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STRUCTURE AND TRANSPORT PROPERTIES OF DOUBLE DOPED $Mg_{1-x}(Al_{0.5}Li_{0.5})_xB_2$

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A series of polycrystalline samples of $Mg_{1-x}(Al_{0.5}Li_{0.5})_xB_2$ ($0 \le x \le 0.6$) and $Mg_{1-x}Al_xB_2$ ($0 \le x \le 0.4$) were synthesized by the conventional solid state reaction method and their structure and superconductivity were investigated by means of x-ray diffraction (XRD), ac susceptibility and resistivity. The XRD patterns of $Mg_{1-x}(Al_{0.5}Li_{0.5})_xB_2$ ($0 \le x \le 0.6$) samples show that the predominant phase was of MgB_2 type and there was a minor amount of impurity phases for the $x \le 0.4$ samples. A marked increase in intensity of impurity phases can be clearly observed for the $x = 0.6$ sample. Similar to Al doping, the double doping leads to a decrease in both the lattice parameters a and c as shown in the inset of Fig. 1.

To obtain the superconducting transition temperature, both resistivity and ac susceptibility measurement were made. The T_c obtained from magnetic measurement is approximately consistent with that from ρ-T curves. Fig. 1 illustrates the variation of zero resistivity, T_c^0, as a function of substitution level x for $Mg_{1-x}(Al_{0.5}Li_{0.5})_xB_2$ and $Mg_{1-x}Al_xB_2$. The T_cs for the double-doped samples are systematically higher than that of the single Al doped samples. The difference of T_c^0s between the two systems increases and it reaches about 10 K for the two $x = 0.4$ samples.

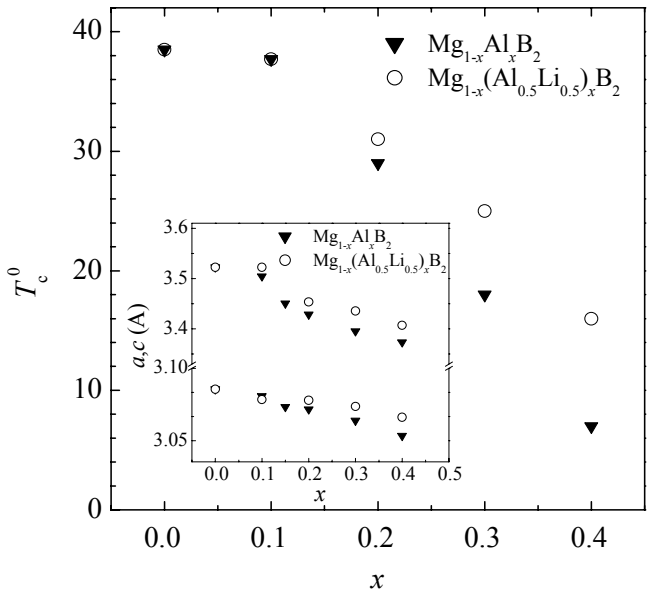
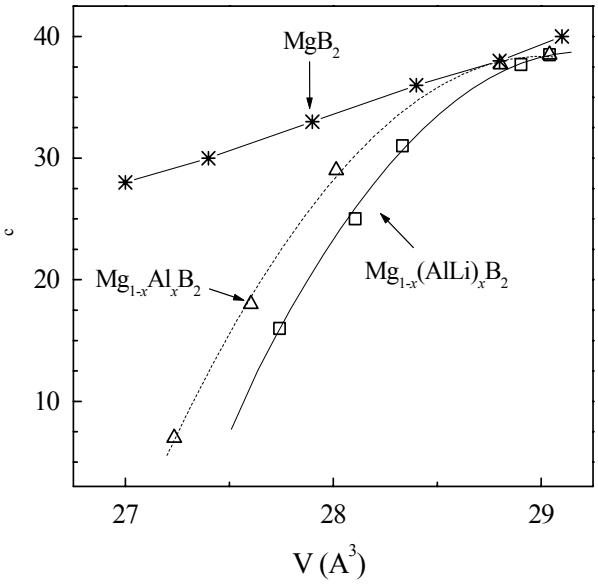


Fig. 1. T_c^0 dependence of doping level x for $Mg_{1-x}(Al_{0.5}Li_{0.5})_xB_2$ and $Mg_{1-x}Al_xB_2$. The inset illustrates the lattice parameter a and c as a function of x.

High-pressure experimental results indicated that MgB_2 remains strictly hexagonal until the high pressure [1]. The large value of critical temperature variation with small modification in the unit-cell volume demonstrates that Mg-B and B-B bonding distances are crucial in the superconductivity, which can be used to understand our results, i.e., Al doping in $Mg_{1-x}Al_xB_2$ leads to a faster decrease in lattice parameters than the double doping with the same doping level, thus the decrease in T_c with Al doping is faster than that with double doping.

To clarify the factors that influence the superconducting transition temperature, we calculated the dependence of T_c on the unit-cell volume and plotted $T_c(V)$ in Figure 2. The result from high-pressure experiment was also given in the figure for comparison. At low doping level, the volume dependence of T_c values are close for the three cases and the T_cs show a approximately linear volume dependence. With further decreasing V, a remarkable deviation from linear $T_c(V)$ behavior for the chemical substituted cases can be clearly observed. The structural transition for the Al doped MgB_2 system taking place as $x \approx 0.1$ may be a possible factor causing the deviation. However, the structural transition, as well as the 'pressure effect', cannot be used to account for the fact that with same unit-cell volume the double-doped system has lower T_c than Al doped system. Obviously the change of carrier concentration is not the main cause resulting in different $T_c(V)$ between the two systems. In fact, the effect of carrier concentration on T_c is a little different between MgB_2 and high T_c cuprates. Hall effect experimental results [2] showed that the charge carriers in MgB_2 are holes with a density of 1.7 – 2.8×10^{23} holes cm^{-3} at 300 K, which is about two orders of magnitude higher than the charge carrier density for high Tc cuprates. This value corresponds to 2.5 – 4 holes per unit-cell in MgB_2. Therefore a little change in carrier concentration may not show significant influence on T_c in MgB_2 system, which is in contrast to that in high-T_c cuprates. From the variation of lattice parameters with doping one may find that in order to get same unit-cell volume, the doping level for the double doped system is always higher than the Al doped system, which means that the disorder for the former is higher than that for the latter with same unit-cell volume. The strong disorder or localized structural distortion may be the origin causing the different T_c(V).



ig.2 T_c as a function of unit-cell volume for $Mg_{1-x}(Al_{0.5}Li_{0.5})_xB_2$ and $Mg_{1-x}Al_xB_2$ and MgB_2.

References

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2. C. Buzea and T. Yamashita, Supercond. Sci. Technol. **14** (2001) R115.