Dynamics of Nanocomposite revealed by X-ray Photon Correlation Spectroscopy

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Rubber filled with nanoparticles (fillers), such as carbon black and silica, shows reinforcement effects; the addition of fillers improves the mechanical and viscoelastic properties, such as elastic modulus, tear strength, and wear resistance [1]. The understandings of its mechanism is greatly important for industries, such as the tire industry, from the viewpoint of both ecology and tire safety. For example, tire manufactures constantly make an effort to reduce their products' rolling resistance to help the environment by minimizing the use of fossil fuel. However, care must be taken so that the improvement in rolling resistance does not reduce incompatible performance characteristics such as wet traction. Indeed, tire rolling resistance and wet traction are both dictated by the energy losses but encompass different deformation magnitudes and frequencies. To achieve developments of nanocomposites that would have viscoelastic responses upon deformation such that the above seemingly incompatible properties are fulfilled, the mechanism of reinforcement effect should be clarified. The majority of previous research has focused on the structure of filler/rubber and the macroscopic rheology of the composite. Understanding of the microscopic structure and dynamics will be a clue to clarify the mechanism of complex viscoelastic behavior of filled rubber.

To elucidate the nature of reinforcement effect, we have developed X-ray photon correlation spectroscopy (XPCS) [2] at SPring-8. XPCS corresponds to dynamic light scattering in an X-ray region. By using XPCS, one can obtain the information regarding the microscopic dynamics of filler in nanocomposites. The combination of time-resolved ultra-small-angle X-ray scattering (USAXS) [3] and XPCS, and the development of indirectly illuminated X-ray area detector for XPCS [4] have enabled us to investigate the detailed dynamics of filler in rubber. The filler dynamics greatly depend on the volume fraction of filler and the interface between filler and rubber. The aging phenomenon of filler dynamics has been clearly observed [5].

In this presentation, an overview of the XPCS and our application to nanocomposites will be described. In addition, future prospects of XPCS using a new generation light source such as XFEL will be discussed.

References

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