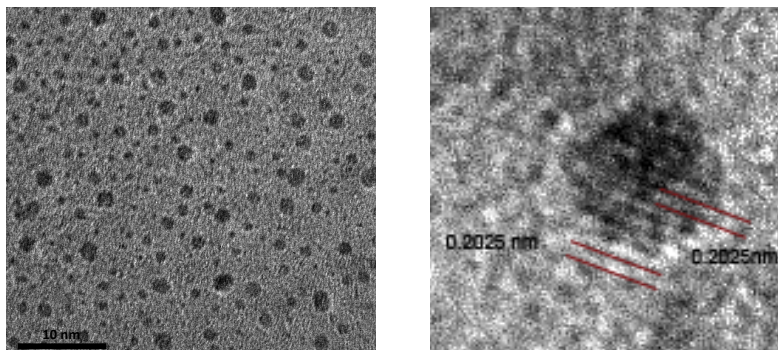


Precipitation Strengthening of Aluminum by Transition Metal Aluminides

Research Team

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Transition metals (TM) have great potential as additives to aluminum alloys that are intended for high temperature applications because, upon heat treating the alloy, they form thermally stable transition metal aluminide particles of the form Al_3TM . In this respect, the most useful of the metal aluminides is zirconium because of its low cost and its ability to form coherent Al_3Zr particles that have the $L1_2$ crystal structure. Unfortunately, our measurements show that the cooling rate that is necessary to retain the minimum amount of zirconium (0.6 wt. pct.) necessary for significant strengthening in a super-saturated solid solution with aluminum is about $90^\circ C/s$, which is un-attainable by traditional casting processes. However, our measurements also show that the cooling rate necessary to retain 0.4 wt. pct vanadium and 0.1 wt. pct. zirconium in a super-saturated solid solution with aluminum is only $35^\circ C/s$. This is an important finding as it means that, unlike the Al-0.6Zr alloy, the Al-0.4V-0.1Zr alloy may be processed into useful components by traditional high pressure die-casting. Moreover, our measurements show that the hardness of the Al-0.4V-0.1Zr alloy does not degrade even after holding the alloy at $300^\circ C$ for 150 hours. Also, our measurements show that the tensile yield strength of the Al-0.4V-0.1Zr alloy at $300^\circ C$ is about 3 times higher than that of pure aluminum. The increase in hardness and strength is due to formation of $Al_3(Zr,V)$ particles uniformly dispersed in the aluminum matrix. Examination of these particles with high resolution transmission electron microscopy (HRTEM) and conventional transmission electron microscopy (TEM) show that they are spherical with a 5nm radius, coherent with the aluminum matrix, and have the $Al_3(Zr_{0.125},V_{0.875})$ composition and the $L1_2$ crystal structure. It also shows that the crystallographic misfit that existed between the Al_3Zr particles and the aluminum matrix is almost eliminated by partially substituting vanadium for zirconium.



HRTEM photomicrograph showing the $Al_3(Zr_xV_{1-x})$ precipitate particles in aluminum.