SOLID-LIQUID INTERACTION IN CONFINING NANOENVIRONMENT AND ITS APPLICATION FOR SMART STRUCTURES

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Advanced intelligent materials and systems are of immense importance to a wide variety of engineering applications. Currently, the most widely used intelligent materials are shape memory alloys, ceramics, and polymers that can undergo thermoelastic or electroelastic deformations. However, the energy densities and the displacements of these materials, although already close to their limits, are still far from satisfactory. To produce smart devices that can provide large output energies and strokes, new mechanisms must be discovered.

Recently, we carried out an experimental study on a novel application of nanoporous technology [1-3]. When a nanoporous material, e.g. a porous metal, is immersed in an effectively wetting liquid, the liquid can infiltrate into the nanopores. If the solid-liquid interface is electrifiable, as the electrical potential difference increases, due to the electrocapillary effect, the liquid-solid interfacial energy can vary considerably. Since the properties of different solid-liquid interfaces change with different rates, in a multiple-liquid system, the contact surfaces of liquids tend to move, accompanied by the release of excess interfacial energy and a large variation in system volume. As a first-order estimation, the energy density of this system is

$$E^* \approx \Delta\gamma \cdot A \tag{1}$$

where $\Delta\gamma$ is the excess interface energy and A is the specific surface area of the nanoporous material, often in the range of 100-1000 m^2/g; and the volume change is

$$\Delta V \approx V_{\mathrm{pore}} \tag{2}$$

where V_{pore} is the specific pore volume of the nanoporous material. If the potential difference is changed back, the system configuration is reversible, and thus the system exhibits a shape memory characteristic. Similar system behaviors can also be achieved by changing temperature, T, as the wettability is thermally controllable.

The attractions of the nanoporous intelligent system include: (1) the high energy density associated with the large surface area of nanoporous material; (2) the large displacement; (3) the compatibility with both large-scale and small-sized electro/thermo-hydraulic devices, as well as microelectromechanical systems (MEMS); (4) the short response time; (5) the simplicity in fabrication; and (6) the high controllability, reliability, and repeatability.

References

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