PREVENTION OF HYDROGEN EMBRITTLEMENT IN AL-Zn-Mg ALLOYS BY DISPERSION OF NOVEL PHASES

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Al-Zn-Mg alloys are known to be representative high-strength aluminum alloys that exhibit hydrogen embrittlement similar to steels. We have previously proposed that hydrogen-induced debonding of the MgZn2 interface is the origin of hydrogen embrittlement in Al-Zn-Mg alloys. MgZn2 is the primary precipitate in Al-Zn-Mg alloys and is responsible for the strengthening mechanism of this alloy, but the MgZn2 interface also acts as a hydrogen trapping site. The hydrogen trapping energy at the MgZn2 interface has been reported to be a maximum of 0.35 eV/atom at the (111)Al//(0001)MgZn2 coherent interface and 0.55 eV/atom at the (110)Al//(1100)MgZn2 semicoherent interface. This trapped hydrogen reduces interfacial cohesive energy, resulting in macroscopic hydrogen-induced quasi-cleavage fracture originating from interfacial debonding. This is the mechanism of quasi-cleavage fracture in Al-Zn-Mg alloys that we have clarified.
The key to preventing hydrogen embrittlement in Al-Zn-Mg alloys is to reduce trapped hydrogen at the MgZn2 interface. As a specific strategy, we propose to disperse novel phases having hydrogen trapping energies greater than that of the MgZn2 interface. Aluminum is chemically active, and the addition of trace elements during casting leads to the formation of second phases with a variety of compositions and crystal structures. We have found, via DFT calculations, that some phases, such as Al31Mn6Cu2, Al11Mn3Zn2, Mg32(Al, Zn)49, have hydrogen trapping energies above the MgZn2 interface, as depicted in Figure 1. Phases with complex compositions and structures exhibit high hydrogen trap energies, while phases with simple compositions and crystal structures, such as Al2Cu and Mg2Si, have low internal hydrogen trap energies.
We fabricated aluminum alloys dispersed with these second phases in the matrix and observed the deformation and fracture behavior in situ using synchrotron X-ray tomography. The results indicate that quasi-cleavage and intergranular fractures can be significantly suppressed with dispersed Mn-bearing second phase and Mg32(Al, Zn)49. This study concludes that the dispersion of novel phases with high internal hydrogen trap energy remarkably contributes to the prevention of hydrogen embrittlement in Al-Zn-Mg alloys.