Development of thermal switch material using structure change in organic film including nanostructure

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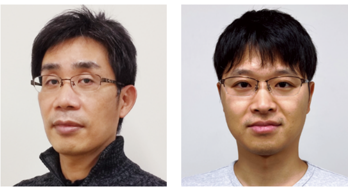

Abstract

Temperature-triggered thermal switch, which causes thermal conductivity change in response to the environmental temperature, is attracting much attention as one of the thermal management devices. Previous studies have focused on the increase of On/Off switching ratio. On the other hand, for the social application, it is also required to tune the switching temperature. However, there have been no experimental studies about it. In this study, we are aiming at tuning the switching temperature by using the order-order transition of liquid crystalline block copolymer film including anisotropic nanostructures. Choosing the different type of mesogens in the side chain of liquid crystal part modulated the order-order transition temperature, resulting in the tuning of switching temperature. This success leads to the social application of thermal switch under various temperature situations.

Background & Results

Thermal management devices are attracting much attention for overcoming the issue of heat generation in electronic devices. Among them, thermal switch allows us to control thermal conductivity. Previous studies have focused on the increase of On/Off switching ratio. On the other hand, for the social application, it is also required to tune the switching temperature. However, there have been no experimental studies about it.

In this study, we focused on the liquid crystalline block copolymer including anisotropic nanostructures. In the blockcopolymer, the order-order transition occurs at the certain temperature: the morphology of nanostructure is changed from cylinder (low temperature phase) to sphere (high temperature phase)(Fig. 1). Furthermore, the transition temperature depends on the type of mesogens in the side chain of liquid crystal part. The block copolymer films with the different order-order transition temperatures of 360 and 390 K exhibited thermal conductivity switching behaviors (On/Off switching ratio ~ 2) at the different temperatures of ~360 and ~390 K, respectively(Fig. 2). This result highlights that the control of molecular structure can be a renewed methodology of tuning the switching temperature. Furthermore, we revealed that the magnitude of On/Off switching ratio is attributed to the anisotropy of nanostructures in block copolymer and the heat scattering at the nanostructure interfaces. This gives new insight for heat transport physics in organic materials.

Significance of the research and Future perspective

This study realized the tuning of switching temperature in thermal switch by choosing the different type of mesogens in the side chain of liquid crystal part, which is related to the order-order transition temperature. This tuning method of switching temperature has high versatility because this method can be applied to various material systems only if the switching temperature depends on the molecular structure. In the future, this success will lead to the development of thermal management organic material at low cost, and will contribute to the realization of the society using thermal energy efficiently.

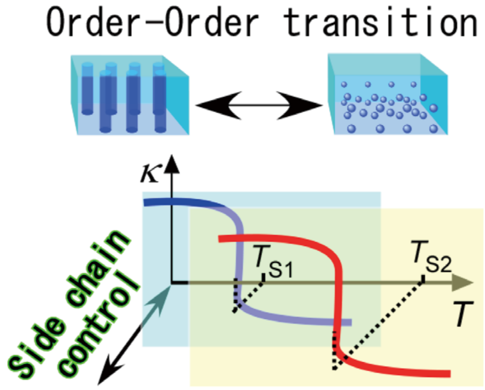

Fig 1 Tuning the switching temperature in thermal switch using the order-order transition in liquid crystalline block copolymer. Choosing the type of mesogens in the side chain in liquid crystal part modulates the switching temperature.

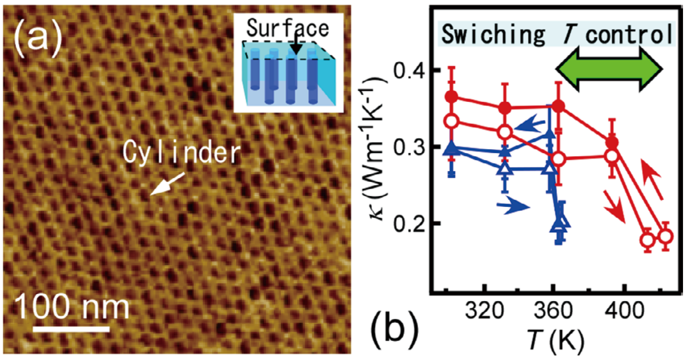

Fig 2 (a) Atomic force microscope image of the surface of block copolymer including cylinder (low temperature phase).
(b) Thermal conductivites (κ) of block copolymer films as a function of the environment temperature (T). The block copolymer films with the different order-order transition temperatures of 360 (the triangles) and 390 K (the circles) exhibit thermal conductivity switching behaviors at the different temperatures of ~360 and ~390 K, respectively.

Patent

Treatise Ishibe, Takafumi; Kaneko, Tatsuya; Uematsu, Yuto et al. Tunable thermal switch via order-order transition in liquid crystalline block copolymer. Nano Letters. 2022, 22 (15), 6105-6111. doi: 10.1021/acs.nanolett.2c01100

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Keyword thermal management, nanotechnology, organic film, structure phase transition