# Quantified Elastic Modulus Mapping of Rubber Blend Under Temperature Control Using Hitachi Proprietary SIS-QuantiMech

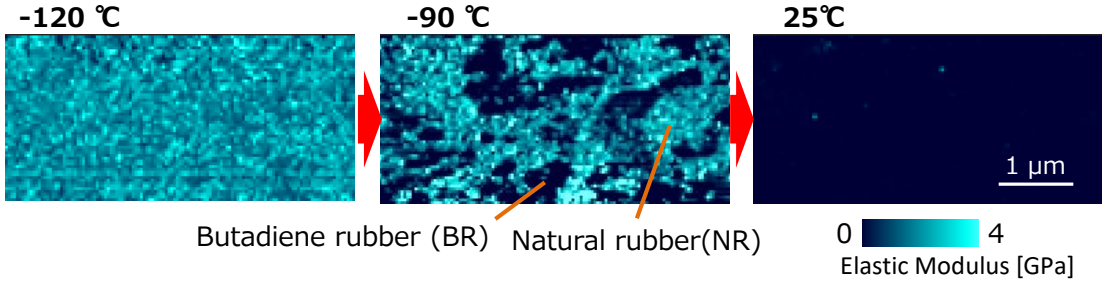


Fig.1 Temperature-dependent elastic modulus mapping of rubber blend revealed by SIS-QuantiMech (Model: AFM5300E)

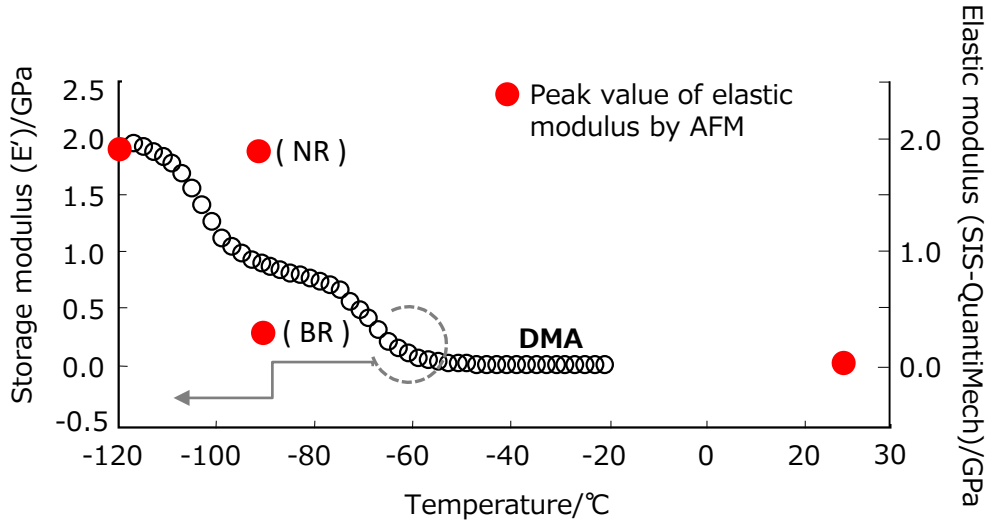


Fig.2 Result of elastic modulus of rubber blend by DMA and AFM (SIS-QuantiMech)

Models: AFM5300E and DMA7100

Hitachi SIS-QuantiMech offers quantified mechanical-property mapping based on the collection of force curve via Hitachi propriety Sampling Intelligent Scan (SIS) at single pixel level and subsequent derivation of the modulus of elasticity that is governed by AFM tip sharpness, spring constant, and the deflection sensitivity of the AFM cantilever as well as selection of the most appropriate model to fit the data.

Fig. 1 shows the elastic modulus mapping of a rubber blend composed of both natural rubber (NR) and butadiene rubber (BR) at three different temperatures. Fig. 2 plots the peak value of the elastic modulus distribution obtained in Fig. 1 and measurements of the storage modulus by a dynamic viscoelasticity device (DMA).

The derived modulus of elasticity measured by the AFM at the low temperature of -120 °C was about 1.9 GPa, which is in agreement with the storage modulus measured by the DMA. At the room temperature (25 °C), the modulus of elasticity is significantly lower at round 3 MPa. Both elastic modulus mappings are with very little contrast variation due to the fact that the two rubber components are either all in a glassy state at -120 °C or all in a rubbery state at 25 °C. On the other hand, binary contrasts were exhibited in the elastic modulus mapping at -90 °C. As the Tg of BR is lower than -90 °C and Tg of NR is higher than -90 °C, regions of the dark contrast with a calculated modulus of elasticity of 0.24 GPa and those areas with a brighter contrast with the calculated modulus of elasticity of 1.9 GPa can be assigned as the BR and NR domains, respectively.

In this case study, it is demonstrated that SIS-QuantiMech can render high–resolution and localized measurements of elastic modulus that are not achievable by macro analysis techniques such as DMA. It also proves that SIS-QuantiMech in conjunction with temperature control is an effective approach for compositional mapping of polymer complex, especially for those containing components with a very low Tg. In this regard, Hitachi's high-vacuum AFM5300E provides superior and wide-ranging temperature control from -120 °C to 800 °C and thus allows for the component differentiation of NR/BR mixtures by sample cooling at -90 °C.

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# Measurement of Elastic Modulus of Rubber Blend under Cooling Using SIS-QuantiMech

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| Recommended configuration | Recommended configuration |
|---|---|
| Environment Control Unit AFM5300E | |
| ・Evacuation System 1 for (TMP+RP) | |
| ・Heat/Cool Sample Stage | |
| ・Temperature Controller | |
| ・Cantilever: SI-DF3P2 | |
| Probe Station AFM5000 II | |
| ・SIS-ACCESS/SIS-QuantiMech | |
| | |
| Dynamic Mechanical Analyzer DMA7100 | |

AFM5300E

DMA7100