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New Materials at the Metal-Insulator Boundary

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Many materials were prepared which we believe are close to a metal-insulator boundary. Some of these materials were new compounds. Others were based on known compounds, but the composition was systematically varied to move close to the metal-insulator boundary. Superconductivity frequently occurs near such boundaries. Most of the materials prepared were oxides. However, some new oxysulfides and oxyselenides were also prepared.

Many thin films with the infinite layer structure were prepared. These were based on SrCuO_2 , which is an insulator. By substitution of some La for Sr, one should move through a metal-insulator boundary to a metallic state. Our results indicate that this does in fact occur, but unequivocal evidence for superconductivity was not found in any case. Some of the unusual and unexplained anomalies in electrical resistivity vs. temperature reported by others were also observed in our work. Our X-ray diffraction studies of these thin films indicate a very high level of defects.

Superconductors showing the highest T_c can be considered as $A/M^{2+}/\text{Cu}/\text{O}$ phases where M^{2+} is Ca, Sr, or Ba and A is Hg, Tl, Pb, and/or Bi. The T_c increases with changing A going from right to left in the periodic table: $\text{Bi} \rightarrow \text{Hg}$. This suggests that going further in that direction might produce even higher T_c . We thus attempted to prepare layered $A/M^{2+}/\text{Cu}/\text{O}$ phases where A is Pt. It is known that Pt^{2+} can occur in two-fold linear coordination to oxygen. This is the same coordination that Hg^{2+} has in the $\text{Hg}/M^{2+}/\text{Cu}/\text{O}$ superconductors. Thus, it is reasonable to expect structural analogues with Pt^{2+} . However, the desired layered phases were not obtained, and superconductivity was not observed in any of our $\text{Pt}/M^{2+}/\text{Cu}/\text{O}$ samples.

Because superconductivity has recently been found in a ruthenium oxide based system, we decided to study the $\text{Tl}_2\text{Ru}_2\text{O}_{7-x}$ system where a metal-insulator transition as a function of temperature is known to occur. By changing synthesis conditions and composition, the properties of the samples were varied from semiconducting to metallic. However, no samples show evidence of superconductivity down to 5 K.

$\text{Tl}_2\text{Nb}_2\text{O}_{7-x}$ is isostructural with $\text{Tl}_2\text{Ru}_2\text{O}_7$. A change from metallic to insulating properties might be expected as x increases. Samples could only be prepared over the range of x from 0.0 to 0.6. All samples were insulating and did not show evidence of superconductivity.

Several new compounds were prepared containing Bi^{5+} because compounds such as $\text{KBi}^{5+}\text{O}_3$ are starting points for producing superconductors, if substitutions can provide a change to a metallic state. Some of the new Bi^{5+} compounds prepared were $\text{LiBi}^{5+}\text{O}_3$ (not isostructural with $\text{KBi}^{5+}\text{O}_3$) and $\text{ABi}_2^{5+}\text{O}_6$ phases where A was Mg or Zn. No substitution into these insulating phases produced metallic or superconducting materials.