Lyotropic Liquid Crystals Alignment using Magnetite NPs for Production of Anisotropic Mesoporous Materials

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Lyotropic liquid crystals (LLCs) are mesophases, a state of matter with a behaviour between liquids and solids, which are formed when amphiphiles such as surfactants are dissolved in water at specific concentrations and temperatures. Depending on the latter, LLCs can manifest into different phases, including bicontinuous cubic, hexagonal and lamellar.
In recent years, LLCs have been widely exploited as templating agents to fabricate mesoporous inorganic materials that retain the original structure of the templating system [1], for catalysis, drug delivery, pollutant adsorption and chromatography. In particular, the hexagonal LLCs are extensively used, consisting of cylindrical micelles packed into randomly oriented domains of hexagonal arrays, [2] therefore lacking a long-range anisotropic order.
Imposing a preferred overall orientation remains a major challenge; however, the resulting templated porous materials could benefit from enhanced mass transport and reduced pressure drop. Although several strategies have been explored to orient such domains, [2] these attempts have not yet been translated into the preparation of monoliths with anisotropic porosity.
Here, we propose a strategy to fill this gap using LLCs containing oils [3], which can swell the lipophilic domains of both the direct (H_1) and reverse (H_2) hexagonal phases. Remarkably, these "swollen" LLCs can host hydrophobic magnetite nanoparticles (MNPs). [4] In a static magnetic field, such MNPs-doped LLCs are expected to align parallel to the field, thereby providing anisotropic templates. To prove the versatility of this approach, we propose two strategies. First, we explore a sol-gel process templated by MNPs-doped H_1, using a common silica precursor (i.e., tetramethoxysilane). Second, we investigate an H_2 phase containing MNPs dispersed in a polymerisable oil (i.e., methyl methacrylate), which is then photopolymerised. Upon condensation or polymerisation in a magnetic field, and after surfactant removal, porous, anisotropic monoliths can be obtained.
Preliminary results demonstrated the production of MNPs-doped H_1 and H_2, and that MMA-based systems can retain their structure after polymerisation in the absence of MNPs. As next steps, optimisation of the composition will be considered for both inorganic and organic systems, and tests will be carried out in mild magnetic fields to produce anisotropic materials. Once obtained, the resulting monoliths can be tested to assess the effect of anisotropy on mass transfer compared with analogous isotropic samples.

References:

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