学位論文の審査結果の要旨

In this dissertation, the focus has been forwarded to the development and investigation of shape memory epoxies (SMEPs) and SMEP nanocomposites which prepared via latex technology. The most significant results achieved in this dissertation are given as follows:

(1) A facile and environmental-friendly method to prepare SM epoxy materials has been developed. In the first strategy, epoxy-graft-polyoxyethylene octyl phenyl ether (EP-g-TX100) was synthesized, which is a novel reactive copolymer emulsifier for preparing of water-borne epoxy (WEP). The chemical structure and emulsifying ability of EP-g-TX100 were systematically characterized by Fourier transform infrared spectroscopy (FTIR), nuclear magnetic resonance spectroscopy (NMR), field emission scanning electron microscopy (FE-SEM), transmission electron microscopy (TEM). In the second strategy, WEP via phase-inversion technology was synthesized. After that, the freeze-drying and hot-press molding technology was applied to prepare the samples. The results show that the as-synthesized emulsifier EP-g-TX100 exhibits the expected structure, can covalently react with the curing agent through the side chains, and has excellent emulsifying ability for epoxy in water. WEP particle has an average diameter of 137 nm, with particles ranging from 50 nm to 300 nm. Furthermore, the final epoxy products show excellent shape memory (SM) property.

(2) Carbon nanotube (CNT)/WEP SM nanocomposites were successfully synthesized via freeze-drying and hot-press molding. The morphology and mechanical properties of the nanocomposites were investigated by TEM, SEM, dynamic mechanical analysis (DMA) and tensile testing. The SM properties of the nanocomposites were evaluated by fold-deploy SM testing. The effects of filler content and recovery temperature on the SM properties were revealed through systematic variation. Results confirmed that CNTs were homogenously dispersed and incorporated into the WEP matrices. Thus, significant improvements in the mechanical and SM properties of the nanocomposites were achieved. Moreover, CNT/WEP SM foams were prepared. The SM properties of the foams were evaluated together with other physical properties. Compression and thermo-mechanical cycle tests were performed to measure the effects of the CNTs on the mechanical performance of the foams. The foams had a high shape recovery and fixity ratio of more than 90% even after several thermo-mechanical cycles with the addition of 1.0 wt% CNTs. The CNTs significantly enhanced the strength of the WEP SM foams.

(3) In-situ grown silica/WEP SM nanocomposites were successfully synthsized by hydrolysis of tetraethoxysilane (TEOS) within the WEP and prepared via freeze-drying and hot-press molding method. The morphology structure and the effect of the content of the in-situ formed silica on the mechanical and SM properties of the silica/WEP composites were studied. The experimental results indicated that the silica particles were homogenously dispersed and well incorporated into the epoxy matrix. Significant improvements were achieved in the mechanical property of the organic-inorganic hybrid materials. The silica/WEP composites exhibited high shape recovery and fixity ratio approximately 100% even after 10 thermo-mechanical cycles. Moreover, silica/WEP SM foams were synthesized and prepared without extra blowing agent. The micrograph and mechanical properties of the foams were closely related to the freeze-drying time. The final foams have excellent SM properties even after several thermo-mechanical cycles. The properties obtained

in the epoxy foams may offer new opportunities for their use in future structural applications.

WEPs, as novel versatile environmentally-friendly materials, are being attached great importance in engineering field and mainly used in coatings, metal primers, epoxy cement concrete, glass fiber sizing, and wood adhesives, etc., and additional function of SM will be a good aspect for extending their further applications. Furthermore, the strategy for obtaining SM epoxy materials will pave the way for designing and developing the functional SM effect polymers. The proposed method is applicable to various host polymers and does not require organic solvents.

All of the above results indicated that the novel techniques and approaches used in this dissertation have resulted in a successful innovation of shape memory nanocomposites. The paper publications support the dissertation with fruitful contents. The developed functional nanocomposites and the related technologies are expected greatly to be useful in materials science and practical engineering applications.

In conclusion, the dissertation has enough contents as a doctoral dissertation, and well written with a fruitful research results. The evaluation committee concludes that this dissertation is fully acceptable as a doctoral dissertation for the earlier graduation in the chair of smart materials science and technology, the department of bioscience and textile technology.

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