringe barrel **506** for mixing and stabilizing blood. The blood gets collected in the syringe barrel **506** with the open cell foam material **502** embedded inside the syringe barrel **506**. The stabilized blood can then be dispensed for analysis. In one embodiment, the syringe assembly **500** is an arterial blood gas syringe and the stabilized blood can be dispensed for blood gas analysis.

[0090] In one embodiment, the syringe assembly **500** acts as a flow-through chamber for the effective mixing of a blood sample with the dry anticoagulant powder **504** within the open cell foam material **502**. In other embodiments, the open cell foam material **502** may contain other dry substances. The effective mixing is achieved by passing the blood sample through the open

cell foam material **502** having the dry anticoagulant powder **504** distributed throughout its microstructure.

[0091] Referring to **Fig. 13**, a view of the microstructure of the open cell foam material **502** having a dry anticoagulant powder **504** distributed throughout its microstructure is illustrated. Referring to **Fig. 14**, a view of the microstructure of an untreated foam material **502** is illustrated. Referring to **Fig. 16**, a graph is illustrated demonstrating the anticoagulant uptake by a blood sample flowing through an open cell foam material having a dry anticoagulant powder distributed throughout its microstructure.

[0092] **Figs. 17-20** illustrate an exemplary embodiment of a specimen mixing and transfer system of the present disclosure. Referring to **Figs. 17-20**, in one embodiment, a blood transfer system **600** includes a syringe assembly **602**, a line **604**, and a container **606**. In one embodiment, the container **606** contains blood **608**.

[0093] In one embodiment, the line **604** includes an open cell foam material **612** having a dry anticoagulant powder **614** therein. The anticoagulant can be loaded into the open cell foam material **612** having pores, as described above. The open cell foam material **612** is disposed within the line **604**. The line **604** includes a first end **616** and a second end **618**.

[0094] In one embodiment, the syringe assembly **602** includes a syringe barrel **620** and a sidewall **622** defining an interior **624**. Referring to **Figs. 17-20**, the line **604** is adapted to place the syringe assembly **602** and the container **606** in fluid communication. For example, the first end **616** of the line **604** can be in fluid communication with the contents of the container **606**, and the second end **618** of the line **604** can be in fluid communication with the syringe assembly **602**.

[0095] The open cell foam material **612** is placed in the line **604** for mixing and stabilizing blood. In one embodiment, the blood **608** is transferred from the container **606** to the syringe barrel **620** via the line **604**. For example, a blood sample, e.g., blood **608**, passes through the line **604** with the open cell foam material **612** embedded inside the line **604** as the blood gets collected into the syringe barrel **620**. In this manner, the blood **608** is stabilized before entering the syringe barrel **620**. After the stabilized blood **608** is contained within the syringe barrel **620**, the stabilized blood **608** can then be dispensed for analysis.

[0096] In one embodiment, the line **604** acts as a flow-through chamber for the effective mixing of a blood sample with the dry anticoagulant powder **614** within the open cell foam material **612**. In other embodiments, the open cell foam material **612** may contain other dry substances. The effective mixing is achieved by passing the blood sample through the open

cell foam material **612** having the dry anticoagulant powder **614** distributed throughout its microstructure.

[0097] The present disclosure provides a material that includes pores and has a dry anticoagulant powder within the pores of the material, as described above. In one embodiment, the material is a sponge material. In other embodiments, the material is an open cell foam. In one embodiment, the open cell foam is treated with an anticoagulant, as described in detail above, to form a dry anticoagulant powder finely distributed throughout the pores of the material.

[0098] The present disclosure provides different applications and embodiments of the material. For example, in one embodiment, a specimen mixing and transfer device of the present disclosure is adapted to receive a sample. The specimen mixing and transfer device includes a housing, a material including pores that is disposed within the housing, and a dry anticoagulant powder within the pores of the material. In one embodiment, the material is a sponge material. In other embodiments, the material is an open cell foam. In one embodiment, the open cell foam is treated with an anticoagulant to form a dry anticoagulant powder finely distributed throughout the pores of the material. A blood sample may be received within the specimen mixing and transfer device. The blood sample is exposed to and mixes with the anticoagulant powder while passing through the material.

[0099] A specimen mixing and transfer device of the present disclosure offers uniform and passive blood mixing with an anticoagulant under flow-through conditions. A specimen mixing and transfer device of the present disclosure could catch blood clots or other contaminants within the microstructure of the material and prevent them from being dispensed into a diagnostic sample port. A specimen mixing and transfer device of the present disclosure enables a simple, low-cost design for passive flow-through blood stabilization. A specimen mixing and transfer device of the present disclosure enables precisely controlled loading of an anticoagulant into the material by soaking it with an anticoagulant and water solution and then drying the material to form a finely distributed dry anticoagulant powder throughout the pores of the material.

[00100] A specimen mixing and transfer device of the present disclosure may provide an effective passive blood mixing solution for applications wherein blood flows through a line. Such a specimen mixing and transfer device is useful for small blood volumes, e.g., less than 50 μL or less than 500 μL , and/or where inertial, e.g., gravity based, forces are ineffective for bulk manual mixing by flipping back and forth a blood collection container such as is required for vacuum tubes.

[00101] In other embodiments of the present disclosure, the material can be utilized with a specimen mixing and transfer system or a syringe assembly, as described above.

[00102] While this disclosure has been described as having exemplary designs, the present disclosure can be further modified within the spirit and scope of this disclosure. This application is therefore intended to cover any variations, uses, or adaptations of the disclosure using its general principles. Further, this application is intended to cover such departures from the present disclosure as come within known or customary practice in the art to which this disclosure pertains and which fall within the limits of the appended claims.

CLAIMS

1. A specimen mixing and transfer device adapted to receive a fluid sample, comprising:

a housing having a first end comprising an inlet for receiving the fluid sample, a second end comprising an outlet for expelling at least a portion of the fluid sample therefrom, and a sidewall extending therebetween;

a material including pores disposed within the housing between the inlet and the outlet;

a dry anticoagulant powder within the pores of the material;

a mixing chamber, the material disposed within the mixing chamber; and

a dispensing chamber in fluid communication with the mixing chamber, wherein the dispensing chamber holds the fluid sample mixed with the dry anticoagulant powder until it is desired to transfer the fluid sample from the outlet of the specimen mixing and transfer device.

2. The specimen mixing and transfer device of claim 1, wherein the sample is a blood sample.

3. The specimen mixing and transfer device of claim 1, wherein, when the blood sample is received within the housing, the material is configured to allow the blood sample to pass therethrough for effectively mixing the blood sample with the dry anticoagulant powder.

4. The specimen mixing and transfer device of claim 1, wherein the material is an open cell foam.

5. The specimen mixing and transfer device of claim 1, wherein the material is a sponge.

6. The specimen mixing and transfer device of claim 1, wherein the housing further comprises an inlet channel in fluid communication with the inlet and the mixing chamber and an outlet channel in fluid communication with the mixing chamber and the outlet.

7. The specimen mixing and transfer device of claim 6, wherein the dispensing chamber is disposed between the mixing chamber and the outlet.