3D imaging of degradation process at the interface of rubber and metal by CT-XAFS

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Brass (Cu-Zn alloy)-coated steel cords, which are the structural reinforcements of rubber tires, react with sulfur in rubber to form complex multilayers of metal sulfides. During practical use under high-temperature and humidified conditions, the structure and chemical composition of the multilayer gradually change by sulfurization, leading to decrease in adhesion strength, but the structure and spatial distribution of metal sulfides have not been clarified well. In this study, we investigated the nondestructive visualization of the degradation process of the rubber-brass interface by Cu-K-edge CT-XAFS imaging for the first time.

A rubber sample containing 1 wt% of brass particles (Cu/Zn ratio = 75/25, φ0.3 × 0.2 μm) was processed for initial vulcanization. After the first Cu K-edge CT-XAFS measurement, typical hydrothermal degradation for 3 days was performed for the sample. The CT-XAFS measurements and the hydrothermal degradation processes (+11 days and +(11+14) days) were repeated for the sample. The CT-XAFS measurements were performed for the same field of view of the sample and the set of CT-XAFS imaging data was subjected to linear combination fitting analysis (E = 8.850-9.200 keV) for the three components of brass (Cu^{0+}), Cu_2S (Cu^{1+}), and CuS (Cu^{2+}). The reconstruction of the parameters of the amounts of the three species was conducted and the three-dimensional images of the distribution of the species were obtained.

Fig. 1 shows the reconstructed 3D images of brass, Cu_2S, and CuS distribution in the rubber sample visualized by the CT-XAFS. The brass particles originally existed in the rubber sample and Cu_2S, which was key for the adhesion of rubber and brass, was formed around the brass particles. After the hydrothermal treatment, the formation of Cu_2S and CuS was clearly observed in the three-dimensionally reconstructed images obtained by the CT-XAFS imaging. Accompanied with the increase in the reaction time of the hydrothermal treatment, the distribution of Cu_2S and CuS were widely changed in the rubber sample. The CT-XAFS imaging and the spatial distribution of the sulfide species will be discussed.

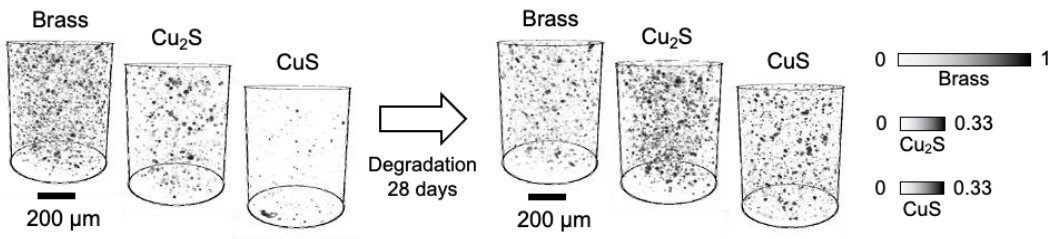

Fig. 1 3D images of brass, Cu_2S, and CuS distributions in rubber visualized by CT-XAFS.