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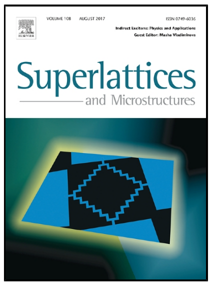

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The crossover between tunnel and hopping conductivity in granulated films of noble metals

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Abstract:

The conductivity of thin films composed by clusters of gold and silver nanoparticles has been studies in a wide range of temperatures. The switch from a linear to an exponential thermal dependence of the conductivity manifests the crossover between the tunnel and hopping regimes of the electronic transport at the temperature of 60C. The characteristic thermal activation energy that governs hopping of electrons between nanoparticles is estimated as 1.3 eV. We have achieved a good control of the composition and thicknesses of nano-cluster films by use of the laser ablation method in colloidal solutions.

1. Introduction

Granulated metallic films are considered as promising building blocks for various nano- and micro-electronic applications. These applications take advantage of the unusual electronic and optical forms of the granulated films. In particular, the hysteresis in resistivity of granulated silver films deposited on a GaAs surface has been reported in Ref. [1]. Similar films on deposited on sapphire surfaces may serve as electronic memory elements. The characteristic current-voltage characteristics of granulated golden films deposited on dielectric substrates have been studied in [2-5]. Clusterized metallic structures exhibit the broadening of electronic level characteristic of the tunnel conductivity. Ref. [7] reports on the photoemission in a clusterised film of palladium illuminated by low frequency light. Ref. [8] reports on the formation of superconducting clusters that demonstrate the unconventional Josephson tunnelling through dielectric layers whose widths exceed the coherence length of the corresponding bulk superconductor.

Nano-thermometers and gas sensors may also be based on this granulated metallic films [9,10]. Electronic properties of such films strongly depend on the sizes and on the density of the constituent metallic nanoparticles. In particular, the mechanism of electronic conductivity is governed by the mean distance between nanoparticles: if the mean distance is less than the size of the particles, one can expect the tunnel mechanism to dominate, in general. The tunnelling probability depends on the size of nanoparticles, distances between them and the shape of tunnel barriers [11] The variation of the thickness of the film as well as the transition from amorphous to crystalline structure of the film dramatically affect the conductivity [12]. For these reasons, it is important to be able to achieve a precise control on the thickness and the morphology of the film when depositing metallic nanoparticles on surfaces [13]. In this study, we use the laser ablation method for the synthesis of metallic nanoparticles in colloidal solutions and the laser-assisted deposition technique in order to form bi-metallic films of controllable morphology. We study the surface resistivity of the resulting films as a function of the thickness of the film, of the density of metallic nanocrystals and of temperature. We observe the crossover from tunnel to hopping