ROLE OF T PHASE IN THE HYDROGEN EMBRITTLEMENT SUPPRESSION FOR AL-ZN-MG-CU ALLOYS

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Hydrogen embrittlement of high-strength aluminum alloys impedes efforts to develop ultrastrong components in the aerospace and transportation industries. Understanding and utilizing the interaction of hydrogen with core strengthening elements in aluminum alloys, particularly nanoprecipitates, are critical to break this bottleneck. Herein, we show that hydrogen embrittlement of aluminum alloys can be largely suppressed by switching nanoprecipitates from the η phase to the T phase. The T phase-induced reduction in the concentration of hydrogen at defects and interfaces primarily contributes to the suppressed hydrogen embrittlement. Transforming precipitates into strong hydrogen traps is proven to be a potential strategy for hydrogen embrittlement suppression [1].

Firstly, we show through first-principles simulations the excellent hydrogen trapping capacity in the interior of T-$Al_2Mg_3Zn_3$ precipitates with a maximum binding energy of 0.6 eV (Fig. 1a). Secondly, comparative experiments were conducted to test the effects of T phase in hydrogen embrittlement suppression for high-strength aluminum alloys, taking a quaternary Al-5.6Zn-2.5Mg-1.6Cu (wt%) alloy as a model material. The aging temperature was increased from 120 (LT) to 150 ℃ (HT) to induce transformation from η phase to T phase.

In-situ tensile tests indicated significantly improved elongation due to the change in nanoprecipitates (Fig. 1b) at same strength and hydrogen concentration levels. The presence of T phase was confirmed by transmission electron microscopy (Fig. 1c) and atom probe tomography (Fig. 1d). 4D observations using synchrotron radiation X-ray tomography demonstrated that the presence of T phase strongly resists crack growth. High-density three-dimensional strain maps (Fig. 1f), obtained by tracking the movement of numerous micron-sized S-phase particles, enabled the nondestructive examination of T phase effect on the strain evolutions around crack tips. Hydrogen partitioning behavior among various hydrogen trap sites indicated a considerably high amount of hydrogen trapped at T precipitates, voids and vacancies, providing realistic insights into the role of precipitates in hydrogen embrittlement (Fig. 1g).

The hydrogen embrittlement suppression strategy, through modification of precipitates, is expected to be effective in various high-strength aluminum alloys due to the wide availability of T precipitates or their variants and can also inspire the development of HE-resistant alloys with similar switchable nanostructures.

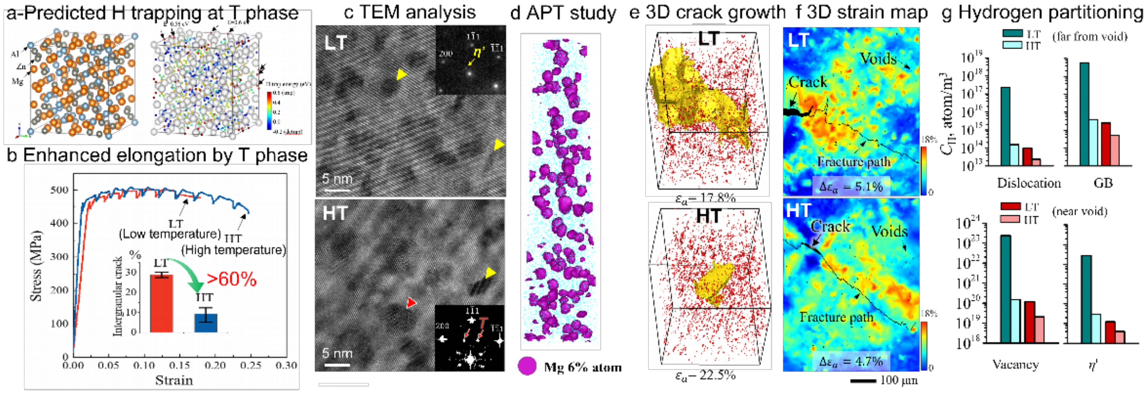

Figure 1 – Transforming precipitates from η phase to T phase to improve hydrogen embrittlement resistance. a) first-principles simulations; b) tensile curves; c)TEM observations; d) APT tests; e) in-situ 3D imaging of H-induced intergranular cracks; f) 3D strain evolution; g) hydrogen partitioning among various trap sites.

Reference:

[1] Wang Y, Sharma B, Xu Y, Shimizu K, Fujihara H, Hirayama K, …& Toda H. Switching nanoprecipitates to resist hydrogen embrittlement in high-strength aluminum alloys. Nature communications, 2022, 13(1): 1-8