Department of Materials Science and Engineering,

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Zoom link: https://drexel.zoom.us/j/99292578144

Quaternary Solid Solutions in the $(M_{1-x}M'_x)_2AlB_2$ and $(Mo_{1-x}M'_x)AlB$ Systems

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Abstract

The MAB phases are layered ternary transition metal borides (TMB), with atomically laminated crystal structures comprised of transition metal, M, boride layers (M-B) interleaved by single or double layers of A, typically Al. Quenching studies were performed on Cr_2AlB_2, Cr_3AlB_4, and Fe_2AlB_2 to investigate the exact reaction mechanism for MAB formation. It was determined that during formation, all MABs undergo a topotactic transformation, retaining the structure of the MB building blocks in the final MAB form. Using the reaction mechanism determined from these quenching studies, $(M_{1-x}M'_x)_2AlB_2$ solid solutions were synthesized via pressureless sintering along a two-step reaction process, first by synthesizing $M_{1-x}M'_xB$ binary boride solid solutions, then reacting them with Al. For the $(Mo_{1-x}M'_x)AlB$ solid solutions, two-part single-step synthesis was used due to limitations in processing temperatures. A range of solid solutions between existing MABs and 3d and group 5-6 transition metals were attempted.

Powder X-ray diffraction of select systems show lattice parameter shifts and unit cell expansions indicative of successful solid solution formations.

In this work, a full range of $(Fe_{1-x}Mn_x)_2AlB_2$ solid solutions were synthesized, and magnetic studies were performed. It was determined that over the range of Mn loading, the solid solutions exist as ferromagnetic, canted antiferromagnetic and antiferromagnetic. Increased Mn loading leads to a reduction in T_c, however during evaluation of the magnetocaloric effect, it was found that a Mn loading of x = 0.2 has a greater relative cooling power than Fe_2AlB_2 between 0-20 °C.

Polycrystalline $(Mo_{1-x}Cr_x)AlB$ is synthesized for the first time. For the first time $(Mn_{1-x}Cr_x)_2AlB_2$ solid solutions were synthesized and are continuous over the entire range of substitution. Bulk synthesis of these solid solutions was also attempted via vacuum hot pressing in single and two step reactions. For $(Mn_{1-x}Cr_x)_2AlB_2$, scanning electron microscopy and energy dispersive spectroscopy was used to confirm single phase bulk solid solutions.

Overall, the only successful quaternary MAB solid solutions produced via pressureless sintering were between atomic nearest neighbors of existing MAB phases. A full range of solubility (x = 0 – 1) exists between MABs of the same structure (MoAlB and WAlB in $M_2A_2B_2$; Fe_2AlB_2, Mn_2AlB_2 and Cr_2AlB_2 in M_2AlB_2).