Fabrication and In-Depth Evaluation of Self-Sensing Metallo-Polyelectrolyte Complexed Gels for Metal Ion Filtration

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The accumulation of heavy metal ions in wastewater poses significant health and environmental risks as heavy metals are known to be toxic and bioaccumulate in living organisms. In recent years, metallo-polyelectrolyte complexed (MPEC) gels composed of charged polymer chains binding with metal cations have emerged as promising candidates for metal ion filtration. MPEC filters generally undergo two separate processes: absorption and sensing the amount of metal ions uptaken. However, it is underexplored whether or not a self-actuating filter can both absorb and sense the uptake of metal ions at the same time. To fabricate a material that could carry out both processes at the same time, acrylic acid resins were photopolymerized via stereolithography-based 3D printing with varying pH levels, and the resulting gels were swelled in solutions containing Na^+, Ca^{2+}, and Al^{3+} ions. It was found that in solutions of sodium and water, gels with a pH of 2.56 exhibited greater strain at equilibrium than gels with a pH of 3.74, while in solutions of calcium and aluminum, gels with a higher pH exhibited greater swelling. This shows that the binding affinity of metal ions to the polymer chains is dependent on their valency, as well as the initial pH of the polymer. Correlating the absorption degrees of the material with the specific structural changes they undergo when reacted with different metals allows for the development of a self-actuating filter that can perform both absorption and sensing without any electrical devices, which opens up new possibilities for efficient and real-time monitoring of metal ion absorption processes.