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Effects of Magnetic and Non-Magnetic Impurities in MgB_2: A Point-Contact Study of Single Crystals

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We studied the effects of chemical substitutions, either magnetic (Mn) or non-magnetic (Al, C), on the energy gaps of MgB_2 by means of directional point-contact spectroscopy (PCS) in state-of-the-art single crystals. Here we discuss two noticeable cases, i.e. $Mg_{1-x}Mn_xB_2$ crystals with x up to 0.015, and $Mg_{1-x}Al_xB_2$ crystals with x up to 0.32. In both cases, we used a pressure-less PCS technique in which a thin Au wire is put in contact with the side surface of the crystal by means of a small drop of Ag paint. The gaps Δ_σ and Δ_π were obtained through a two-band Blonder-Tinkham-Klapwijk (BTK) fit of the Andreev-reflection conductance curves of the resulting contacts. Both in Mn- and Al-doped MgB_2, the gaps decrease on decreasing the critical temperature of the contacts, T_c^A (at which the Andreev-reflection structures disappear), but remain clearly distinct down to $T_c^A \simeq 10$ K. Once analysed within the two-band Eliashberg theory, the Δ_σ and Δ_π vs. T_c^A curves give information about the effects of Mn and Al substitutions on the different scattering channels (interband and intraband, magnetic or non-magnetic). It turns out that the main effect of Mn is to increase the spin-flip scattering within the σ band (with smaller contributions from either the $\pi - \pi$ or the $\sigma - \pi$ channels), as also confirmed by first-principle bandstructure calculations. In the case of Al, the band-filling effect is largely dominant. An increase in non-magnetic interband scattering is possible, but small enough not to give rise to gap merging.

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