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High throughput reciprocating electroosmotic micropump for blood plasma separation using in the blood panel microfluidic device

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Lab-on-a-Chip (LOC) integrated microfluidics has been a powerful tool for new developments in analytical chemistry. These microfluidic systems enable the miniaturization, integration and automation of complex biochemical assays through the reduction of reagent use and enabling portability. There are many applications in clinical, veterinary, agricultural, food industry and environmental which analyzing the chemical composition of the samples could be useful, but the inaccessibility to the chemical laboratories is postponing these tests. For instance, in clinics, Point of care (POC) products presented smartness, speed, cost-effectiveness, and portability. These characteristics have motivated many researchers to develop novel instruments based on this technology. Current work proposes a novel combination of electroosmotic and capillary forces to design high throughput blood plasma separation microfluidic chip. Miniaturization of the a human blood test device and separation of red blood cells by low DC voltage in a short time as a point of care device was objective of current work. In principle, the blood plasma separation is based on the filtration and electro-osmotic mechanisms. First, the microchannel is filled by capillary flow and blood plasma is drawn in a micro-filter micro-array (MFMA) while red blood cells accumulate in the entrance of MFMA. The red blood cell clogging is an inevitable and major issue in filtration, which can be modulated by increasing the shear rate on the trapped cells that can sweep them away from the entrance of the filtration channel. For this reason, two different mechanisms were introduced in the design and performance of such a microdevice. In the microdevice design, a constriction has been allocated in the middle of the transport channel for increasing the shear rate on the trapped RBCs, resulting reduction of the RBCs accumulation in the entrance of the separation area. This mechanism delays the RBCs clogging of the separation area entrance at the microdevice performance. As the second mechanism, the reciprocating electro-osmotic flow (EOF) was utilized to control the blood cell movement in the microdevice. Under an applied electric field, the motion of blood cells in a microchannel can be controlled by determining the net force of cells due to both EOF of plasma and electrophoresis of cells. In this strategy, after stabilization of the blood plasma process and RBCs accumulation at the entrance of the separation area; the RBCs accumulation has been broken via reverse the DC electro-osmotic flow direction due switch back of electric field. Due to this method the microdevice was fabricated, which consisted of the PDMS (Polydimethylsiloxane) main microchannel (Top part) and the glass etched (down part). The lithography and wet chemical etching methods have been used in order to produce glass etched, micro filter micro array (2- μ m height). Both parts were bonded via an oxygen plasma treatment. Two Platinum electrodes (Roland Consult-Germany) allocated in the inlet and outlets of the main channel were used for creating the electric field. In order to analysis the electroosmotic flow, the ANSYS Multiphysics (ANSYS Academic Research, 14.5 User's Guide, ANSYS, Inc. 2014) was applied to generate a numerical model of electric field distribution inside microchannel. To demonstrate the potential as a clinical tool two different types of test are implemented. First a single test for the qualitative detection of the TSH (thyroid-stimulating hormone). The TSH test measures the levels of TSH, a hormone that is produced and released by your pituitary gland. The official "normal" range for the Thyroid Stimulating Hormone (TSH) blood test runs from approximately 0.5 to 4.5/5.0 μ IU/ml. In this range, a TSH under 0.5 μ IU/ml indicated hyperthyroidism (an overactive thyroid), and a TSH over 5.0 μ IU/ml indicated hypothyroidism (an underactive thyroid). But since the use of the reversible electroosmotic flow allows an increased extraction of plasma, a blood panel for measuring two indicators in the diagnosis of myocardial infarction (MI): Cardiac Troponin (cTnI) and Creatine Kinase MB (CK-MB) have also been implemented by hybridizing the proposed microfluidic circuit with lateral flow immune chromatography technologies. cTnI is a protein found in the cardiac muscle that is released into the blood 4-6 hours after the onset of pain. CK-MB is an enzyme found in the cardiac muscle too, but that is released 3-8 hours after the onset of symptoms, but it lasts up to 72 hours while cTnI can become elevated up to 10 days. A Combination of both measurements in the same test increases the efficiency of the diagnosis. Using this microfluidic device, substantial separated blood plasma was observed for voltages lower than 50 V. Consequently 1 μ L human blood plasma 99% purity where, filled with collecting channel and plasma reservoirs from 10 μ L human blood. The capability of the presented microdevice for separating and gathering blood plasma pave the way for portable blood analysis in biomedical application as a point of care device or cell separation in different samples.

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