

Polymeric hydrogels are a class of soft materials composed of a hydrophilic polymer network filled with an aqueous solution. Due to their high solvent content and solid consistency, hydrogels exhibit properties of both solids and liquids. The polymer network "immobilizes" the solvent, preventing its flow. On the macroscale, the three-dimensional network preserves the hydrogel's shape, stores mechanical energy, and participates in deformation processes, while on the microscale, small molecules undergo diffusional processes. These unique properties make polymeric hydrogels highly interesting and contribute to their growing popularity in material science.

One particularly intriguing characteristic of hydrogels is the volume phase transition (VPT) phenomenon, where the gel transforms from a swollen to a shrunken phase, and vice versa. The extent of this reversible volume change can be as large as a thousandfold, resulting in significant changes in the material's properties. Even small changes in environmental conditions—such as temperature, pH, ionic strength, the presence of specific ions, or an electric/magnetic field—can trigger this transition. This adaptability to external changes classifies hydrogels as smart materials.

While pH- and thermo-sensitive hydrogels have been extensively studied, a new class of electroresponsive hydrogels has emerged. These gels undergo swelling/shrinking or shape changes in response to redox processes, opening up new possibilities in electrochemical device construction. Though promising, these redox-responsive gels have not been fully explored, and further improvements are necessary to enable their practical use in electrochemical actuators. Key challenges include improving the speed of the VPT process, mechanical stability, and reversibility of the phase transition.

The aim of this project is to synthesize new advanced electroresponsive gel materials with tailored properties and use them to construct electrochemical actuators. The structure, composition, and size of the gel materials will be optimized to achieve mechanically stable actuators with reversible and fast volume changes induced by an electrical potential.

The development of these advanced gel materials aligns with current trends in material science. As electroresponsive gels are relatively new, their potential applications are not yet fully demonstrated in the literature. The successful synthesis of new electrosensitive materials that can be easily controlled with electrical stimuli is expected to have a significant impact on the development of soft electrochemical actuators. These gels, where electrical energy is converted into mechanical work during the volume phase transition, hold great promise for applications such as artificial muscles and soft robots. The ability to induce volume changes with an electrical impulse also makes these gels suitable for use in pumps and valves. Furthermore, their electro-sensitivity makes them highly promising for applications like transdermal and intra-body implant drug delivery systems, bridging the gap between electronic devices and living organisms.