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Dominant defects in hydrogen-embrittled iron detected by positron annihilation spectroscopy

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It is well known that hydrogen leads to embrittlement in various metals, so that it is very important to clarify the origin of this mechanical degradation. Thermal desorption spectroscopy (TDS) has been often applied to study the defects induced in α-iron by hydrogen embrittlement (HE) and the critical defects are attributed to be the peak at 373 K[1], although its assignment has not been done yet. Positrons are highly sensitive to open-volume type defects. In this work the defects that give rise to hydrogen embrittlement in α-iron have been examined by positron annihilation lifetime spectroscopy (PALS). In a previous study a long lifetime (>300ps) corresponding to the presence of vacancy clusters appeared in PALS measurements of α–iron strained in a hydrogen environment, although those vacancies hardly form without hydrogen [2] . It has been reported that the susceptibility to hydrogen embrittlement strongly depends on the strain rate. It means that the diffusion of hydrogen is related to hydrogen embrittlement, so that we expect hydrogen-vacancy complexes as the crucial defects in HE. Hence, we have investigated the defect dependence on the strain rate in α-iron and tried to elucidate the crucial defects by measuring the temperature dependence of the positron annihilation spectra from 170 K to 520 K.

The positron lifetime vs. temperature dependence for the slow-strained sample is shown in Fig. 1. The longest lifetime due to vacancy clusters increased gradually from 250 K to 370 K. The induced hydrogen-vacancy complexes released hydrogen, and, as a result, the remaining monovacancies became mobile. That is why the vacancy clusters become larger from 250 K to 370 K. On the contrary, HE was not observed in the fast-strained sample: the longest lifetime corresponding to the vacancy cluster remained constant until 300 K and increased at 315 K, indicating that there were no mobile vacancies below 300 K. From these results, it can be concluded that the vacancy-hydrogen complexes are the crucial defects in α-iron in HE.

Fig.1 Positron lifetime dependence on temperature for slow-strained iron during the H charge.

[1] K. Takai *et al. Acta Materialia* 56, 5158 (2008)
[2] K.Sakaki *et al. Scr. Mater.* 55, 1031 (2006)