When heated beyond the critical temperature, a thermosensitive polymeric gel undergoes a hydrophilic-to-hydrophobic phase transition, and shrinks by expelling solvent. In a relatively large sample, however, the homogeneous deformation is limited by solvent transportation, and the material undergoes phase separation and develops heterogeneous structures by nucleating solvent-rich domains.

A Ginzburg-Landau-type phase-field model is developed to study the microstructure evolution in this process, and it reveals a peculiar non-self-similarly coarsening and the formation of a spongy structure with thin walls of dry polymer, independent of the volume fraction of each phase.

To understand the underlying mechanism of the formation of sponge structure, which is commonly seen in various types of soft materials, a theoretical model is formulated. The theoretical analysis confirms that in a spongy structure, the deformation in each phase is more uniform, as favored by the elastic energy and the energy of mixing.

The phenomenon is found to be a direct consequence of the geometric nonlinearity caused by large deformation, and is not present in linear systems. As it is independent of the specific material law, similar spongy structure is expected to appear in any material system capable of large elastic deformation.