Application of X-ray Photon Correlation Spectroscopy to Nanoparticles in Rubber

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Abstract

Colloidal suspension has attracted large attention from both academic and industrial viewpoint [1]. For example, the addition of nanoparticles (filler) to rubbery materials greatly improves the mechanical and viscoelastic properties, and thus being used for controlling the properties of nanocomposite. To elucidate the physical picture of this reinforcement effect, much effort has been devoted for clarifying microscopic structure and dynamics of filler in rubbery materials. Filler nanoparticles generally form complex hierarchical structures: each stage of hierarchy shows specific responses to external forces, thereby resulting in the characteristic bulk viscoelastic properties. We have studied the spatio-temporal hierarchical structure of filler nanoparticles in rubber by using two-dimensional ultra-small-angle X-ray scattering (USAXS) and X-ray photon correlation spectroscopy (XPCS). In this presentation, we describe the application of XPCS to filler nanoparticles in rubber as well as introducing the present situation of XPCS in Japanese synchrotron facilities.

XPCS experiments have been performed at BL40XU, SPring-8 (Japan). A quasi-monochromatic X-ray from helical undulator is used for producing partially coherent X-rays. The speckle patterns have been monitored by using an indirectly-illuminated X-ray CCD detector [2]. Styrene-butadiene rubber containing carbon black or silica has been used as the samples.

When the XPCS was applied to uncross-linked rubber containing silica particles, its dynamics showed aging behavior reflecting the release of local stresses that were induced during the mixing process of rubber and filler [3]. By combining XPCS with Diffracted X-ray Tracking measurement, we have succeeded in measuring both translational and rotational motion of nanocrystals in rubber simultaneously [4]. When heterodyne measurements are applied, the dynamics in stretched samples can be studied [5]. These results show that XPCS is quite useful for observing microscopic dynamics in complex fluids, indicating that XPCS is used as a microrheological measurement [6].

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Keywords – X-ray Photon Correlation Spectroscopy, Reinforcement Effect, Dynamics

References