

The Effects of Na doping in SrRuO₃

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The discovery of high temperature superconductors in cuprates and colossal magnetoresistance in manganites has spurred a renewed interest in the study of transition metal oxides particularly among perovskite and "perovskite-like" materials. One such material is the orthorhombic perovskite SrRuO₃, which is a bad metal and orders as an itinerant ferromagnet at $T_c=165\text{K}$. Band structure calculations of SrRuO₃ indicate that the conduction band is more complicated than a simple one-band picture, and this is supported by Hall measurements that show a sign change as temperature is varied. In order to gain a better understanding regarding the role of the conduction band electrons, divalent Sr is replaced with monovalent Na, with doping levels ranging from 0% to 22%. The Sr_{1-x}Na_xRuO₃ was then studied with respect to its structural, transport, and magnetic properties from 2K to 300K.

Using Bragg's law and X-ray diffraction data, the lattice parameters of the doped SrRuO₃ were calculated. Surprisingly, the lattice parameters increase with Na doping. One would expect the lattice parameters to decrease as the larger Sr²⁺ (1.18 Å) are replaced with Na⁺ ions (1.02 Å). This may imply that the Na is being added either interstitially rather than directly replacing the Sr sites or is replacing the Ru sites.

Electrical resistivity measurements for $2\text{K} \leq T \leq 300\text{K}$ were made using the van der Pauw technique by attaching gold leads to the four corners of the sample with silver epoxy. In order to reduce lead resistance, a varying potential was applied to the leads. Sr_{1-x}Na_xRuO₃, at high temperatures, was metallic, although the resistivity of the doped samples was considerably higher than the undoped sample, most likely due to the lattice deformation caused by the Na ion. A noticeable difference between the doped and undoped samples arises in the lower temperature region where the temperature dependent resistivity for the doped samples clearly shows tendency toward insulating behavior below 55K. This transition temperature decreases with the increase of Na doping level and may be related to the change in sign of the Hall coefficient from positive to negative at $T \sim 50\text{K}$ in the pure SrRuO₃ case, indicating a change of the charge carrier from holes to electrons.

Susceptibility measurements show a clear ferromagnetic transition for all doping levels, with the Curie temperature (T_c) suppressed as the doping levels increase. This is also seen in the suppression of the onset of the ferromagnetically related Fisher-Langer anomaly in the resistivity data. This decrease is surprising since it is usually seen that when T_c is decreased, the cell volume has also been decreased, either by doping or an increase in pressure. We, as stated above, measured an increase in lattice parameters due to the doping.

The existence of a metal-nonmetal transition was expected when SrRuO₃ was doped with Na. The behavior of the lattice and the Curie temperature were not expected and require further investigation. Further work is needed to more closely investigate the effect hole doping has on this system, and also to better understand where the doping occurs in the system. Of particular interest would be careful measurement of the Hall effect on the doped systems to explore the relative concentration of electron/hole carriers with respect to Na concentration, and how these concentrations change as a function of temperature.