MAGNETIC PARTICLES RETAINING ON OPEN AND CLOSED SYSTEMS

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Abstract: In recent decades the application of magnetic iron oxide micro- and nano-particles has been established in various technological fields, such as magnetic separation of biomolecules and ions, biosensors, biofuel production and others [1,2]. Working with iron oxide particles is becoming main stream subject thanks to the facility thatthis kind of materials can be functionalized with a variety of chemical groups which confer them specific selective or catalytic properties [3]. Furthermore, iron oxide nano-particles present magnetic properties, and in particular super-paramagnetism, which allows to remotely control them making their manipulation easy and cost-effective [4]. In addition, a new method of synthesis has been recently proposed, which can guarantee a cost-effective production of magnetic particles that may further reduce the running cost of separation methods based on magnetism [5]. Nevertheless, biotechnological applications of iron oxide particles are still confined to research level (lab scale devices) or for low throughput clinical applications [6]. Indeed, most systems based on the use of magnetic elements are designed to work with microfluid dynamic or can process samples in bath-based fashion, therefore discontinuously. The need of robust and high-productive methods is demanded especially in bioscience where, independently from the reaction or process involving magnetic particles, once such composite materials are mixed or added to a given solution, inevitably at the end of workflow they must be separated/harvested from the reaction vessel. Therefore, it is vital for a good productivity and processivity of reactions involving magnetic particles to ensure that large volumes of solution can be treated, and magnetic particles withdrew in the most fast and accurate way. The purpose of this paper is to compare an open and a closed type magnetic trapping system regarding their efficiency using two different types of magnetic sources.

Introduction

In both experiments [7,8], for the liquid solution we used ethanol ≥ 98% (Honeywell, Germany), oleic acid 90% (Alfa Aesar, Germany) and Iron oxide (Fe_3O_4) magnetic particles containing large polydomains with an average size of 200-400 nm, purchased from Chemical Store, USA.

We dissolved magnetic particles in ethanol containing 5% of oleic acid. Specifically, oleic acid was used to obtain a colloidal solution of dispersed magnetic particles. 0.1 grams of magnetite (Fe_3O_4) particles have been dissolved in 100 ml of alcoholic solvent by thoroughly shaking the flask. The resulting solution was homogenous, with magnetite particles well dispersed and showed an intense dark color; however, sedimentation of particles occurred when the solution was left un-stirred for long time.

Open system. Simulations in ANSYS were realized aiming to design, study and optimize the appropriate magnetic surface. An experimental setup was designed in order to verify the simulations. The setup is formed by an array of permanent magnets, a plastic surface, a peristaltic pump and silicon tube.

A 10x10 cm plastic foil was used together with 42 small neodymium magnets to realize the magnetic surface.

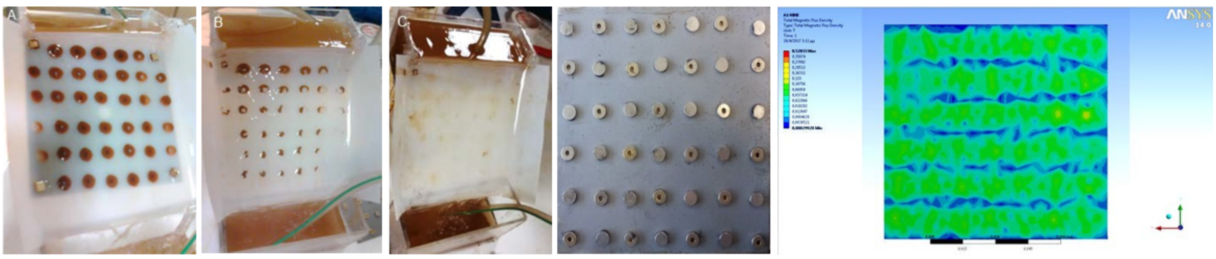

Fig.1. Open system setup A) the SPIONs are retained at the areas above the magnets B) after the magnets are removed, the flow gradually washes away the SPIONs C) after a few seconds the SPIONs are completely removed D) Neodymium magnets array and E) total magnetic field density produced.

The setup was consisted of a plastic surface (ABS) (120x100x1mm), the array of 42 neodymium magnets (N52) (2x5mm) underneath the plastic surface, a peristaltic pump, two tanks and a silicon tube (d=4mm).

The SPIONs were suspended in an ethanol-oleic acid mix in order to avert agglomeration and they were being circulated via the pump through the magnetic surface. From the first pass, the SPIONs were retained on the surface. After removing the magnetic array, the SPIONs started washing away with the flow. The same experiment was repeated several times at different velocities in order to assert the max velocity allowing the SPIONs to be retained on the surface and they were in accordance with the simulations.

Closed system. A Teflon hose 100 mm length with a 4 mm external diameter and 3 mm internal diameter was used for the experiment. 80 mm of the Teflon hose were coiled into 8 turns around a 50 ml tube. The magnetic field was generated by striped North-South magnetic lines. The anisotropic flexible ferric magnetic strip (Neodymium Iron Boron, NdFeB) was 40 mm wide and has been purchased from Magnitech, Greece. The magnetic core can easily be inserted into the tube with the coiled Teflon hose. A peristaltic pump was used and a hose with a diameter of 4 mm, and a 3-way splitter with a manually adjustable valve (Figure 2).

We assumed that the magnetic particles that are close to the hose walls move slower than those in the center and thus, they can be retained easier by the magnetic field. However, since a spiral geometry was used, the mixing of the particles was allowed and statistically, most of the particles could be trapped. Thus, it can be assessed that the purity of the solution depends not only on the velocity of the fluid, but also on the number of the turns of the helical coil and the concentration of the particles in the solution.

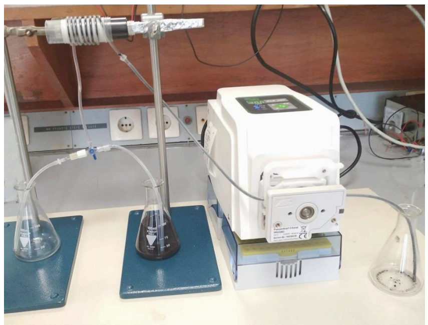

Fig.2. Experimental setup. Peristaltic pump, tube, magnetic core and valve are depicted

The peristaltic pump was set to a pumping rate of roughly 0.1 ml/sec and one side of the propelling hose was immerse in alcoholic solution containing particles, whereas the other side connected to the inlet pipe of the spiral. As the solution started to reach the pipe wrapped around the magnetic surface, the magnetic particles initiated to be trapped along the entire spiral. Once all alcoholic mixture was pumped through the spiral hose the peristaltic pump was let to run for a few seconds more in order to empty all the piping system. The solution deprived of magnetic particles was collect in a specific flask, and almost all magnetic particles were trapped by the spiral hose. Last, to elute magnetic particles from the system, we first separated the magnetic core from the spiral hose and subsequently used 20 ml of alcoholic solution to remove and collect magnetic particles in a separate flask. After passing the 20 ml of fresh alcoholic solution, the magnetic particles were completely removed from the spiral hose.

Comparison

In terms of efficiency, both systems provided a satisfying separation rate (up to 90%). Depending on the application, each process can provide some cos and pros. The open system is able to work for materials of various shape and size, something that is more restricted in the closed system. Such kind of materials could be the products from a mining process. However, the closed system can become fully automatic and provide a high throughput for biotechnological processes.

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