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Superconducting state of metallic clusters: Potential for room temperature superconductivity, nano-based tunneling networks

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Nanoclusters form a new family of high temperature superconductors. We focus on small metallic nanoclusters M_n (n is the number of atoms) which contain delocalized electrons. These electrons form energy shells similar to those in atoms or nuclei (e.g., s,p,d,..). The presence of the shell structure and the corresponding orbital degeneracy 2(2L+1) leads to an increase in the effective density of states and to a great strengthening of the pairing interaction. It turns out that under special, but perfectly realistic conditions, the superconducting pairing is very strong and leads to high T_c. For some specific clusters (e.g., Al_{56}, Zn_{83}) T_c reaches $\sim$150 K and the energy spectrum becomes strongly modified. With a realistic sets of parameters, it should be possible to raise T_c up to room temperature. Specific experiments capable of detecting this phenomenon can be identified (spectroscopic, magnetic and thermodynamic measurements). The observation of a heat capacity jump for Al_{45}^- and Al_{47}^- clusters at T_c $\sim$200K (Cao et al.,2008) yielded first experimental support for the phenomenon: the amplitude, width and position of the jumps are in good agreement with the theory. Pairing also raises the possibility of observing intercluster Josephson tunneling. The discrete nature of the spectrum makes the analysis very different from that for conventional superconductors. Especially interesting is the case of resonant tunneling. The effect is promising for the creation of superconducting tunneling networks at high T_c (potentially at room temperatures), and with current densities greatly exceeding those of usual superconductors.