Measurement of the Mechanical Strength of Single- and Multi-layered Metal Nanoparticle Sheets on Soft Polymer Substrates by Nano-indentation

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In this work, we report the measurement of the mechanical strengths of monolayers comprising silver and gold nanoparticles (AgNPs and AuNPs) on soft polymer substrates by using the nano-indentation method based on atomic force microscopy (AFM). The synthesized silver nanoparticles (5 nm silver core capped with myristic acid) and gold nanoparticles (10 nm gold core capped with oleylamine) were both mono-dispersible into toluene. The metal nanoparticles can be self-assembled to form monolayers (single nanoparticle thick) at the air-water interface after the solvent evaporated in terms of Langmuir method. By compressing the monolayers of metal nanoparticles to proper surface pressure, a large area of uniform monolayer of metal nanoparticles can be obtained at the air-water interface. Then, the monolayer of metal nanoparticles can be transferred onto hydrophobic solid substrate by using Langmuir-Schaefer method. Here, we used the freshly prepared polydimethylsiloxane (PDMS) as substrate to deposit the metal nanoparticles monolayer. By using such method, it is easily to form multilayered nanoparticles layers. We have fabricated PDMS stamps of different hardness by tuning the ratio of monomer to curling agent as well as the aging temperature. The mechanical strength of the metal nanoparticle layers transferred onto the PDMS substrate were measures using AFM nano-indentation by using cantilevers with different spring constants. Fig.1a shows the optical microscope image of silver nanoparticles layers transferred on PDMS substrate. The layer number is obviously distinguishable by the colors. A simple schematic diagram of the deformation of the nanoparticles layers on PDMS is shown in Fig. 1b. The measured force-indentation curves on bare PDMS, single and double layer silver nanoparticles are shown in Fig. 1c which shows great reproducibility. The mechanical response of the nanoparticle layers was obviously different from that of the PDMS, which help us to open up new ways to understand the mechanical properties of nanomaterials.

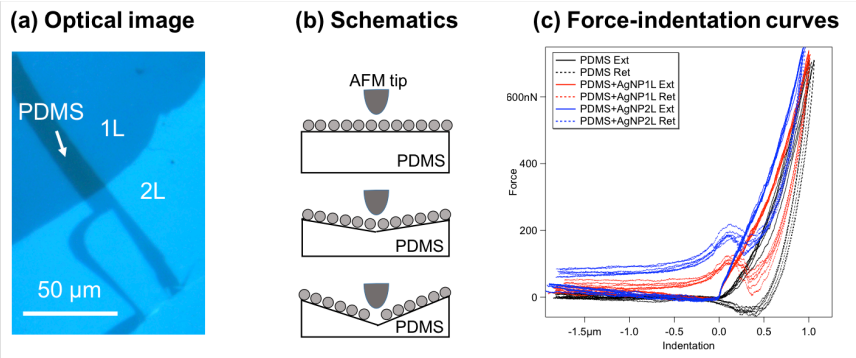

FIG.1. (a) Optical image of silver nanoparticles layers on PDMS substrate; (b) Schematics of the fracture process of the nanoparticles layers on soft substrate during nano-indentation; (c) Force-indentation curves measured under bare PDMS, single and double layer silver nanoparticles layers on PDMS.