A7: Complex bisensitive hydrogel systems

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Motivation:

The ability to equip hydrogels with stimuli responsiveness and to couple them to functional components is one of the core prerequisites of microfluidic systems. Two prominent pathways are known to lead this coupling of properties: Either by mixing different functional monomers into the polymerisation mixture during gel formation or by merging two different gels into one. The entire range of methods to achieve mixing on a molecular level can be used, starting from interpenetrating networks (IPNs), semi-IPNs, grafting a second polymer onto the first one, going all the way to pH sensitive beads and physically mixing two hydrogels. An important aspect of hydrogels is their morphology which is set by the crosslinking density, ultimately governing the movement of molecules in the final matrix. The dynamics of macroscopic changes of the hydrogels even after triggering a response is also heavily influenced by the network morphology. Together with projects B5 (Richter Group) and B7 (Gerlach Group), this project will set the basis for responsive and powerful microfluidic processors and also for force-compensating piezo-resistant pH sensors.

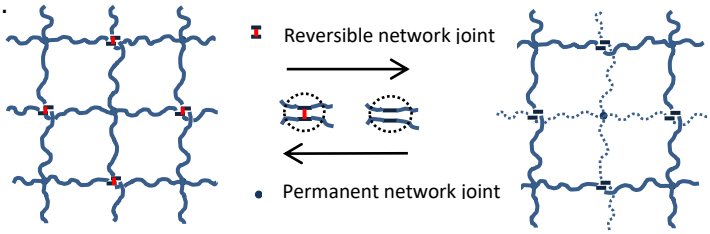

Fig. 1.: Change of the network density

State of the art and preliminary work

Stimuli-responsive hydrogels will see various applications as actuators and sensors. A thorough understanding of the thermodynamic and kinetic details of the swelling process will be key for their applications in microsystems. It is already known that an IPN has a superior stability in comparison to separate single networks. On top of that, an in-depth study of network-specific diffusion coefficients was conducted for the stimuli-induced swelling behaviour of pH- and temperature sensitive IPNs (Krause et al. Soft Matter 2016), revealing the desired insights into the swelling process. This ultimately led to an incorporation of such gels in to force-compensating sensors (Sensors Letters 2017). Ongoing work transferred this principle onto redox-sensitive IPNs with reversible disulphide bonds. Here, a gel with reversible redox-responsive joints was combined with a non-responsive main gel with permanent network joints. One of the next tasks is to finish the transfer of this principle towards a gel with responsive and reversible joints as side chains.

Scientific goal and project aims

The general aim of the 3rd phase remains the synthesis of stimuli responsive hydrogel matrices where their shape, outer and inner structure allows for an application in microfluidic systems as sensors and valves. In order to reach the ideal responsive behaviour, new responsive units will be screened to get the most fitting behaviour for microfluidics. It is important to note that the induced change can be a sole internal change in the network structure, or one that is detected as a macroscopic change in shape. Reversible network joints will be applied dually, as the free functional groups after breaking the network joints will be used to detect external analytes like bio(macro)molecules, ions or other functional molecules by complexation or forming chemical bonds. The principle will be developed towards both envisioned applications. On top of that, the concept of reversible bonds in the side chains will be expanded towards host-guest interactions or photochemical reactions in the swollen gel. Opening and closing valves on a microfluidic chip to control the diffusion barrier of nanoparticles is where this branch of the project will lead. Ideally, the diffusion barrier is changed, but the macroscopic volume of the gel remains unchanged, representing an ideal example where a pure internal change in the network structure with no macroscopic change will be reached and applied in the project.