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Tomography for Bridging Nano and Macro: Semi-Spontaneous Interfacial Debonding

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This presentation reports the recent progress in understanding hydrogen embrittlement mechanisms in high strength Al-Zn-Mg system aluminium alloys with high Zn concentration. We have clarified that the hydrogen in high strength Al-Zn-Mg system aluminium alloys is originated from the debonding of nano-scopic precipitate / aluminium matrix interfaces. It is commonly believed that the coherent and semi-coherent interfaces of such nanoscopic precipitates do not contribute to damage initiation and growth. It has however been proved that the interface is a prefereable trap site for hydrogen and exhibits hydrogen-accelerated spontaneous microcracking under high hydrogen concentration. This presentation also covers the prevention methods for the hydrogen embrittlement by controlling local hydrogen partitioning in the alloys.

High Zn (10% mass Zn) Al-Zn-Mg-Cu aluminum alloys were mainly used in this study. To identify the influences of intermetallic particles on the hydrogen partitioning and embrittlement behaviors, two alloys with different Fe and Si contents were used with two levels of pre-existing hydrogen concentration levels. It has been demonstrated that if we can increase Zn concentration up to 10 mass % or so, we can obtain ultra high strength for aluminium as shown in Fig. 1. It has however been generally experienced that such high Zn concentration causes detrimental stress corrosion cracking and hydrogen embrittlement, implying that such aluminium alloys are not practically used.

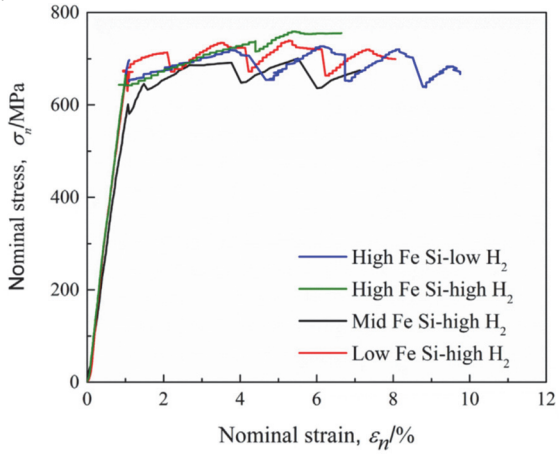

Fig.1 Stress-strain curves recorded during the in-situ tensile test of Al-10Zn-2.4Mg alloy with different hydrogen and impurity contents[1)].

It has been recently reports that aluminium / precipitate ($MgZn_2$) interface can trap hydrogen relatively strongly, which is different from the commonly accepted myth that aluminium / precipitate ($MgZn_2$) interface does not trap hydrogen at all. It is also interesting to note that aluminium / precipitate ($MgZn_2$) interface exhibites singular behavior in the first principles simulations that spontaneous debonding occurs under high hydrogen concentration at the aluminium / precipitate ($MgZn_2$) interface without any expernal disturbance such as loading. It has been confirmed by estimating hydrogen partitioning among various nano-scopic defects such as dislocations, vacancies, grain boundaries, nano voids, etc. as well as the aluminium / precipitate interface that the majority of hydrogen in the aluminium alloys is trapped at the aluminium / precipitate ($MgZn_2$) interface due to its high binding energy with hydrogen as shown in Fig. 2. As a consequence, hydrogen embrittlement is observed as shown in Fig. 1 for high H_2 materials, resulting in the marked reduction in mechanical properties such as ductility.

It has been also reported that intermetallic compound particles, which are usually dispersed in aluminium alloys as coarse particles of typically a few μm in diameter, are one of the hydrogen trap sites in Al-Zn-Mg-Cu aluminum alloys. The fractional area of hydrogen-induced quasi-cleavage cracks on tensile fracture surface decreases with an increase in the volume fraction of the intermetallic particles (i.e. Al_7Cu_2Fe), indicating that such specific intermetallic compound particles can enhance the resistance to hydrogen embrittlement, thereby such intermetallic particles can be use effective inhibitor for hydrogen embrittlement. Quantitative assessment of localized hydrogen repartitioning behavior during deformation was performed to quantitatively understand the hydrogen embrittlement behavior in the high Zn Al-Zn-Mg-Cu aluminum alloys. The hydrogen repartitioning behavior is strongly.

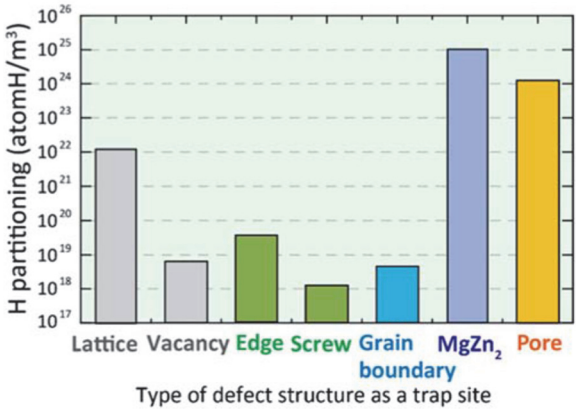

Fig. 2 Hydrogen partitioning behaviour in Al-Zn-Mg alloys. Theoretically-derived estimates of hydrogen partitioning at various defect sites, which were derived based on thermodynamic equilibrium condition and first-principles calculations[2)].

References

(1) H. Su, et al., Acta Mater., 176(2019), 96-108.
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