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14. ABSTRACT
This program was broadly focused on the search for better and higher temperature superconductors. Our specific program was to critically examine plausible claims of very high temperature trace superconductivity reported in the literature. The approach involved thin-film synthesis of such candidate materials and examination of both their electronic properties using XPS/UPS and their local (trace) physical properties using scanning probes. Based on our previous careful assessment of claims of trace superconductivity in the literature, we selected two cases for focused study: WO3 with Na deposited on its surface, and graphite/graphene sulfur interfaces. (See attachment for the entire abstract)

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This program was broadly focused on the search for better and higher temperature superconductors. Our specific program was to critically examine plausible claims of very high temperature trace superconductivity reported in the literature. The approach involved thin-film synthesis of such candidate materials and examination of both their electronic properties using XPS/UPS and their local (trace) physical properties using scanning probes. Based on our previous careful assessment of claims of trace superconductivity in the literature, we selected two cases for focused study: WO_3 with Na deposited on its surface, and graphite/graphene sulfur interfaces. While so far no very high T_c superconductivity has been observed, we note that recent theoretical ideas about routes to higher T_c superconductivity remarkably may explain what is going on. In any event, they define definite strategies for future work, which we will continue under our new MURI program. These two cases are discussed in greater detail below.

At the same time, during this program, we have brought our local scanning probe capabilities (constructed under AF DURIP support) to an operational level. This includes a cryogenic, UHV, multi-probe, coarse scanning capability equipped (so far) with local normal point contact spectroscopy (local energy gap) and 4-point transport (local resistivity) probes. A Hall probe will be added shortly for magnetic measurements. In addition, we have brought our scanning tunneling potentiometer instrument to operational level. This truly unique instrument is capable of local transport measurements on a nanometer length scale.

Initially, thin films of both doped and undoped WO_3 were deposited using PLD. Low temperature superconductivity was observed at high doping as reported in the literature. Building on this work, we have now deposited alkali metals on the surfaces of WO_3 films, in order to replicate the conditions present in the papers reporting trace high T_c superconductivity. We find that the over-layers lead to a reduction of the sheet resistance of the WO_3, but superconductivity was not observed. Using XPS/UPS measurements, we have confirmed that the presence of these over-layers leads to electron donation into the normally unoccupied W d-band, explaining the reduction in resistivity. The next step would be to make local measurements on these samples using our new cryogenic, multi-probe scanning physical property measurement system mentioned above. These measurements will be undertaken as part of our DoD MURI program.

Most interestingly, a model calculation by Kivelson and coworkers finds that high T_c superconductivity can arise from the proximity effect between a normal metal and an insulating material containing negative-U centers. The possibility that this mechanism is at play due to a composition gradient near the surface of WO_3 associated with the Na over-layer is intriguing to say the least.

In addition, we investigated the reported very high-Tc superconducting anomalies at graphite/sulfur interfaces. Our approach was to grow so-called epitaxial graphene by heat-treating the surface of SiC – a well-known process – and then deposit sulfur on the surface. While we were successful in growing and characterizing good graphene layers, we were not successful in controllably putting down a sulfur layer on top due to lack of a good source of atomic sulfur. Simple thermal K-cells only produce multi-atom sulfur complexes (e.g., dimers, trimers etc) that have a very low sticking coefficient. Fortunately, from other funding sources, we have acquired resources for a plasma-based source of sulfur that will produce atomic sulfur. Meanwhile we are studying our graphene layers using our scanning tunneling potentiometer in preparation for similar studies when the sulfur layers are present.

As for the case of WO_3, an intriguing theoretical idea has recently put forth that may provide a mechanism for high T_c superconductivity at graphene/sulfur interfaces. Sawatzky and Zaanen have argued that the presence of large anions (e.g., sulfur) in a material might lead to the formation of bi-excitons due to their very large polarizability. This possibility as a route to high T_c was among those discussed at the program on "The Physics of Higher Temperature Superconductors" at KTIP last summer. The conclusion was that the idea was surely interesting and should be examined more carefully. We are now considering how to proceed as part of our new MURI program, using the new atomic sulfur source.