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Superconductors in a Strong Low-Frequency ac Electric Field[1]

R. TAO, Dept.of Physics, Temple University, Philadelphia, PA — The electric-field induced ball formation has been observed for high temperature superconducting particles, MgB_2 powder, and low temperature superconducting particles in a low frequency ac electric field. Different from the situation with a static electric field, the superconducting particles in an ac field first form chains along the field direction if the electric field is below a critical value E_{c1}. As soon as the field exceeds E_{c1}, the chains are broken and the particles aggregate into balls. The experiment has found that E_{c1} is a function of frequency ω. To understand the experimental results, we consider a bulk superconductor in an ac field. The electric field is along the x direction and the bulk superconductor has its surface at $x = 0$, perpendicular to the field and is located at $x \geq 0$. The electric field penetrates into the superconductor: for $x > 0$, $\vec{E}(x) = \vec{e}_x E \exp(-x/l_s)\cos(\omega t)$, where l_s is the electric-field's penetration depth and E is the electric field at the surface of $x = 0$. With this model, we have found that if the electric field is strong enough, Cooper pairs near the surface are depleted and a positive surface energy is produced. This induced surface energy is responsible for the formation of superconducting balls. The critical electric field to produce the positive surface energy E_{c1} is found to be related to the binding energy of a Cooper pair$\Delta(T) = 2\epsilon_f - \epsilon$ and the frequency ω. As ω increases, E_{c1} goes up, too. A comparison between the theory and experimental results will also be made.

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