

## UV- sensitive Hydrogel GelMA Filled with FeCo-PET Particles

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### Summary:

The purpose of this study was the preliminary development of a biocompatible material suitable for soft actuating. In this paper we present the process and results of UV-sensitive GelMA synthesis, which has an addition of FeCo particles, and we confirm its responsibility to the magnetic field. The development of soft biocompatible materials could lead to the creation of new applications in biomedicine through controlled actuation, for example, for precise drug delivery.

**Keywords:** hydrogels, soft actuation, magnetic particles, ultra violet, biocompatibility

### Background, Motivation and Objective

Since the development of a biocompatible 3D-printable hydrogel, its function tuning has been of significant importance in research. Among these developments, the increasing interest in remotely stimuli-responsive and biocompatible components to the magnetic field could lead to new applications in various fields [1]. With its 3D-printable properties, it can be considered as a component for miniaturised devices in the form of soft microactuators or active microvalves. So far, such soft actuators have been made of conventional thermoresponsive hydrogel materials such as PEGDA, PNIPAM [2]. However, their fabrication often relies on traditional, less scalable methods. Meanwhile, these materials have limited mechanical strength and slow response. In this paper we present the preliminary study of the development of a UV-sensitive hydrogel mixed with magnetic particles and the simple result of its response to the magnetic field.

### Materials and Methods

For hydrogel synthesis, we chose gelatin methacryloyl (GelMA). To determine the degree of substitution (DS) of amide groups with methacryloyl in GelMA, we used the 2,4,6-trinitrobenzenesulfonic acid (TNBS)-based assay. To make the hydrogel structures harden, we used a UV exposure. For this we incorporated photosensitive agents (lithium phenyl-2,4,6-trimethylbenzoylphosphinate (LAP; Sigma Aldrich, US). Furthermore, we added the magnetic particles (MPs) (FeCo or SmFeN) whose size was determined by SEM microscopy. However, these MPs in an aqueous environment are

unstable. This can be prevented with the surface coating of the particles that makes them hydrophilic. For the coating, polyethylene terephthalate (PET) was used. To make the PET coating, the MPs were ultrasonicated in PET/hexafluoro-2-propanol (HFLP, Sigma-Aldrich, US). Then the MPs were released from solution, washed in ethanol, and dried. To confirm the coating, we used SEM and Fourier Transform Infrared (FT-IR) analyses. Furthermore, the MPs were placed in the synthesised hydrogel, the channel was formed aside MPs and UV-cured (Fig. 1). To confirm the responsiveness of the hydrogels with MPs to the magnetic field, a commercial magnet (~ 100 mT) was used. As a liquid, to be guided through the channel, we chose blue-coloured water.

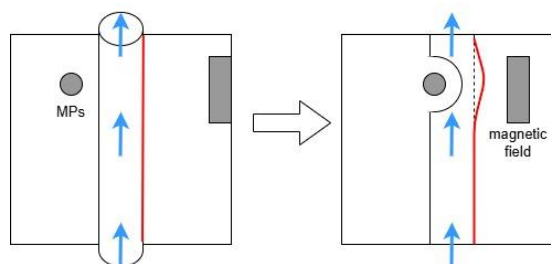


Fig. 1. A scheme to confirm if the liquid in the tunnel can be controlled.

### Results

We confirmed the particles' surface was successfully coated with the PET (Fig. 2 a-d). The evidence is the black contrast on the photodiode-backscattered electron (PDBSE) image; the particle appeared black (PET presence), while the white areas represent uncoated FeCo (Fig. 2d).

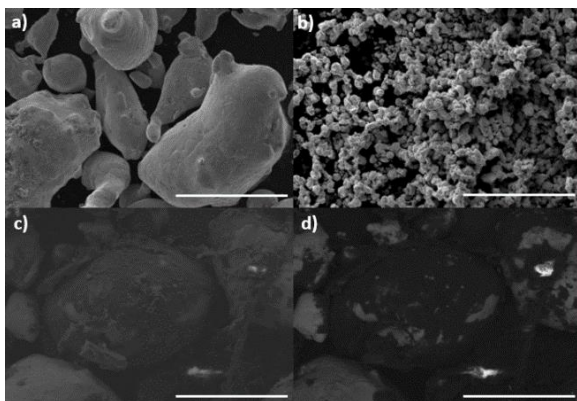


Fig. 2. SEM images of magnetic particles a and b) without coating, for FeCo (a) and SmFeN (b); c and d) with the PET coating, only FeCo covered by PET is seen in the usual image (c) and the photo diode-backscattered electron detector image (d). The scale bar was equal to 40  $\mu\text{m}$ .

In the FT-IR analysis, a characteristic peak (1725  $\text{cm}^{-1}$ ) was observed indicating C = O ester that is related to the presence of PET (Fig. 3). The coating for the SmFeN particles was not observed; hence, those particles were excluded from further research.

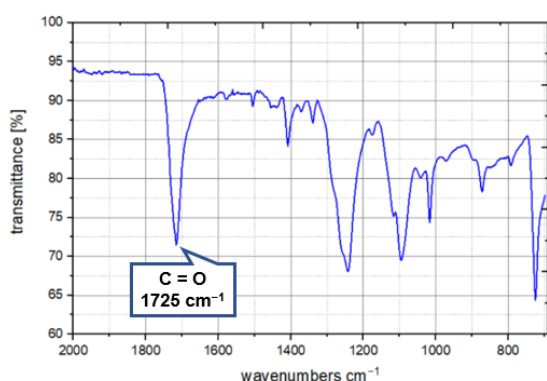


Fig. 3. The graph of the FTIR analysis for FeCo particles covered by PET.

In the hydrogel, the channel was formed with a dia  $\sim 1$  mm along which the FeCo-PET were placed. As the water was introduced into the channel, the influence of the magnetic field presence on the hydrogel with particles was observed (Fig. 4). As a consequence, the blue line was moved ( $\sim 0,7$  mm) due to the channel wall bending toward the magnet. Meanwhile, the blue line returned to its original state as the magnet was away.



Fig. 4. The effect of the magnetic field on the flow channel with the blue coloured water line, without the presence of the magnet (left) and with the magnet in its proximity (right).

## Discussion

The process of synthesis of a UV-sensitive GelMA was described as being an alternative way to obtain a hydrogel at low cost. Furthermore, the issue related to the combination of the hydrogel with the MPs was presented, and the results of its response to the magnetic field. We overcame the MPs instability in an aqueous environment by coating them with PET and as a result, we showed that they responded to the magnetic field even if they were submerged in the hydrogel. The as-prepared hydrogel, due to its UV sensitivity, enables formation of the meso-scale channel that guides the fluid, yet having from its other site of the wall the inkjet MPs. Thanks to these preliminary data, it is possible to progress toward developing the 3D-printable process with the adequate precision so as to design and build a soft actuator with the controlled working performance. The development of soft biocompatible materials with MPs for controlled actuation could lead to the creation of advanced prosthetics, minimally invasive surgical tools, and precise drug delivery systems, significantly improving patient outcomes and quality of life.

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