Research Description

University of Virginia

November 17, 2006

Studies of atomic clusters containing tens or hundreds of atoms have gained much interest in recent decades because of their potential to bridge the gap between isolated atoms and bulk systems. Notable results include the observation of a shell structure, similar to that found in electronic shells of single atoms. Theoretical calculations show that certain levels within this shell structure allow for strong Cooper pairing. These calculations also show that these particular shell levels, which are realistically attainable, could show substantially higher values of the superconducting transition temperature T_C than are observed in the bulk material.

The number of electrons in the familiar electronic shell structure is analogous to the number of atoms N in the cluster. Certain clusters sizes are energetically favorable; these "magic clusters" of size N_m have geometries resulting in lower total energies. Magic clusters are of interest to supercondictivity applications because of their high density states in the HOS and LUS levels. If the energy gap between these two levels is smaller than or comparable to the pairing energy gap, the magic cluster will be in the superconducting phase.

Our group at the University of Virginia is capable of mass-selecting metallic clusters and probing their energy. Clusters of various sizes are created by a pulsed ND:YAG laser, then pushed through the a narrow temperature-controlled canal by an appropriately timed pulse of He gas. After passing through the canal long enough to thermalize, the clusters emerge between the plates of a mass spectrometer. The voltage between the plates is then switched on, causing ionized clusters to accelerate through a long tube toward a microchannel plate detector. The purpose of this time-of-flight mass spectrometer is to identify the masses of the clusters by their arrival time. Once the arrival time of a particular cluster of interest is identified, a pulse from a UV laser is triggered to photodetach the extra electron from the cluster. The energy of this electron is measured and, upon repeating this process many times, an energy spectrum for the cluster is obtained.

The calculations which motivate this work predict that at temperatures near T_C, strong pairing will have a substantial impact on the cluster energy spectrum. The onset of pairing should increase the minimum excitation energy. Our group will first look for this energy increase in Al clusters at around 90K, the predicted T_C for "magic" Al clusters. Future research will include the search for diamagnetism in superconducting Al clusters.