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Ferromagnetism and localization in $Ga_{1-x}Mn_xAs$, $Ga_{1-x}Mn_xP$, and in between[1]

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Because of their potential as both injectors and filters of spin-polarized carriers, ferromagnetic semiconductors may play an important role in spin-based electronics, or *spintronics*. Ferromagnetic semiconductors are formed by the substitution of a relatively small fraction of host atoms with a magnetic species. $Ga_{1-x}Mn_xAs$ has been the most thoroughly studied material among these, and ferromagnetism in it arises from hole-mediated inter-Mn exchange. The Curie temperature T_C in $Ga_{1-x}Mn_xAs$ has been shown to increase with increasing concentration of substitutional Mn acceptors. However, room temperature ferromagnetism in this canonical system has been elusive due to challenges in materials synthesis—namely, raising x while avoiding the formation of second phases or compensating defects. Increasing $p-d$ exchange by modifying the host semiconductor via anion substitution (e.g., replacing As with P) is a significantly less explored route by which T_C may be raised. We are investigating the effect of anion substitution in ferromagnetic $Ga_{1-x}Mn_xAs_{1-y}P_y$ formed by ion implantation followed by pulsed-laser melting. In the endpoint compound $Ga_{1-x}Mn_xP$ T_C is found to vary linearly with x, and non-metallic transport is observed for x up to $\sim$4.2%, corresponding to a T_C of $\sim$62 K compared to $\sim$112 K for $Ga_{1-x}Mn_xAs$ with a similar x. Dilution of the endpoint compound $Ga_{1-x}Mn_xAs$ with P results in a precipitous decrease in T_C to below 60 K for y=2.8%. Remarkably, $Ga_{1-x}Mn_xAs_{1-y}P_y$ films undergo a metal-insulator transition between y=1.5% and 2.3% even as x is held approximately constant indicating that alloy disorder in the anion sublattice induces hole localization, which in turn may be responsible for a strong suppression of T_C. Thus, while anion substitution may enhance $p-d$ exchange, localization effects must be considered when developing a suitable picture for ferromagnetism in these materials.

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