The crucial defects induced in iron and stainless steel upon hydrogen embrittlement by positron annihilation spectroscopy

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Austenitic stainless steels are considered to be one of the most important structural materials for hydrogen energy systems. It is well-known that the Ni equivalent is strongly related to the hydrogen susceptibility and ANSI 316L with 12mass% Ni shows highly resistant to hydrogen embrittlement (HE). However, the hydrogen susceptibility is also dependent on a strain temperatre and shows maximum around -70 ºC. This phenomena is explained by the trade-off between hydrogen diffusion and stability of fcc-phase. Hydrogen stabilizes a formation of vacancies, so that it is very important to investigate their behavior in HE. In this study, austenitic stainless steels, ANSI 316L, strained at low temperatures were investigated by positron annihilation lifetime spectroscopy (PALS) and the crucial defects in HE were discussed. PALS is one of the most powerful methods to directly detect open-volume type defects in metals and enables us to obtain information on their size, chemical state and amount.

ANSI 316L sheets were exposed to 95 MPa of hydrogen gas at 300 ºC for 72 h and the hydrogen concentration was estimated to be 90 ppm. The specimens were subject to tensile stress at temperatures from -150 ºC to RT. ANSI 316L showed no hydrogen susceptibility at -150 ºC and RT, while the fractured surface of the specimen straining at -70 ºC showed the quasi-cleavage, indicating HE took place. The fractured sample strained at RT showed the formation of a lot of smaller vacancy clusters, indicating the agglomeration of the monovacancies. Hydrogen stabilized a formation of vacancies, so that the vacancies can homogeneously agglomerate to form small vacancy clusters because the stress-induced martensitic phase cannot form. On the other hand, larger vacancy clusters formed in the fractured sample strained at -70 ºC. It is understood that the straining at -70 ºC induced highly strained fields, such as at the boundary between the fcc and martensitic phases, where a lot of vacancy-hydrogen complexes locally formed and agglomerate to larger vacancy clusters. It is considered that they possibly become the embryos of the quasi-cleavage. The straining at -150 ºC induced a lot of vacancy-hydrogen complexes and the formation of vacancy clusters could not be observed. Further, aging at RT lead to a formation of much larger vacancy clusters. It means that vacancies with a high density are locally formed, but they cannot diffuse and agglomerate at -150 ºC. It is, therefore, concluded that the crucial defects upon HE in the austenitic phase are vacancy-hydrogen complexes with a high density induced by a strain localization. Further the results on the iron upon HE will be discussed.

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