PERCOLATION IN 2D NANOPARTICLE FILMS FROM COLLOIDAL SELF-ASSEMBLY

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Using evaporation of colloidal suspension nanoparticle droplets on flat substrates is a common method to form 2D nanostructured films. Despite the simplicity of the treatment, the nanoparticle self-assembly is a non-equilibrium process and creates a variety of spatial patterns, including well-ordered superlattices, percolated networks, fractal-like aggregates, and distinct islands. Competing effects from nanoparticle diffusion and solvent dewetting lead to this complexity. We perform electrical and topographic measurements on Au nanoparticle films on glass substrates with atomic force microscopy. In general cases, percolation phenomena emerge as the nanoparticle concentrations increase to appropriate values. The non-ohmic characteristics of the disordered films, as shown in Figure 1, can be approximately interpreted by a quasi-1D percolation path of tunnel junctions [1].

While percolation and self-assembly both play important roles in transport through nanoparticle films, particularly near phase transitions, the studies focused on their relation were surprisingly rare. Compared with the "classical" percolation due to entirely random particle occupancies, the percolation affected by self-assembly shows different critical points because of different cluster-forming dynamics. We use a two-dimensional lattice gas model to simulate the nanoparticle aggregation patterns and percolation during solvent evaporation with Monte Carlo dynamics [2]. The Hamiltonian contains the nearest neighbor (particle-particle, particle-solvent, and solvent-solvent) interactions and the chemical potential for the solvent evaporation. This model shows not only strong agreement with the observed patterns in experiments, but also gives us an insight into the emergence of the percolation under the effect of the self-assembly. Figure 2 shows an example pattern from the simulation.

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References:

[1] P.-E. Trudeau, A. Escorcia, and A.-A. Dhirani, J. Chem. Phys., **199** (2003) 5267.

[2] E. Rabani, D.R. Reichman, P.L. Geissler, L.E. Brus, Nature, **426** (2003) 271.

Figures:

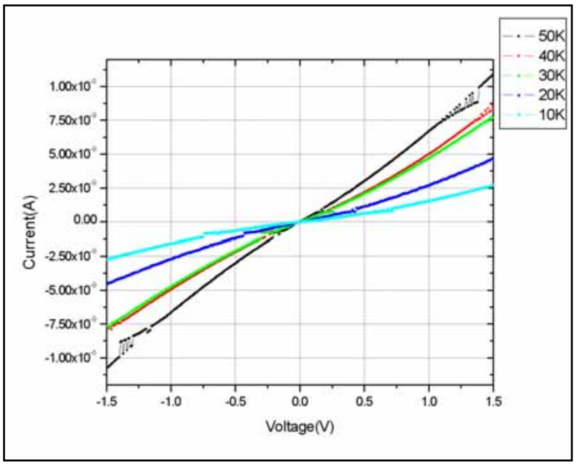

Figure 1. Typical non-ohmic behaviors observed in disordered Au nanoparticle films.

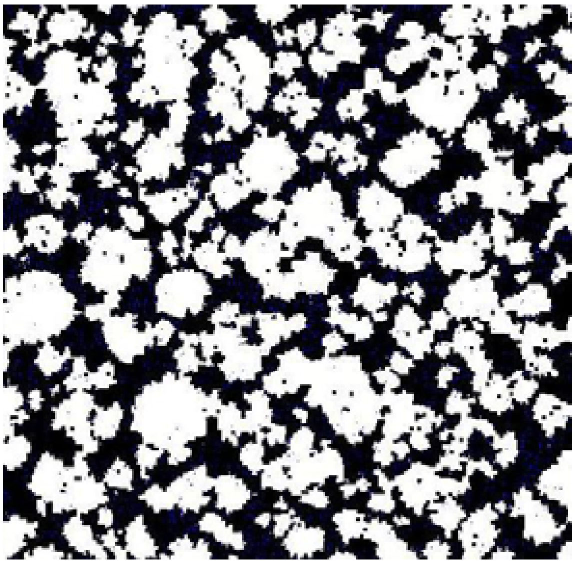

Figure 2. The dark dots represent nanoparticles. Even in lower surface coverage, self-assembly may make percolation happen.