hydrogel materials, electrical fields have been used as a patterning vehicle. This approach exploits the inherent charge and permanent dipole moment characteristics exhibited by many molecules in order to enable direct (DC) or alternating (AC) current to manipulate and localize them within the 3D hydrogel space. For example, Ahadian et al. used dielectrophoresis to create 50 µm-deep cylindrical patterns of aligned carbon nanotubes within a methacrylated gelatin hydrogel in order to create muscle myofibre structures (Ahadian et al. 2014) while Dai et al. used a modified electrophoresis-based device including a porous membrane to define and create 20 µm-deep patterns of nanoparticles within agarose hydrogels (Dai et al. 2012). These electric field-based techniques have been limited to using non-biological molecules and creating relatively shallow patterns.

Mata's group has recently developed a 3D-electrophoresis-assisted-lithography (3DEAL) platform that integrates fundamental principles from native polyacrylamide gel electrophoresis by using electric fields to manipulate proteins in their native state; affinity chromatography by immobilizing molecules within a hydrogel; and microfabrication by using a porous mask to define the printing regions. The 3DEAL technique is simple and affordable, and enables printing within multiple types of hydrogels and using multiple kinds of molecules, including native proteins. The main design element is the capacity to control the electric fields to allow the migration of water molecules, buffer ions, and printing molecules, while selectively preventing the movement of printing molecules. Functional patterns of parallel and perpendicular columns, curved lines, gradients of molecular composition, and patterns of various proteins ranging from tens of microns to centimeters in size and depth can be generated within a large number of hydrogels (Aleman et al. 2014).

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