Abstract

In the first part of this work, silica nanoparticles and alternative or additional filler phases were incorporated into hydrogels based on the temperature-sensitive poly(N-isopropylacrylamide) (PNIPAm).

Nano-SiO2-filled porous PNIPAm hydrogels with an enhanced force response (up to 100 g) to temperature stimuli were obtained by increasing several times the pore wall thickness, which was achieved via reducing the solvent (porogen) content during the gels’ cryo-synthesis. A similar optimization of the force response was also carried out for analogous gels reinforced by nano-TiO2, in which the reinforcing effect of the filler is weaker.

Partial intercalation of amylopectin starch into divinyl-crosslinked bulk as well as porous PNIPAm gels several times improved their extensibility. In case of starch-rich bulk gels, a very fast and extensive one-way deswelling in response to increased temperature was achieved (re-swelling upon cooling is much slower), which is attributed to specific properties of the starch-PNIPAm interface. In doubly-filled bulk PNIPAm/nano-SiO2/starch gels, a very strong synergic reinforcing effect of both fillers is observed, due to specific hydrogen bridging between the three phases. Highly porous cryogels based on PNIPAm/nano-SiO2/starch displayed a highly improved extensibility and toughness.

Very attractive gels displaying a promising potential as actuators or switches responsive to multiple stimuli (electrical current, induction, heat or light) were obtained by incorporating polyaniline (PANI) as second filler into porous PNIPAm/nano-SiO2 gels. An especial success of this part of work was the selective chemical deposition of PANI exclusively inside of the pore walls of the precursor PNIPAm/nano-SiO2 gels. In addition to very fast temperature-responsiveness, electrical conductivities as high as 74 000 µS/cm were achieved.

In the second part of this work, organic filler phases were incorporated into rigid organic-inorganic matrices based on polymethylsiloxane networks (chemically related to silica).

Similarly like in case of the above PNIPAm/SiO2/PANI gels, polyaniline – in this case in the form of microparticles – was employed to lend electrical conductivity to the polysiloxane matrix (good results above 40 wt.% PANI), while the mechanical properties of the matrix were preserved. The PANI filler was dispersed either as a colloid during the sol-gel-process of matrix monomers, or it was added as a micro-powder prior to the final cure of the siloxane resin.
An interesting inverse-phase-composite also based on the polysiloxane matrix was filled with polypropylene-oxide-rich epoxy powder. 20–70 wt.% of this filler were incorporated as sacrificial material, in order to obtain SiOC foams as final products via pyrolysis, during which also the matrix underwent a chemical change. Macro-porosities of 35–70 vol.% were obtained, in combination with high SiOC foams’ moduli (up to 10 GPa) and compressive strengths (up to 38 MPa).