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Proposal of a Thermoresponsive Gel-Based Temperature-Sensitive Magnetic Fluid

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This study explores a new approach to improving temperature-sensitive magnetic fluids (TSMFs), which are used in passive heat transfer devices. Conventional TSMFs contain magnetic nanoparticles (MNPs) whose magnetization decreases as temperature rises. We propose enhancing this temperature response by incorporating MNPs into thermoresponsive gels with an upper critical solution temperature (UCST). Because UCST gels swell at higher temperatures, the concentration of MNPs per unit volume decreases as the gel expands. As a result, the reduction in magnetization is expected to arise from both the intrinsic thermal demagnetization of the nanoparticles and the swelling-induced decrease in particle density. To test this concept, we first fabricated millimeter-scale UCST hydrogels containing Mn–Zn ferrite nanoparticles. These bulk gels were then ground into smaller fragments to obtain micro- and nanoscale gel particles. Optical microscopy showed that the resulting particles had a broad size distribution, ranging from the nanoscale to the microscale, with some particles reaching several hundred micrometers in size. This result confirms that grinding can successfully produce small MNP-containing UCST gel particles, although further size separation may be required to obtain more uniform samples. The key question was whether the thermoresponsive volume-change behavior of the original gels would be retained after reducing them to the nanoscale and incorporating MNPs. To evaluate this, we measured the hydrodynamic diameters of the gel particles at 5℃ and 50℃ using dynamic light scattering (DLS). The average diameter increased from 48.1 nm at 5℃ to 61.4 nm at 50℃, clearly indicating that the particles swelled as temperature increased. These results demonstrate that the thermally induced swelling behavior of the UCST gel was preserved even at the nanoscale after the incorporation of MNPs. Overall, these findings suggest that dispersions of MNP-containing UCST gels could serve as a new type of TSMF with enhanced temperature sensitivity. By combining the natural temperature-dependent demagnetization of MNPs with the swelling-driven reduction in nanoparticle density, this system may improve the performance of passive heat transfer devices.

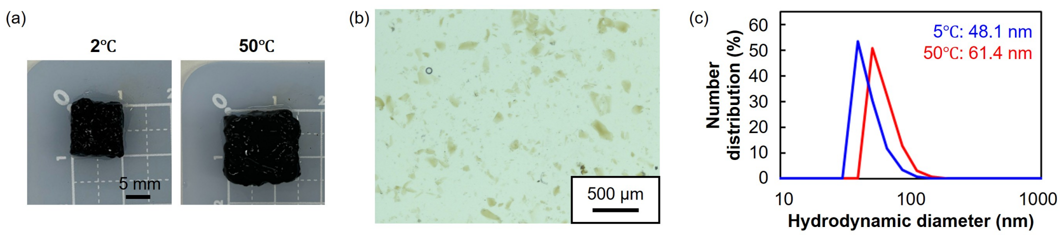

Figure 9: Photographs of (a) millimeter-scale UCST hydrogels containing MNPs, (b) ground UCST hydrogels containing MNPs, and (c) DLS results.

Type:

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