

electrodes placed along a flow channel to result in the pumping of the fluids comprising the sample components. As is described in the art, the configurations for each of these electrode based pumps are slightly different; for example, the effectiveness of an EHD pump depends on the spacing between the two electrodes, with the closer together they are, the smaller the voltage required to be applied to effect fluid flow. Alternatively, for EO pumps, the spacing between the electrodes should be larger, with up to one-half the length of the channel in which fluids are being moved, since the electrode are only involved in applying force, and not, as in EHD, in creating charges on which the force will act.

[0229] In a preferred embodiment, an electroosmotic pump is used. Electroosmosis (EO) is based on the fact that the surface of many solids, including quartz, glass and others, become variously charged, negatively or positively, in the presence of ionic materials. The charged surfaces will attract oppositely charged counterions in aqueous solutions. Applying a voltage results in a migration of the counterions to the oppositely charged electrode, and moves the bulk of the fluid as well. The volume flow rate is proportional to the current, and the volume flow generated in the fluid is also proportional to the applied voltage. Electroosmotic flow is useful for liquids having some conductivity and is generally not applicable for non-polar solvents. EO pumps are described in U.S. Pat. Nos. 4,908,112 and 5,632,876, PCT US95/14586 and WO97/43629, incorporated by reference.

[0230] In a preferred embodiment, an electrohydrodynamic (EHD) pump is used. In EHD, electrodes in contact with the fluid transfer charge when a voltage is applied. This charge transfer occurs either by transfer or removal of an electron to or from the fluid, such that liquid flow occurs in the direction from the charging electrode to the oppositely charged electrode. EHD pumps can be used to pump resistive fluids such as non-polar solvents. EHD pumps are described in U.S. Pat. No. 5,632,876, hereby incorporated by reference.

[0231] The electrodes of the pumps preferably have a diameter from about 25 microns to about 100 microns, more preferably from about 50 microns to about 75 microns. Preferably, the electrodes protrude from the top of a flow channel to a depth of from about 5% to about 95% of the depth of the channel, with from about 25% to about 50% being preferred. In addition, as described in PCT US95/14586, an electrode-based internal pumping system can be integrated into the liquid distribution system of the devices of the invention with flow-rate control at multiple pump sites and with fewer complex electronics if the pumps are operated by applying pulsed voltages across the electrodes; this gives the additional advantage of ease of integration into high density systems, reductions in the amount of electrolysis that occurs at electrodes, reductions in thermal convection near the electrodes, and the ability to use simpler drivers, and the ability to use both simple and complex pulse wave geometries.

[0232] The voltages required to be applied to the electrodes cause fluid flow depends on the geometry of the electrodes and the properties of the fluids to be moved. The flow rate of the fluids is a function of the amplitude of the applied voltage between electrode, the electrode geometry and the fluid properties, which can be easily determined for each fluid. Test voltages used may be up to about 1500 volts,

but an operating voltage of about 40 to 300 volts is desirable. An analog driver is generally used to vary the voltage applied to the pump from a DC power source. A transfer function for each fluid is determined experimentally as that applied voltage that produces the desired flow or fluid pressure to the fluid being moved in the channel. However, an analog driver is generally required for each pump along the channel and is suitable an operational amplifier.

[0233] In a preferred embodiment, a micromechanical pump is used, either on- or off-chip, as is known in the art.

[0234] In a preferred embodiment, an "off-chip" pump is used. For example, the devices of the invention may fit into an apparatus or appliance that has a nesting site for holding the device, that can register the ports (i.e. sample inlet ports, fluid inlet ports, and waste outlet ports) and electrode leads. The apparatus can including pumps that can apply the sample to the device; for example, can force cell-containing samples into cell lysis modules containing protrusions, to cause cell lysis upon application of sufficient flow pressure. Such pumps are well known in the art.

[0235] In a preferred embodiment, the devices of the invention include at least one fluid valve that can control the flow of fluid into or out of a module of the device, or divert the flow into one or more channels. A variety of valves are known in the art. For example, in one embodiment, the valve may comprise a capillary barrier, as generally described in PCT US97/07880, incorporated by reference. In this embodiment, the channel opens into a larger space designed to favor the formation of an energy minimizing liquid surface such as a meniscus at the opening. Preferably, capillary barriers include a dam that raises the vertical height of the channel immediate before the opening into a larger space such a chamber. In addition, as described in U.S. Pat. No. 5,858,195, incorporated herein by reference, a type of "virtual valve" can be used.

[0236] In a preferred embodiment, the devices of the invention include sealing ports, to allow the introduction of fluids, including samples, into any of the modules of the invention, with subsequent closure of the port to avoid the loss of the sample.

[0237] In a preferred embodiment, the devices of the invention include at least one storage modules for assay reagents. These are connected to other modules of the system using flow channels and may comprise wells or chambers, or extended flow channels. They may contain any number of reagents, buffers, enzymes, electronic mediators, salts, etc., including freeze dried reagents.

[0238] In a preferred embodiment, the devices of the invention include a mixing module; again, as for storage modules, these may be extended flow channels (particularly useful for timed mixing), wells or chambers. Particularly in the case of extended flow channels, there may be protrusions on the side of the channel to cause mixing.

[0239] In a preferred embodiment, the devices of the invention include a detection module. The detection module can be separate from the magnetic microchannel, or, more preferably, it is directly linked to the magnetic microchannel by at least one fluidic microchannel. Alternatively, it can be linked to any other modules of the devices of the invention.

[0240] In a preferred embodiment, the detection module comprises one or a multiplicity of arrays, particularly