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Precise control of surface topographies is well-known to development in a wide range of fields of mechanical, optical, and biomimetic applications. Especially, surface processing technologies using liquid crystals (LCs) have offered the advantages of fine control with non-contacting operation and reversibility of surface topographies under external stimuli such as heat, light, and electricity. However, when employing photoinduced reactions, size control in periods and depths of the surface topographies remains a challenge. In this thesis, the author investigated the formation of various surface topographies with heights ranging from nanometers to micrometers induced by simple photopolymerization with structured light. In addition to these investigations, the author demonstrated thermo-mechanical behavior and mechano-optical functions of these LC polymer films with the surface topographies.

In Chapter 2, the author demonstrated to form the surface relief structures on LC polymer films induced by patterned photopolymerization with different slit widths. The resultant films exhibited periodic peak/valley structures in the center of irradiated and non-irradiated areas, respectively. The shapes and heights of the surface relief structures depended on the periodicity of slit widths. Comparing the degree of molecular alignment with the surface relief structures at located positions revealed that molecular transport from non-irradiated to irradiated areas simultaneously induced surface relief structures and molecular alignment.

In Chapter 3, the author serendipitously found surface topography formation, such as canal and well structures with a depth of 1 μm or more, simply by photopolymerization using striped patterns. In addition, circular pattern irradiation achieved the 2D-patterning of canals and wells; this is the first time that a single-step photopolymerization process created such complex, deep surface topographies without using photoresponsive molecules and polarized light. Various analyses, including real-time observation, image analysis, and Fourier transform infrared spectroscopy, were conducted to clarify the formation mechanism of such topographies. These investigations elucidated that anisotropic monomer diffusion based on the polymer concentration gradient was the main factor in forming canal structures.

In Chapter 4, the author investigated the thermo-mechanical responsiveness of the LC polymer films with canal and well structures, resulting in reversible changes in their heights during heating and cooling cycles. Detailed observation of POM images under heat and demonstration of forming canal structures utilizing other skeletons of molecules revealed that the degree of molecular alignment and their reversibility strongly affected the thermal responsiveness of the surface.

In Chapter 5, the author evaluated the optical properties of the LC polymer films with canal structures. The diffraction of the films exhibited reversible changes during heating and cooling cycles, which is correlated with both surface structures and molecular alignment modifications. To explore the effect of the thermal surface changes and molecular alignment on the optical diffraction and transcription of PDMS, the author calculated the FFT intensity profile and analyzed the theoretical model for the transmissive diffraction gratings.

The author believes that this research contributes to the development of a novel method for controlling surface topographies in LC polymer films and can be expected to fabricate next-generation switchable devices and materials.