Degradation of material in high-temperature hydrogen environment simulating SOFC working conditions

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Solid oxide fuel cells are considered to be necessary to realize an economically independent hydrogen society, because these devices have a great potential to meet the huge hydrogen demand when it is used for power generation. However, studies on the structural materials for SOFC and peripheral equipment are very limited.

Creep is the tendency of the time-dependent deformation of a solid material under constant loading and one of the most important material properties for materials used at elevated temperature. There are several reports on the degradation of materials in high temperature hydrogen. However, the mechanism that causes hydrogen embrittlement at room temperature, which is activated by the interaction between dislocations and hydrogen, doesn't work at high temperature because of weak interaction.

The objective of this study is to gain a better understanding of the creep properties in high-temperature hydrogen in order to provide a basic science that ensures the safety of evolving hydrogen technologies that operate at elevated temperature.

I will show the result of the creep testing in argon and hydrogen gases at 600 °C. The material was JIS SUS304 austenitic stainless steel. Results revealed that hydrogen accelerated the creep deformation and significantly reduced the creep life compared to that in argon (Fig. 1). Detail observation of the fracture surface and analysis of the steady state creep behavior indicated that the same creep mechanism operated in both hydrogen and argon environments, which was deduced to be dislocation creep. In dislocation creep, the deformation of the material is dominated by dislocation climb resulting from atom diffusion.

Regarding the mechanisms governing the reduced creep life in hydrogen, hydrogen attack, carbide formation and HELP were investigated. It was confirmed that these effects were minor contributors to the reduced creep life, at least within the creep life range of this study. Alternatively, we consider another plausible role of hydrogen: hydrogen-enhanced vacancy density, which can lead to enhanced lattice diffusion and associated dislocation climb. As a consequence, hydrogen accelerated the creep strain rate and shortened the creep life.

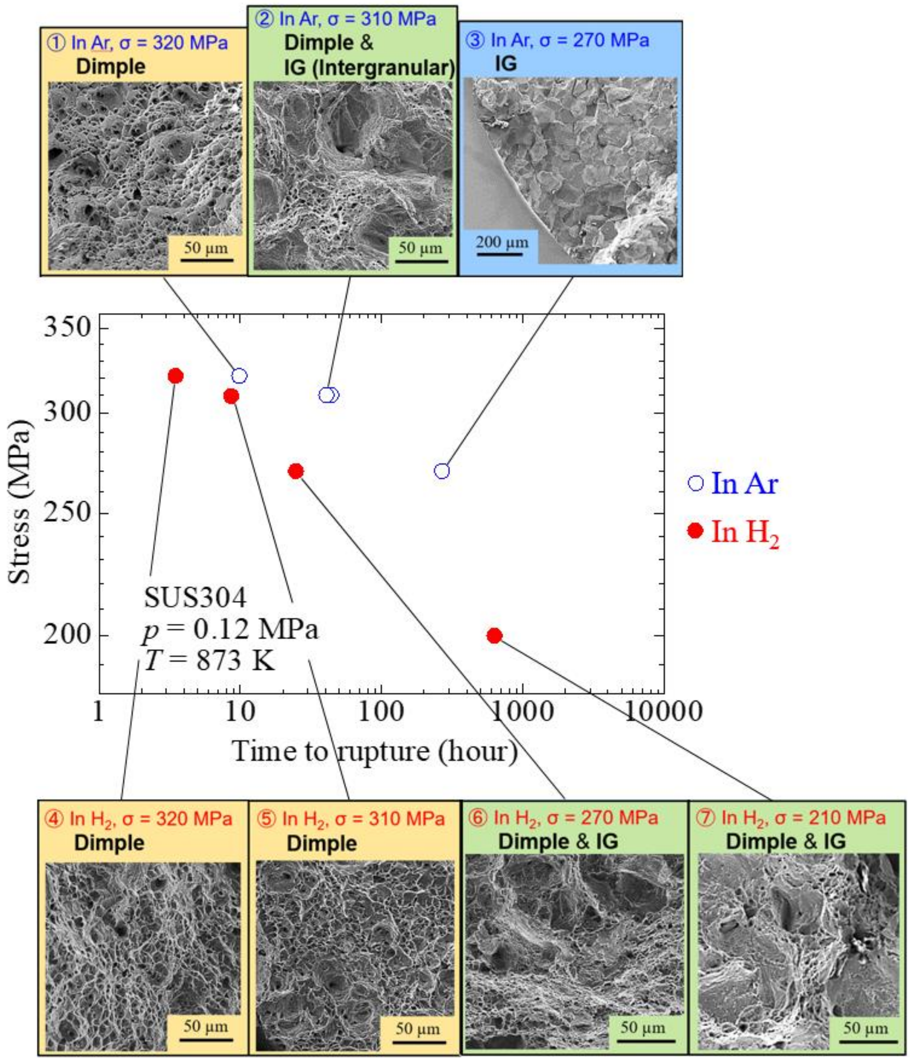

Fig. 1 Creep rupture time curves and fracture surfaces