Electronic devices based on gold nanoparticles: device fabrication, charge conduction mechanism and applications

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Abstract

Gold(Au) nanoparticle(NP) films consisting of nanoparticles modified with self-assembled monolayers have many interesting electrical and optical properties. Many of these properties are strongly affected by the interparticle spacing that can be controlled by the lengths of ligand or linker molecules. Furthermore, NP films hold great potential for sensing applications, such as chemiresistor-type gas sensors. It is important to pursue a simple, efficient method to fabricate mono-and multilayer conductive AuNP films for novel electric, optoelectronic, and nanophotonic devices and chemical sensing applications. We have demonstrated that desirable monolayer and multilayer AuNP films can be achieved by using a simple centrifugal method. When the centrifugal method combines with conventional photo or electron-beam lithography methods and lift-off techniques, two and three-dimensional designed complex AuNP assembled structures can be fabricated.

The electrical conduction properties of AuNP films showed near-exponential distance decay with interparticle spacing, which can be controlled by the surface modification of AuNPs. Because of the competition of pronounced charging effect and interparticle tunneling, one can tune the interparticle spacing to study the Mott-Hubbard metal-insulator transitions. When the devices are close to the MIT, disorder-induced insulating state could be distinguished only at temperatures below 1 K. The insulating case showed a gate-controlled conduction that followed single-electron or resonant tunneling, revealing the presence of charge puddles in the AuNP films. We also report a class of stretchable devices fabricated from AuNP film on polyimide substrates. When the substrate is stretched or bended, the interparticle spacing is altered and results in the device resistance change. Such phenomenon is similar to the piezoresistance effect, which describes a change in electrical conductivity resulted from application of strain to a crystal. In our gold nanoparticle devices, the gauge factor could be as large as 100 when applied by a small strain of 0.5%. Such strain devices could find a wide range of applications in recreation, health care, and robotics.