論文 / 著書情報
Article / Book Information

Title	AFM Nanomechanics for Rubbery Materials
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Citation	The 1st Asia Rubber and Elastomer Federation International Conference 2024 (AREF-IC 2024)
Pub. date	2024, 2

AFM Nanomechanics for Rubbery Materials

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Abstract

Atomic force microscope (AFM)-based nanomechanics [1] is a powerful tool to investigate a wide variety of topics in rubber science and technology, which gives maps of Young's modulus, adhesion *etc.* at nano-scale resolution. The author has been devoted himself to developing the method and applying it to various problems, some of which will be reviewed in this presentation as described below.

An in-situ AFM nanomechanical technique was used to directly visualize the micromechanical behaviours of CB/SBR during compressive strain [2]. We found that CB filled rubbers exhibited heterogeneous local microscopic deformations as shown in Fig. 1, which were related to the dispersion of CB particles in rubber matrices. The local stress distributions of the rubber composites showed heterogeneity, and the stresses were concentrated in the regions near the CB particles during compression. The area of stress concentration gradually expanded with increasing strain and eventually formed a stress network structure. This stress network bore most of the macroscopic stress and was considered the key reinforcement mechanism of CB-filled rubber.

Nanorheological AFM is a measurement technique that maps dynamic viscoelasticity with nanoscale spatial resolution [3]. The technique combines dynamic measurements with quasi-static force curve measurements, allowing quantification of the contact area using a theoretical model of contact elasticity and, therefore, the dynamic modulus. However, the nano-viscoelasticity measured by nanorheological AFM is not in perfect agreement with the macro-viscoelasticity measured by a rheometer. To improve the quantitative performance of the dynamic modulus, a variable was introduced to correct for the difference from the contact area of Johnson-Kendall-Roberts theory. The load dependence of the storage stiffness of polydimethylsiloxane (PDMS) and SBR was investigated to determine variables for each measurement frequency. The novel analytical method gives results in better agreement with the macroscopic measurement method.

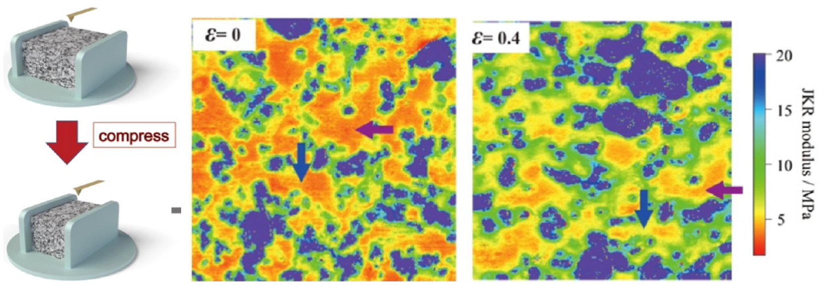

Figure 1. In situ AFM Modulus maps (scan size of 3.0 μm) of the same region at macroscopic compressive strains $\varepsilon = 0$, and 0.4.

Acknowledgements

These works were supported by JST CREST Grant Number JPMJCR17J4, JST-Mirai Program grant number JPMJMI18A2, JSPS KAKENHI Grant Numbers 19H02771, 23H02021.

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