Electronic Supplementary Material (ESI) for Journal of Materials Chemistry C.

Supporting Information

Nanowire Reinforced Nanoparticle Nanocomposite for Highly Flexible Transparent Electrode : Borrowing Idea from Macrocomposites in Steel-wire Reinforced Concrete

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S1. Short AgNW preparation protocol

A clean flask was placed in oil bath. 5.86 g of PVP (Mw = 55 000) in 190 ml of glycerol was heated in the flask at 100 °C for 2 h under continuous magnetic stirring. After PVP completely dissolves in the solution, cool the flask by water. After adding 1.58 g of silver nitrate in the solution, heat the solution at 150 °C. When silver nitrate completely dissolve in the solution, a mixture of 0.059 g of sodium chloride, 0.5 mL of deionized water, and 10 mL of glycerol was added. After 30 minute, the solution is cleaned with excessive methanol with centrifugation at 5000 rpm for 10 minutes, whereas the cleaning step is repeated for three times. The Ag NW is re-dispersed in clean ethanol (99% grade) at 6 wt% for further use.

S2. Filling material in trench by doctor blading process

For material filling process in trench, below methods are used.

Only AgNP in trench: AgNP ink of 50 μl is pipetted onto the mold followed by doctor-blading and drying solvent in 50 °C drying oven. Subsequently, residues are removed by isopropyl alcohol (IPA) and laser sintering process was conducted.

Only AgNW in trench: AgNW ink of 100 μl was pipetted onto the mold followed by doctor-blading on the 50 °C hot plate. After several times of pipetting and doctor blading, residues are removed by IPA and laser welding process was conducted.

AgNW reinforced AgNP matrix: AgNP ink of 50 μl is pipetted onto the AgNW-filled trench by doctor blading method followed by removing residues (by simply wiping out the surface since necessary material is in the trench) and laser sintering process.

S3. Laser processing parametric study

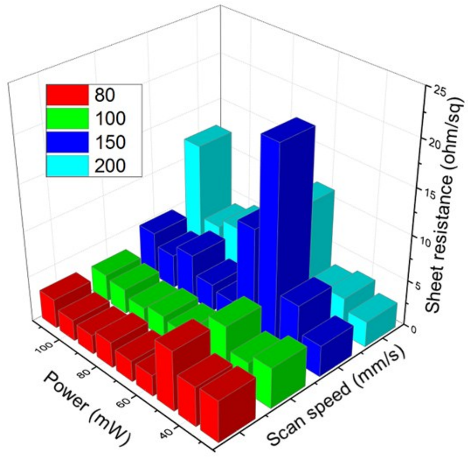

Figure S1. Laser process parametric study for the silver nanowire reinforced silver nanoparticle matrix. Laser power of 30 ~ 110 mW with laser scan rate of 80 ~ 200 mm/s. Every condition was applied for 4 x 4 mm^2 area. For sheet resistance measurement, every laser-processed area were cut out and two terminal measurement is conducted.

In order to describe sintering characteristics of materials, AFM images of various samples are inserted in Figure S2. Though materials were highly filled in non-sintered AgNP matrix, the matrix has no electrical conductance due to organic additives such as dispersing agent. During laser sintering process which make interconnects between nanoparticle by necking, organic additives such as dispersing agents are eliminated. Thus significant volume contraction was induced after laser sintering process. On the contrary, AgNW ink which was cleaned several times with methanol and dispersed in ethanol shows no significant volume changes fater laser-welding process. That is reasonable because this network has low organic additives and laser nanowelding couses confined thermal heating at the NW contact point which only affects the intersection and not other areas[S1].

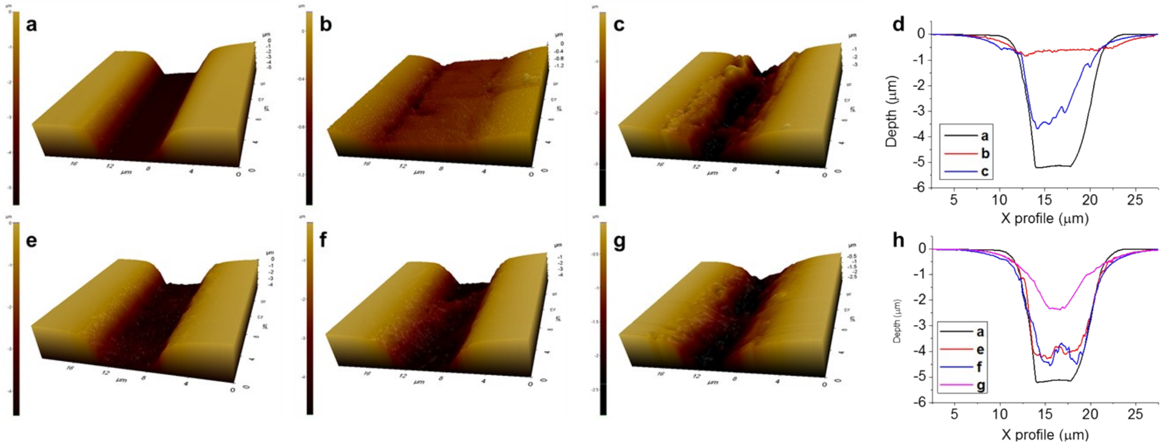

Figure S2. AFM images of various materials in epoxy/PET mold. Each image shows a) Bare Mold, b) Ag nanoparticle (AgNP) ink before sintering, c) AgNP after sintering, d) line profiles of AgNP ink before and after sintering. e) Ag nanowire (AgNW), f) Welded AgNW, g) Ag NW reinforced Ag NP matrix, h) line profiles of AgNW, welded AgNW, AgNW reinforced AgNP matrix. The AFM images have the same lateral scale (20 µm x 20 µm) but a different height scale ((a) -5.5 µm, (b) -1.4 µm, (c) -3.8 µm, (e) -4.5 µm, (f) -4.9 µm, (g) -2.8 µm)

S4. Bending radius and Figure of merits of various transparent conductors

Material	Working Maximum Bending radius	Figure of merit	Reference
ITO	6~7 mm	150 ~ 175*	[23,29,30]
FTO	-	64*	[29]
Graphene	2.3mm	3	[45]
Bi_2Se	Under 2 mm	3	[46]
AgNW/PEDOT:PSS	Under 1 mm	200*	[24]
AgNW	Under 2 mm	200 ~ 349*	[29,30,47,48]
Ag grid	-	129	[23]
Au grid	6 mm	78*	[49]
RGO/Au grid	1.5 mm	89	[49]
This work (AgNP)	10 mm	696	-
This work (AgNW)	Under 1 mm	205	-
This work (AgNW+AgNP)	Under 1 mm	498	-

Table S1. Working maximum bending radius of various transparent conductor from other researches and this work. Working maximum bending radius is designated as the point which resistance increases twice of its original value. '*' represents calculated data by given sheet resistance and transparency.

Reference of supporting information

S1. S. Han, S. Hong, J. Ham, J. Yeo, J. Lee, B. Kang, P. Lee, J. Kwon, S. S. Lee, M.-Y. Yang and S. H. Ko, *Advanced Materials*, 2014, **26**, 5808-5814.