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

Supporting Information

For

A New Approach for Additive-free Room Temperature Sintering of Conductive Patterns Using PVP-stabilized Sn Nanoparticles

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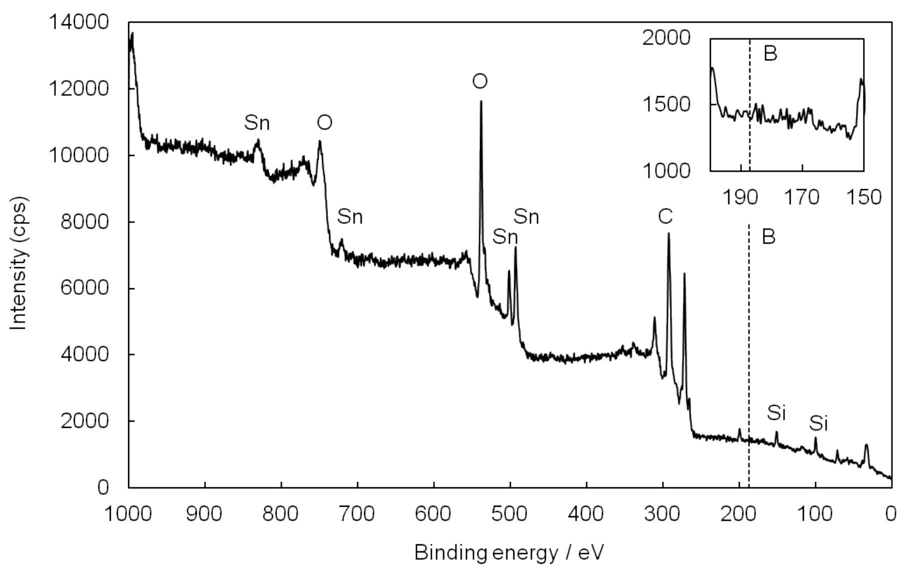

Figure S1. Wide scan XPS spectrum of Sn NPs synthesized using 0.0018 g PVP. The dashed indicated the position of B is used for visual guide. The inset shows expansion spectrum from 150 to 200 eV in the binding energy.

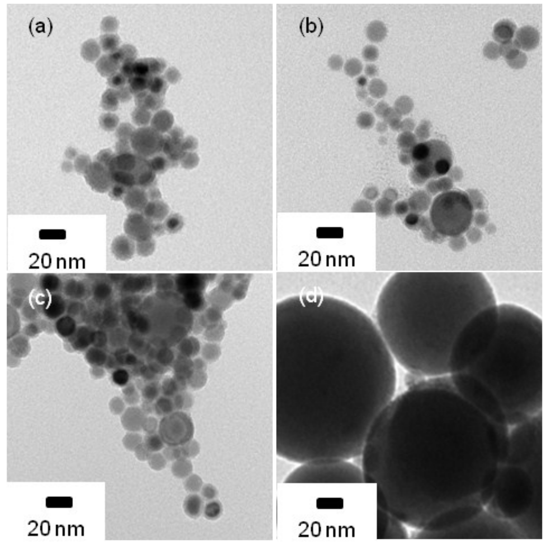

Figure S2. TEM images of Sn NPs synthesized using various amounts of PVP: (a) 2.6710 g, (b) 0.8903 g, (c) 0.1781 g, and (d) 0.0018 g.

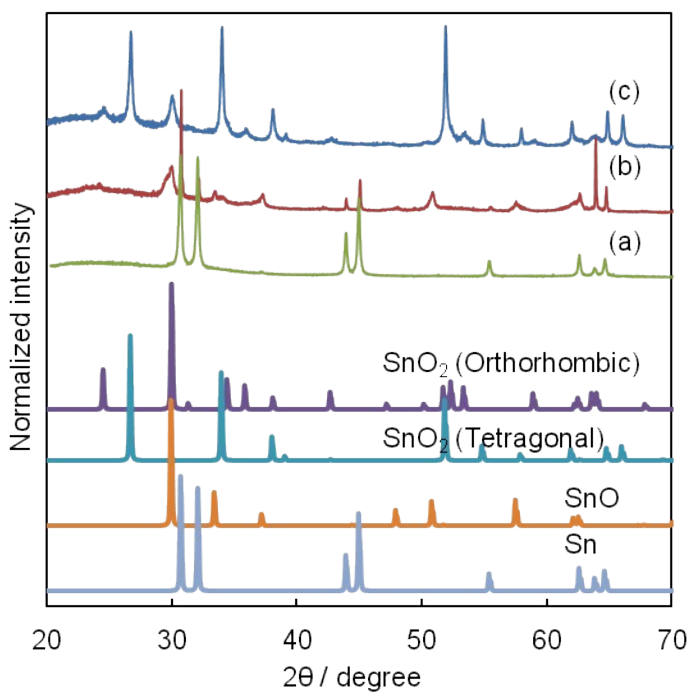

Figure S3. (a) XRD pattern of the as-synthesized Sn NPs using 0.1781 g PVP and of samples after heating to (b) 400 °C and (c) 800 °C. The reference patterns of orthorhombic SnO_2 (JCPDS no. 29-1484), tetragonal SnO_2 (JCPDS no. 41-1445), SnO (JCPDS no. 85-0423), and Sn (JCPDS no. 04-0673) are shown.

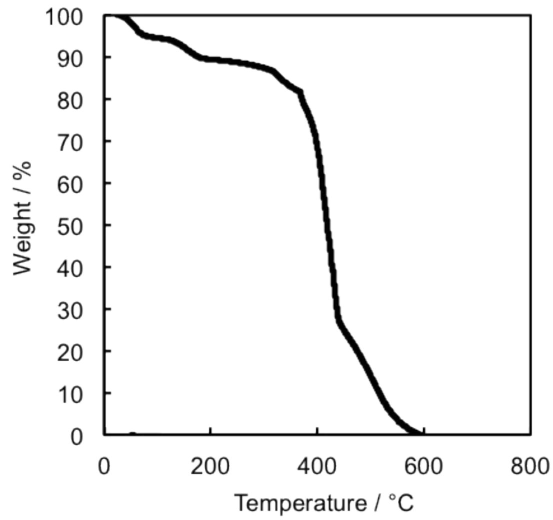

Figure S4. TGA curve of PVP under air. TGA measurement (Shimadzu DTG-60H) was operated using air at a flow rate of 100 cm^3 min^{-1} and at a heating rate of 5 °C min^{-1} from room temperature to 800 °C.

The amount of PVP on the surface (wt%) = 100 – actual weight increment (wt%) × 100 / 127

(eq. S1)

With 127 % = MW(SnO_2)/MW(Sn) × 100 (%), where MW is the abbreviation of the molecular weight.

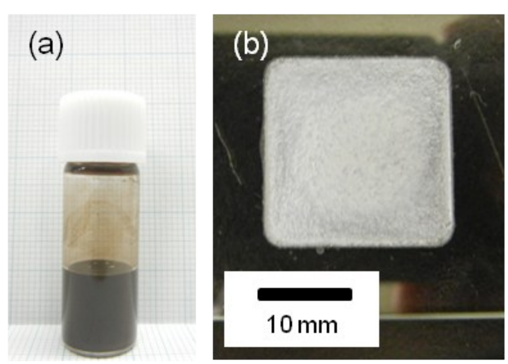

Figure S5. A photograph of (a) Sn conductive ink and (b) the conductive pattern formed after placing Sn NPs onto a glass substrate. Sn NPs were synthesized using 5.3420 g PVP.

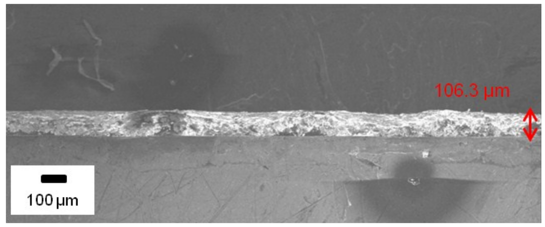

Figure S6. Cross-sectional SEM image of a conductive pattern formed using Sn NPs synthesized using 0.0089 g PVP. The thickness of the pattern was 106.3 µm.

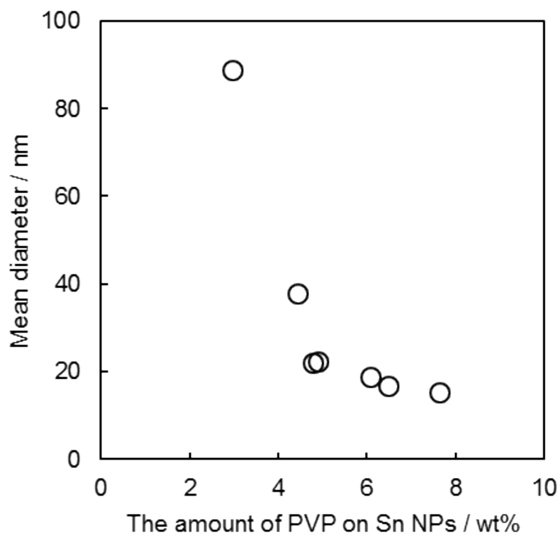

Figure S7. Relation between the amount of PVP on the surface of Sn NPs and the average diameter of Sn NPs.

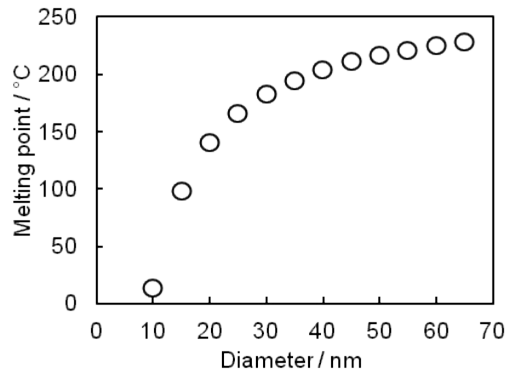

Figure S8. The melting temperature of Sn NPs of different sizes estimated using Gibbs-Thomson equation (eq. S2).

$$\Delta T = 4\sigma M T_{bulk} / \Delta H_m r\rho \qquad \text{(eq.S2)}$$

where r is the radius of Sn NPs, the values of the surface energy, σ = 0.56 J m^{-2},[1] the molecular weight, M = 118.7 g mol^{-1}, the bulk melting temperature, T_{bulk} = 505.1 K, the bulk melting enthalpy, ΔH_m = 7.18 kJ mol^{-1},[2] and the material density, $\rho = 7.365 \times 10^3$ kg m^{-3} are listed for Sn.

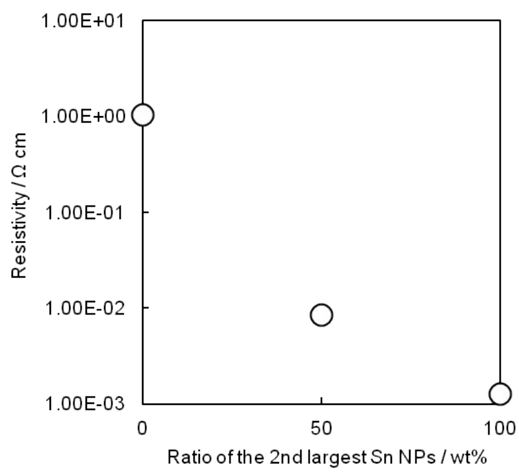

Figure S9. Resistivity of Sn patterns prepared from the smallest Sn NPs (15.2 ± 3.1 nm), the second largest Sn NPs (37.8 ± 12.5 nm) obtained in this study, and their 50 wt% mixture.

Table S1. The ratio of number of Sn NPs with diameter less than 24 nm.

Sample	Size (TEM) / nm	Number of Sn NPs < 24 nm / %
(a)	15.5 $\pm$ 3.1	100
(b)	16.8 $\pm$ 3.3	98
(c)	18.7 $\pm$ 3.8	95
(d)	22.0 $\pm$ 5.0	76
(e)	22.3 $\pm$ 5.1	80
(f)	38.6 $\pm$ 13.2	15
(g)	86.7 $\pm$ 21.6	0

References:

1 Z.F. Yuan, K. Mukai, K. Takagi, M. Ohtaka, W. L. Huang and Q. S. Liu, *J. Colloid. Interf. Sci.*, 2002, **254**, 338.
2 F. Grønvold, *J. Chem. Thermodynamics*, 1993, **25**, 1133.