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Femtosecond laser sintering of silver nanoparticles on a flexible substrate

The technology for sintering metal nanoparticles has recently attracted substantial attention owing to its potential in future micro/nano electronic devices including flexible devices, novel electric circuits, solar cells and mobile devices. Particularly, laser sintering or joining of nanomaterials using short pulsed lasers is emerging as a useful tool for fabricating metal patterns on flexible substrates without substrate damage. [1, 2]

This work investigates femtosecond laser sintering of silver (Ag) nanoparticles on a flexible substrate. Electrical and mechanical properties of the laser-sintered samples as well as their microstructures were examined under various conditions. Ag nanoparticles were deposited on a polyethylene terephthalate (PET) substrate using a spin coating method. A Ti:sapphire femtosecond laser with a regenerative amplification system (wavelength = 800 nm, full width at half maximum = 50 fs, pulse energy < 3.5 mJ, repetition rate = 1 kHz) was employed in the experiment.

Femtosecond laser irradiation could not fully melt the Ag nanoparticles but formed porous structures composed of Ag nanoparticles bonded by surface necking. Mechanical crack, as well as the surface necking, increased with the laser fluence. The laser sintering process decreased the sheet resistance of the sintered Ag film (1.7 Ω/sq) because of formation of the electrical pathway. Furthermore, adhesion strength of the film was substantially enhanced by the process (5B according to ASTM-3359 standard). The laser-sintered film was not separated from the PET substrate in the tape test. Notable was that the femtosecond laser-sintered Ag film attained high flexibility. Compared with the spin coated Ag nanoparticle layer, the sintered film had substantially increased crack resistance. Accordingly, the femtosecond laser-sintered film maintained its high electrical conductivity even after severe bending, for example, after repeated cycles with a radius of curvature as small as 1 mm.

This work suggests that ultrafast laser sintering of metal nanoparticles can be a powerful tool in manufacturing of flexible devices.

Figures

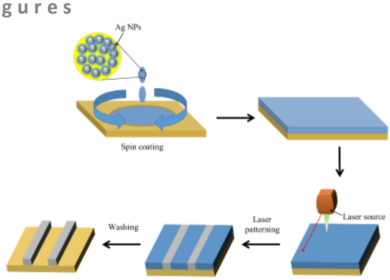

Figure 1: Schematic of laser sintering steps

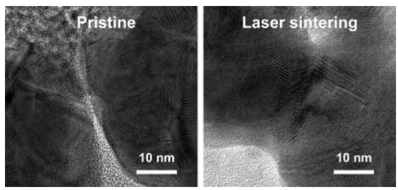

Figure 2: TEM images of before and after laser sintering

References

[1] J. Ha. et al., RSC Advances, 6 (2016), 86232-86239.
[2] Y. Son, et al., Advanced Materials, 23 (2011), 3176.