Synchrotron WAXD Studies on Strain-Induced Crystallization of Vulcanized Natural Rubber

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Abstract

Natural rubber (NR) is a biopolymer and an important material utilized for many different kinds of usage supporting our daily life. One of the most significant applications of NR is tire for vehicles. Among them, the tire for aircrafts should have the highest safety and reliability to avoid tragic accidents due to burst of the tires. To contribute to the safety and reliability of the tire through the prevention of crack growth, strain-induced crystallization (SIC) plays a very important role [1]. Although there are a bunch of research works of the SIC, they are limited in the case of the uniaxial elongation and very few works are available for the case of the multiaxial elongation, which is more important to consider the realistic case of the tire deformation. Therefore, we have studied the SIC behaviors upon the biaxial elongation of NR by measuring the wide-angle X-ray scattering (WAXS) patterns to detect the crystalline reflection peaks at the Japanese synchrotron facility (SPring-8).

Figure 1 displays a state diagram of SIC in the plot of strains ε_X and ε_Y, found for the case of the two-step elongation whereby the specimen was first elongated in Y direction then it was fixed at the elongated state. Further, it was elongated in X direction. In the "No SIC" region for $\varepsilon_Y > 3$, the crystal formed in the first-step elongation in Y direction completely melted away upon the second-step elongation in X direction. This complexity may stem from mismatches of the molecular chain orientation in the amorphous phase as compared to the orientation of the crystallites. Such situation is a characteristic of the chain molecule, very much unusual compared to the case of low-molecular weight compound. The study of SIC in the case of the uniaxial elongation is relevant to the complete matching of these orientation, so that such complexity has never been found.

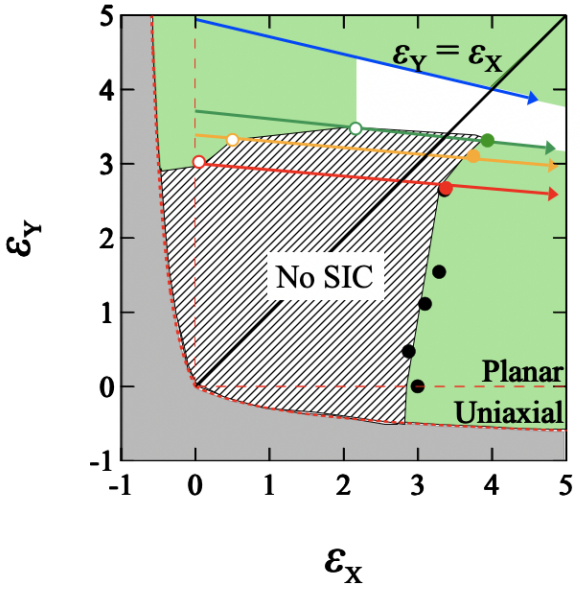

Figure 1. State diagram of SIC in the plot of e_X and e_Y where the specimen was first elongated in Y direction then it was fixed at the elongated state. Further, it was elongated in X direction.

Acknowledgement: This work is financially supported by Japan Science and Technology Agency JST Grant Number JPMJPF2114.

1. T.-Tam Mai et al., Advanced Science, 2024, 11, 2307741.