Decompression Failure of Rubber Seal in High-Pressure Hydrogen Gas

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The hydrogen energy is considered to be a technology that might solve the serious problems of global warming and depletion of fossil fuels. One important task for mechanical engineers and material scientists is the development of materials and systems which are capable of withstanding hydrogen effects. In the case of rubbers, a high-pressure hydrogen decompression causes their internal fracture [1]. This study exposed an unfilled ethylene-propylene-diene-methylene linkage (EPDM) rubber, which is transparent, to hydrogen gas at $\leq$ 10 MPa, and elucidated the mechanism of the internal fracture. The observations by optical microscope (OM) clarified that the crack damage caused by the decompression of hydrogen gas became more serious with increasing hydrogen pressures. The observations of the fracture surfaces by scanning electron microscope (SEM) classified fracture origins into two types, micrometer-size defects and sites without anything. In order to evaluate the nanoscale fracture which is hardly observed by OM, the measurement by acoustic emission (AE) [2] and observation atomic force microscope (AFM) [3] were conducted. According to preliminary results, while AE signals were hardly detected during the deformation process of chain molecules under tensile test, many signals were detected during the fracture process of chain molecules under crack growth test. AE signals were generated from the hydrogen-exposed specimen where no cracks were observed by OM. It is inferred that these AE signals were generated due to nanoscale bubbles, which are hardy observed by OM. Furthermore, from the AFM observation, nanoscale holes were observed in an unexposed specimen, and their number and size increased with hydrogen exposure. This result implies that the rubber matrix is not homogeneous at a nanoscale level, and nanoscale fracture caused by the bubbles occurs even though no cracks are observed by OM. It is presumed that these nanoscale bubbles formed after decompression grew, and then caused internal fracture observed by OM.

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References

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