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Understanding of bending behavior of polymer films is crucial for the development of flexible electronic devices and materials. However, the large bending still remains unclear due to a lack of quantitative analysis methods of fatigue and internal strain. In this thesis, the author developed the bending fatigue tester and flexible strain sensor and investigated the fatigue behavior and the internal strain of bending polymer films. In addition to these investigations, the author designed flexible devices based on the clarified bending behavior.

In Chapter 2, the author analyzed the fatigue behavior of various polymer films subjected to cyclic bending with the developed bending fatigue tester. The increase in the thickness and bending angle increased the surface strain and resultantly shortened fatigue life. It was found that the fatigue life of the polymer films with high toughness and radius of curvature was relatively long. Furthermore, the fracture mode, which can be determined by the change in the radius of curvature, significantly affected the fatigue life. Due to the viscoelastic property of polymers, high-speed cyclic bending accumulated heat, especially in crystalline polymer films, and shortened their fatigue life due to thermal degradation. These investigations elucidated the fatigue behavior of the bending polymer films depending on the test condition, sample thickness, and structure.

In Chapter 3, the author used the machine learning approach for the prediction of the bending fatigue life of various polymer films. The decision tree and random forest models that employed parameters analyzed in Chapter 2 successfully predicted the fatigue life accurately (mean absolute percentage error < 30%) and efficiently (computation time < 1 min). In addition, the random forest model can predict new data, which was not included in the initial dataset, demonstrating good versatility. The analysis of fatigue behavior and prediction of fatigue life of various bending polymer films contribute to the design and selection of substrates for flexible devices.

In Chapter 4, the author explored the bending behavior of a polydimethylsiloxane (PDMS) film through internal strain measurement. A cholesteric liquid crystal elastomer (CLCE) sensor experimentally quantified the internal strain in the bending PDMS film from its selective reflection. The neutral mechanical plane (NMP) position of the bending PDMS film was identified from the measured internal strain distribution. Resultantly, the NMP reversibly shifted by ~160 μm from the center of the thickness toward the inner bending surface during large bending. Furthermore, on the basis of the NMP shifting, the author successfully designed a flexible electronic device that exhibited higher mechanical durability than a device with a conventional structure.

In Chapter 5, using the CLCE sensor, the author clarified that bending could induce the out-of-plane strain in the PDMS film with much less mechanical energy than stretching. This result was theoretically verified as well. In addition, the out-of-plane strain in bending PDMS films was easily controlled by not only the bending degree but also their dimension.

In Chapter 6, the author designed a mechano-responsive material consisting of the CLCE and PDMS films that can mechanically tune the reflection and polarization by bending. Bending strain induced reflection wavelength shift of the CLCE/PDMS films such as blue and red shifts, splitting, and broadening. The author demonstrated the promising applications of bending CLCE/PDMS films for the anti-counterfeit label and light modulator.

The author believes that this research contributes to the elucidation of the bending behavior of polymer films and the development of next-generation flexible electronic devices and materials.