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Study on Mechanism and Performance Enhancement of Thermal Energy Storage with Composite Phase Change Material

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Abstract
To develop high-efficiency electronic cooling systems with instantaneous high power, the exploration of advanced low-temperature thermal energy storage technologies has become an urgent need. Composite phase change material incorporated with a porous skeleton, as a passive heat transfer enhancement technology, can release and absorb large quantities of thermal energy to deal with a mismatch between supply and demand of energy. However, it is a challenging task to investigate the phase change problem because it involves multiple, complex, and mutually coupled physical processes, such as the dynamic evolution of the phase transition interface, convective heat transfer with a porous skeleton, conjugate heat transfer between porous skeleton and phase change material, and the appearance and collapse of void cavities. Moreover, the equivalent thermal conductivity of the composite phase change material is still too low. Therefore, this presentation shows our recent work on the mechanism and performance enhancement of thermal energy storage with composite phase change material. Firstly, a three-dimensional reconstruction technique based on X-ray tomography and a morphological image processing method is established to examine the dynamic solid-liquid phase change heat transfer mechanism of the composite phase change material under different gravity environments and the effect of ultrasonic wave on the heat transfer performance. Secondly, the effects of void cavity distribution on the melting process of the composite phase change material are studied. Thirdly, a locally nonuniform porous skeleton is proposed to solve the problems of low melting rate and uneven temperature distribution along the gravity direction at the late melting stage. Fourthly, an active enhancement method based on TiO_2 nanoparticles, metal foam and ultrasonic field is proposed. The thermal energy storage time distributions, the solid-liquid phase interface and the energy consumption of the TES system are discussed. Finally, the challenges and development trends of low-temperature thermal energy storage with composite phase change material are discussed.