Magnetic Nozzle-Free Embedded 3D (MagNoFE3D) Printing of Water and Aqueous Viscosity Photocurable Inks.

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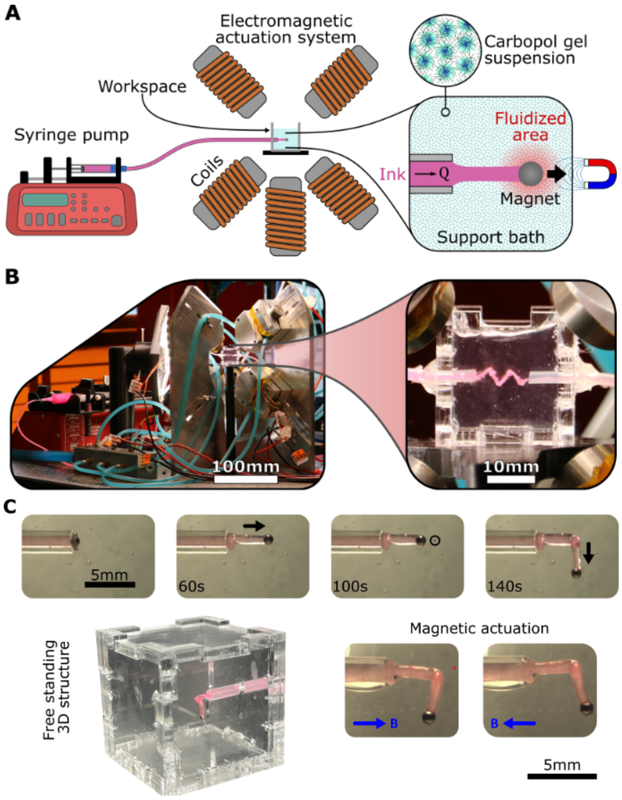
Introduction:

The key functional principle behind extrusion-based printing is the capability of flowing material through a nozzle on demand, which must solidify upon deposition, a behavior exhibited only by some materials. Embedded printing offers a solution to maintain shape fidelity during the deposition of other materials. However, the use of a moving nozzle gives place to other problems, such as bath disturbance and the spreading of the ink. In this study, we introduce a novel embedded printing technique we named MagNoFE3D that eliminates the need for a nozzle by employing a magnetic sphere as the plotting moiety in a support bath. The sphere movement, which is externally steered, locally fluidizes the support bath, guiding the ink to fill the space behind the magnet. We benchmark our method using water ink, where free-form printing is achieved without additional stabilization methods. We also show the creation of solid structures by printing a photocurable ink that is crosslinked and removed from the bath. Moreover, the plotting magnet can be incorporated into the printed part during the crosslinking, thus giving place to a magnetically responsive structure. This advancement paves the way for innovations in fields such as tissue engineering and microrobotics by enabling the fabrication of intricate and functional designs.

Materials and methods:

The electromagnetic actuation system consists of 9 Vacoflux-core coils placed at 30 mm from a common Center. The coils are powered by Elmo Motion Control (Petach-Tikva, Israel) servodrives. The workspace, a 22×22×22 mm Polymethyl methacrylate cubic box, is imaged by two Grasshopper 3 (FLIR, USA) cameras, from the side and the top. The utilized magnet is a nickel plated N50 neodymium spherical magnet of 1 mm diameter (HKCM Engineering, Germany). The embedding bath is 0.4% w/v Carbopol (EDT2020) at 7.4 pH, and the inks used are MIliQ water with a pink colorant (Acrylicos Vallejo, S.L. Spain), and for the photocurable ink, Nordland Optical Adhesive 63 (Nordland Products, USA) was used. The injection was performed using a syringe pump (New Era Pump Systems, USA).

Results and Discussion:



A. MagNoFE3D embedded printing system consisting of an injecting syringe pump and an electromagnetic system to steer the plotting magnet. The movement of the magnet locally fluidizes the Carbopol support bath, opening space and guiding the ink. **B.** Picture of the experimental setup and a double helix printed with coloured water. **C.** Printing, photocuring, washing and actuation of a 3D structure using a photocurable ink.

Conclusions and summary:

MagNoFE3D offers the ability to print water and aqueous viscosity inks within an embedding bath without the need for a stabilization mechanism such as 2-phase separation, co-axial extrusion, in-line crosslinking.