Synchrotron Radiation Scattering and Spectroscopy Applied to Soft Matter Science

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Abstract

Synchrotron radiation produces light that is highly brilliant than conventional X-ray sources. Wave length covers from IR, soft X-ray to hard X-ray. By utilizing wide wave range and high quality of light source, various scattering and spectroscopy can be applied to various soft matter. In this presentation, the authors present our recent researches on SR-IR, XPCS, and SR-SAXS applied to soft matter characterization.

SR source generates brilliant IR beam so that we can achieve high spatial resolution mapping of surface with high SN ratio. The authors characterized the wetting of superhydrophilic polyelectrolyte brushes with water utilizing SR-IR. Reflection interference contrast microscopy showed that the contact angle of a water droplet on the surface was extremely low but remained finite, despite the high affinity of the polyelectrolytes for water. The SR-IR demonstrated that water was present even outside the droplet. These water molecules were confined to the thin brush layer and formed a highly ordered hydrogen bond network, that is, structural water.

Spontaneous molecular aggregation structure development around a crack tip of a segmented polyurethane (SPU) elastomer film consisting of hard segment (HS) and soft segment (SS) was investigated. *In-situ* micro-beam WAXD measurements were applied to the micrometer-scale local structure mapping at the crack tip. The local strain-induced crystallization of soft segment at a crack tip and the anisotropic HS domains alignment toward the crack tip were demonstrated. The mechanisms behind the crack arrest and mechanical strength of the polyurethane elastomer film are attributed to the local strain-induced soft segment crystallization at the crack tip, the mechanical stability of the HS domains, and local stress transfer through the HS rotation.

A molded film of single-component polymer-grafted nanoparticles (SPNP), consisting of a spherical silica core and densely-grafted polymer chains bearing hydrogen-bonding side-groups capable of physically crosslinking, was investigated by *in-situ* ultra-small-angle X-ray scattering (USAXS) measurement during uniaxial stretching process. USAXS revealed that the molded SPNP formed a highly oriented twinned face-center-cubic lattice structure and a [111] plane was aligned nearly parallel to the film surface at initial state. Structural analysis by *in-situ* USAXS using a model of uniaxial deformation induced by rearrangements of the nanoparticles revealed that the fcc lattice was distorted in the stretching direction being proportional to the macroscopic strain until the strain reached 35% and subsequently changed into the other fcc lattice with different orientations. The lattice distortion and structural transition behavior corresponded well to the elastic and plastic deformation regimes, respectively, observed in the stress-strain curve. The rearrangement mechanism of the nanoparticles is well accounted for by a strong repulsive interaction between the densely-grafted-polymer shells on the neighboring particles.

XPCS is a technique, which allow us to characterize the dynamics of nanomaterials with coherent X-ray source. The dynamical behavior of polystyrene-grafted silica nanoparticles dispersed in a polystyrene matrix was studied using XPCS. While at low temperatures the particle motion was hyperdiffusive, the motion became subdiffusive with increasing temperature. This crossover may be a result of the competition between the dynamical heterogeneity of polymer matrix around the glass transition temperature, and the interaction between the polymer brushes and the polymer matrix.