

## **Enhancement of photocurrent in ultra-thin perovskite solar cell by Ag nanoparticles deposited at low temperature**

Yang Liu<sup>a,b\*</sup>, Felix Lang<sup>a</sup>, Thomas Dittrich<sup>a</sup>, Alexander Steigert<sup>a</sup>, Christian-Herbert Fischer<sup>b</sup>, Tristan Köhler<sup>a</sup>, Paul Plate<sup>a</sup>, Jörg Rappich<sup>a</sup>, Martha Ch. Lux-Steiner<sup>a</sup>, Martina Schmid<sup>a,c\*</sup>

a. Helmholtz-Zentrum Berlin für Materialien und Energie GmbH, Hahn-Meitner-Platz 1, 14109 Berlin, Germany

b. Freie Universität Berlin, Institute of Chemistry and Biochemistry, Fabeckstr. 34-36, 14195 Berlin, Germany

c. Freie Universität Berlin, Department of Physics, Arnimallee 14, 14195 Berlin, Germany

Supporting information

Fig. S1

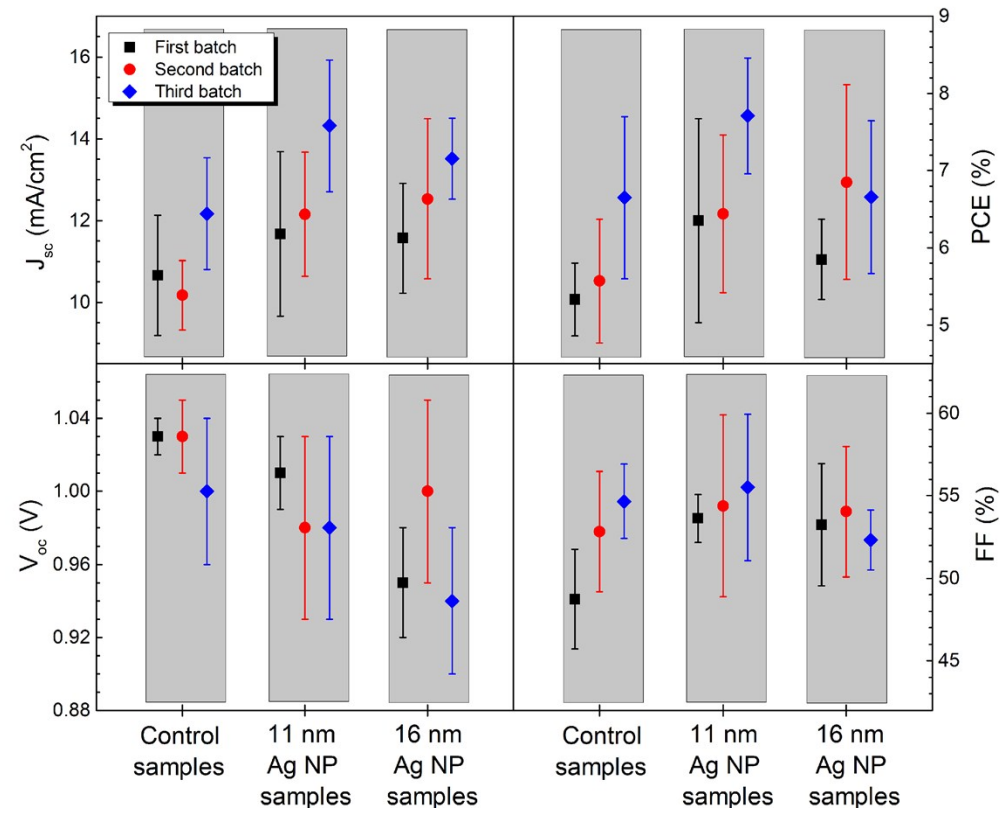


Fig. S1 Average devices performances in three different batches of control samples, 11 nm Ag NP samples and 16 nm Ag NP samples measured by reverse scan.

Fig. S2

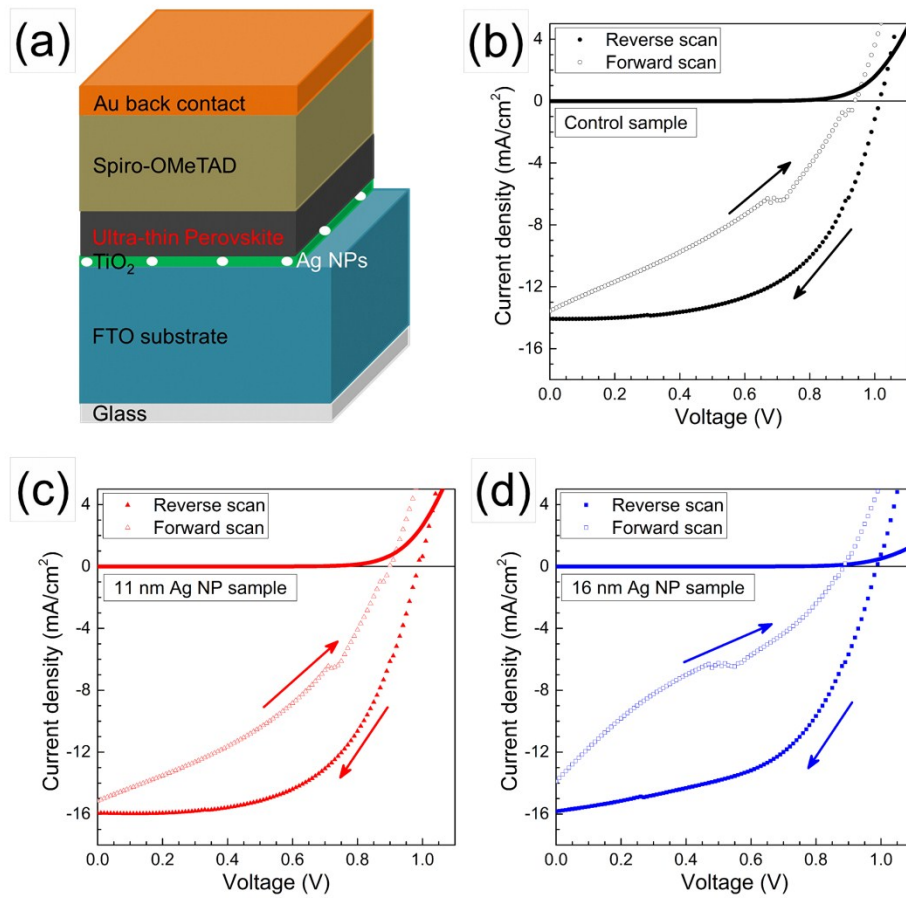


Fig. S2 (a) Schematic device structure of ultra-thin perovskite solar cell with incorporation of Ag nanoparticles at the TiO<sub>2</sub>/FTO interface. *J*-*V* curves of the best PCE ultra-thin perovskite solar cells without (control sample) (b) and with 11 nm (11 nm Ag NP sample) (c), 16 nm (16 nm Ag NP sample) (d) Ag NPs.

Fig. S3

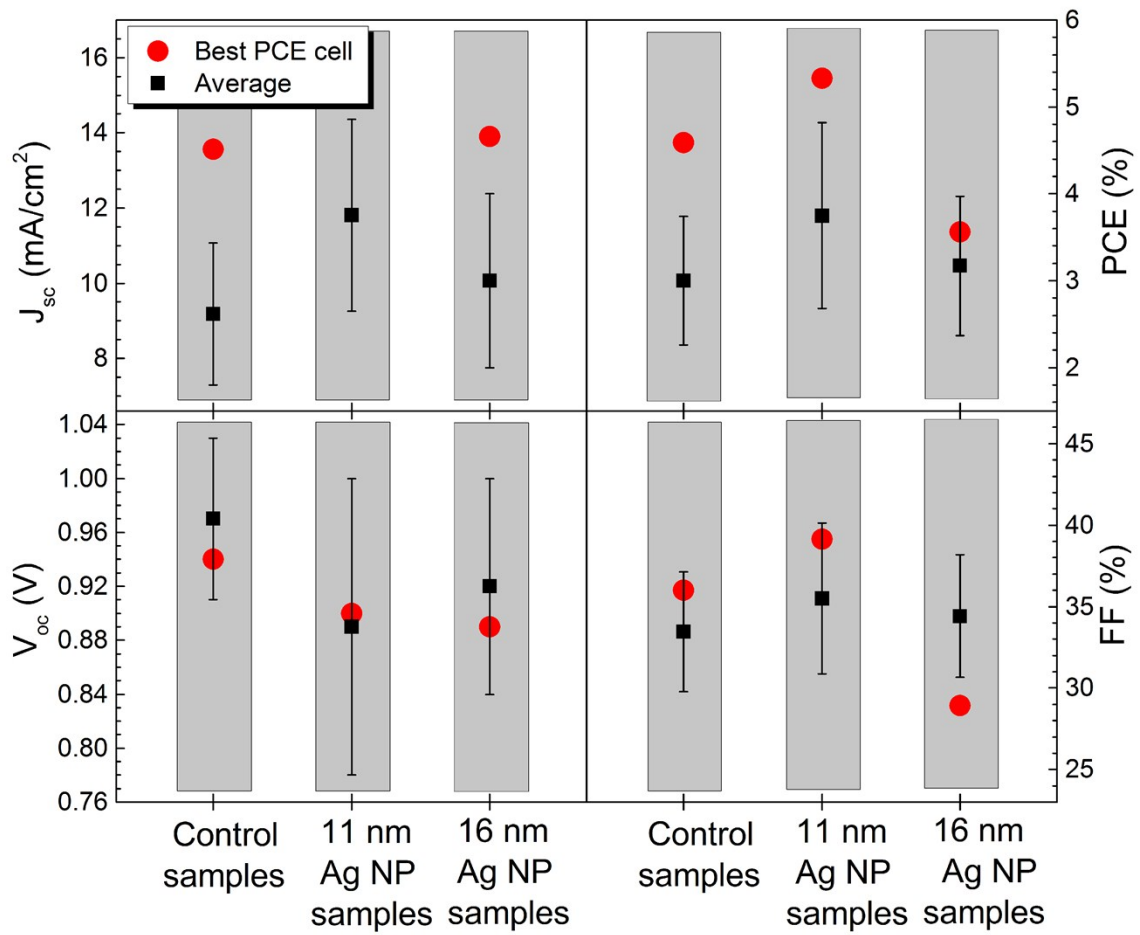


Fig. S3 Average devices performances of control samples, 11 nm Ag NP samples and 16 nm Ag NP samples measured by forward scan.

Fig. S4

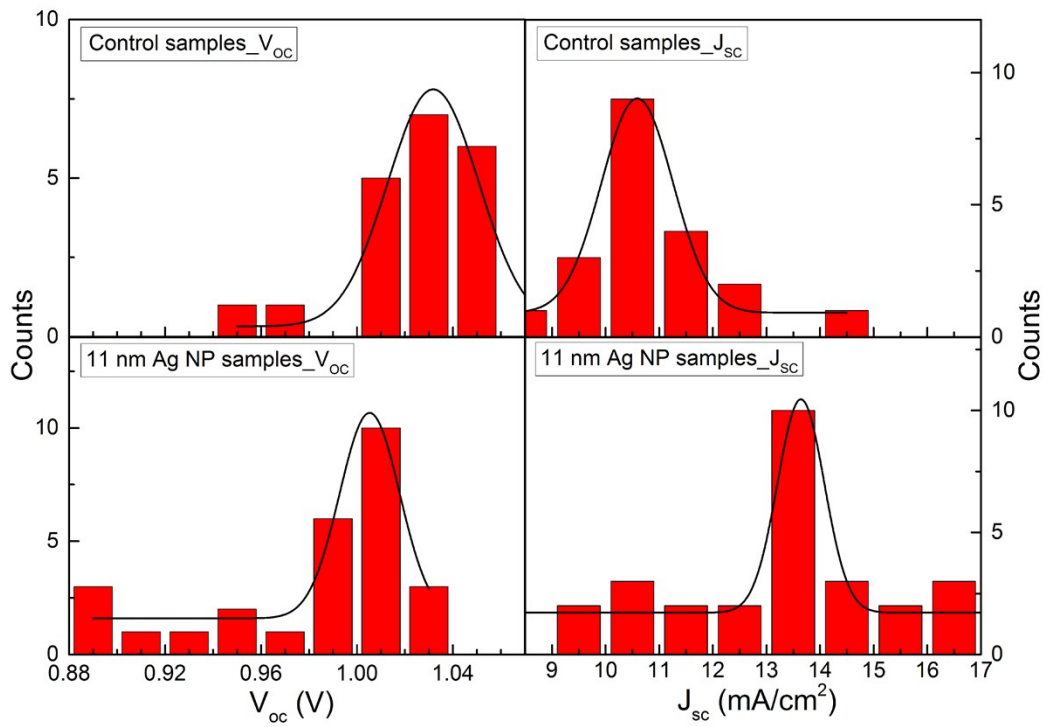


Fig. S4  $V_{oc}$  and  $J_{sc}$  histograms of the control samples and of the 11 nm Ag NP samples.

Fig. S5

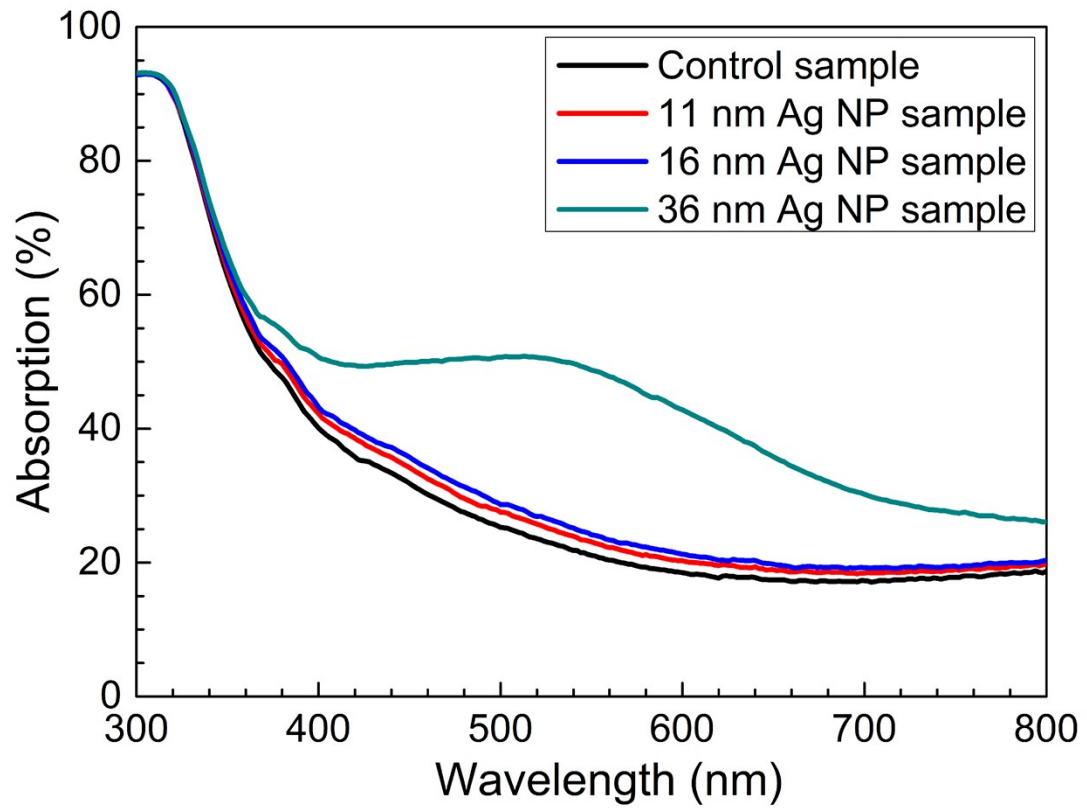


Fig. S5 Absorption spectra of TiO<sub>2</sub> layer/(with and without) different sizes of Ag NPs/FTO/glass.

Fig. S6

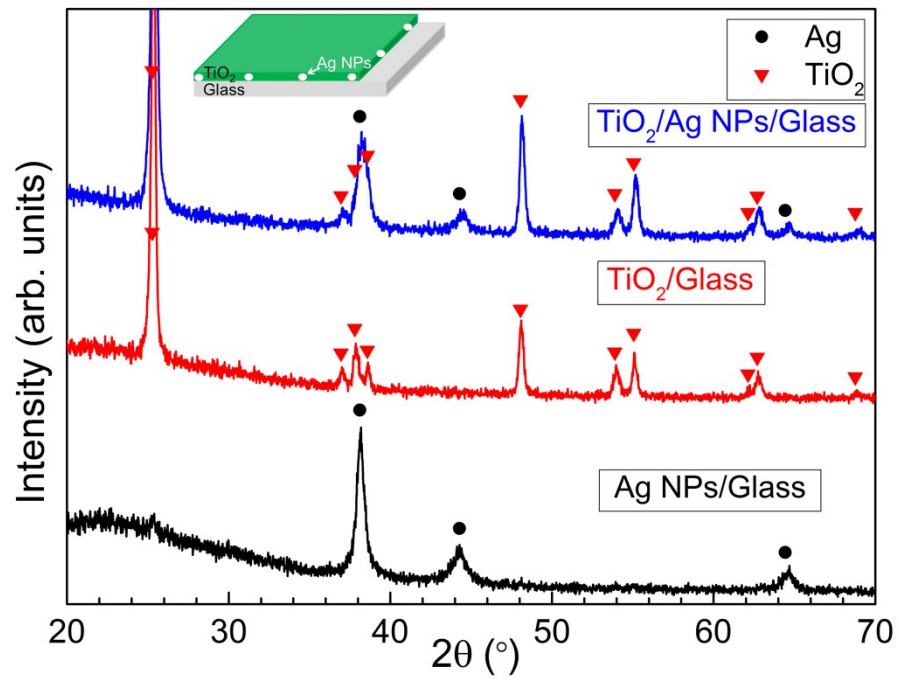


Fig. S6 XRD spectra of Ag NPs/glass, TiO<sub>2</sub>/glass and TiO<sub>2</sub>/Ag NPs/glass samples.

Fig. S7

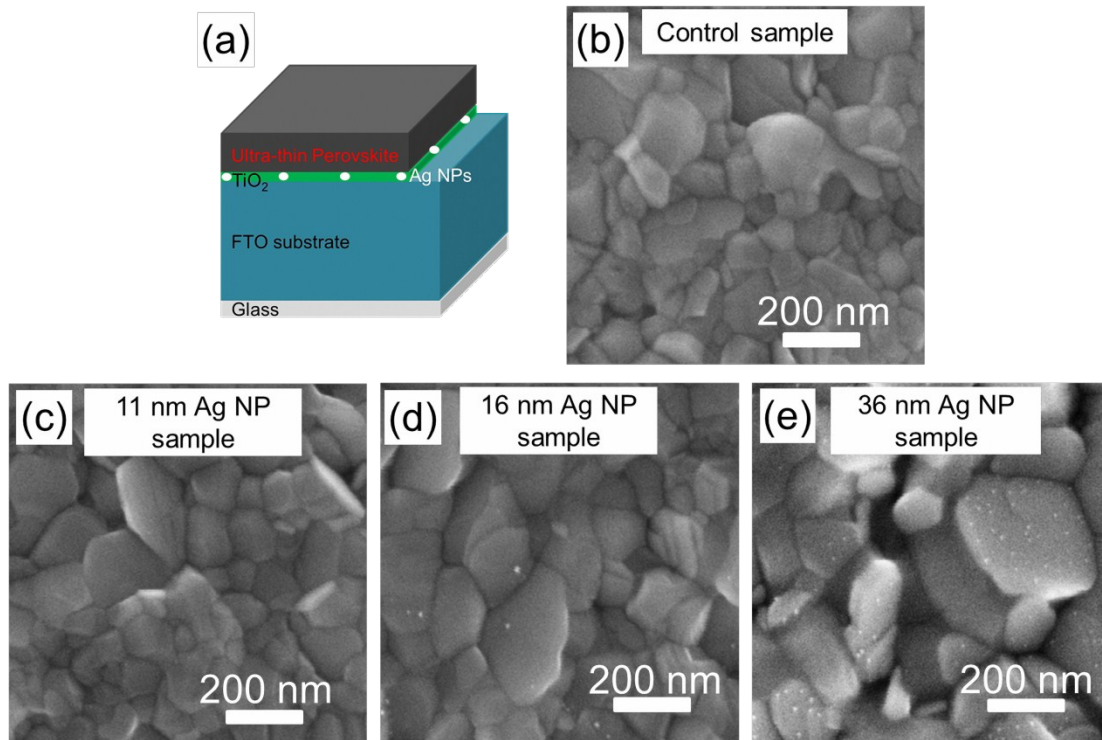


Fig. S7 (a) Schematic sample structure of perovskite layer/TiO<sub>2</sub>/Ag NPs/FTO/glass. (b-e) SEM images of perovskite layer/TiO<sub>2</sub> layer/different sizes of Ag NPs/FTO/glass, among which are (b) control sample, (c) 11 nm Ag NP sample, (d) 16 nm Ag NP sample, (e) 36 nm Ag NP sample.