Analysis of Multiscale Structure of Epoxy Adhesive with Various Crosslink Density in the Single-lap Joint

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Cured epoxy resin (CEP) is mainly synthesized by the polyaddition reaction of epoxy and amine, and are widely used as structural adhesives for automobiles, aircraft, and other applications. To create adhesives with higher adhesive strength, it is important to understand the failure mechanism of adhesive including the structure changes in the microscale from the microscale to the macroscale. In this study, the mechanical properties of single-lap joints (SLJ) with low-crosslinked CEP and the structure changes of multiscale of the adhesive layer during lap shear deformation process are analyzed using lap shear test, digital image correlation (DIC) analysis and synchrotron μ-beam small-angle X-ray scattering (SAXS) mapping measurements.

A commercially available epoxy resin (Epon828, Polysciences, Inc.) with a chemical structure of diglycidyl ether of bisphenol A, and 2-phenylethylamine (2-PEA, f = 2), a primary monoamine, were used for polymerization of CEP. [Amine] / [Epoxy] = 1 and adhered two stain-less steel (SUS304) substrates. SLJ was prepared by curing at 100 °C for 24 hours. The sample name was denoted as CEP-2-PEA-SLJ. The macroscopic and microscopic structure changes during the lap shear deformation process were evaluated using DIC analysis and synchrotron radiation μ-beam SAXS mapping measurements.

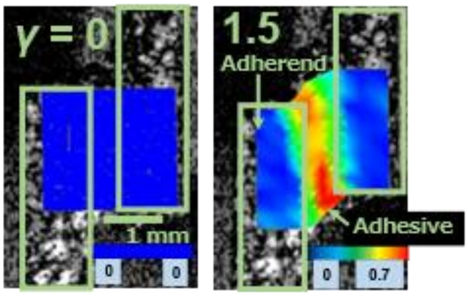

Figure 1 : Strain maps in CEP-2-PEA-SLJ.

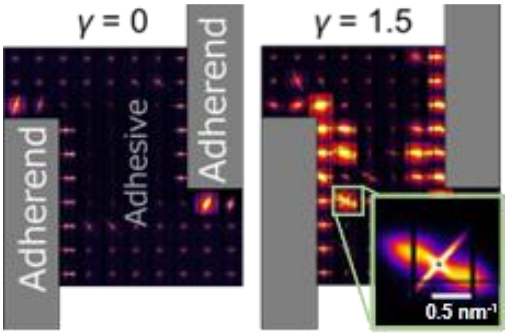

Figure 2 : SAXS patterns of CEP-2-PEA-SLJ during lap shear deformation.

Figure 1 shows the strain maps of CEP-2-PEA-SLJ obtained from the DIC analysis. With increasing strain, the local strain in the adhesive layer also increased and large deformations occurred at the edge positions. This suggests that stress concentration occurred at the edge of the adhesive layer.

Figure 2 shows SAXS patterns of the CEP-2-PEA-SLJ adhesive layer at various positions during lap shear deformation process. In the initial state, streaks from the substrate were observed near the adherend region. At γ = 1.5, a new scattering pattern near the adherend corners, possibly originating from the craze and fibrils, was observed in a direction tilted from perpendicular to the adherend. It is considered that internal structure changes occurred in the stress concentration region and crazes were formed. Furthermore, the stress values decreased during the SAXS mapping measurements. It is suggested that stress relaxation occurred due to the formation of crazes in the adhesive layer and plastic deformation.

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