INFLUENCE OF CHEMICAL SUBSTITUTIONS ON ANISOTROPIC UPPER CRITICAL FIELD IN MgB$_2$: IMPACT OF FERMI SURFACE CHANGES

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Specific band structure of MgB$_2$, with two bands $\pi$ and $\sigma$ involved in superconductivity, leads to high critical temperature, $T_c$, of 39 K and temperature and field dependent anisotropy of superconducting parameters. Chemical substitutions lead to modification of band structure and therefore influence all superconducting parameters, especially $T_c$, the upper critical field, $H_{c2}$, and its anisotropy, $\gamma_{H}$. Magnetic investigations of Mg$_{1-x}$Al$_x$B$_2$ crystals show the slight increase of $H_{c2||c}$ for the samples with small $x$, significant reduction of $\gamma_{H}$ at lower temperatures for Al substituted samples as compared to this of unsubstituted crystals. In Mg(B$_{0.94}$C$_{0.06}$)$_2$ single crystals $H_{c2||c}(0) \approx 85$ kOe is more than twice as large as that one of $\approx 31$ kOe in unsubstituted MgB$_2$. Anisotropy of $H_{c2}$ decreases to about 4 at low temperatures, the value considerably lower than that in MgB$_2$, and its temperature dependence is much less pronounced. The corresponding $H_{c2||ab}(0) \approx 330$-350 kOe is likely close to the maximum enhancement of $H_{c2}$ due to chemical substitutions. The enhancement of $H_{c2}$ can be explained as a disorder effect only if the main result of disorder is to make the $\pi$ bands more dirty while not affecting the $\sigma$ bands as much. However, in addition to disorder and weakened electron-phonon coupling, the impact of the Fermi level shifting into a region with lower $\sigma$ Fermi surface velocities has to be taken into account in the analysis of $H_{c2}$ data as well.

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