Supporting Information for

Facile preparation of water-based antireflective SiO_2 film with high transmittance for perovskite solar cells

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The thickness of the AR film is a crucial factor in the optical performance of the AR film in the dip-coating process and is dependent on the withdrawal speed. Figure S1 shows that the thickness of the AR film increases with an increase in the withdrawal speed. This is because a higher withdrawal speed results in greater viscous force on the glass, leading to a thicker deposited film[1]. When the withdrawal speed equals to 80 mm/min, the film thickness is 110 nm, which is close to 112 nm obtained from $\lambda/4n$. Moreover, the wavelength corresponding to the highest transmittance exhibits a red-shift[2] with the increasing film thickness.

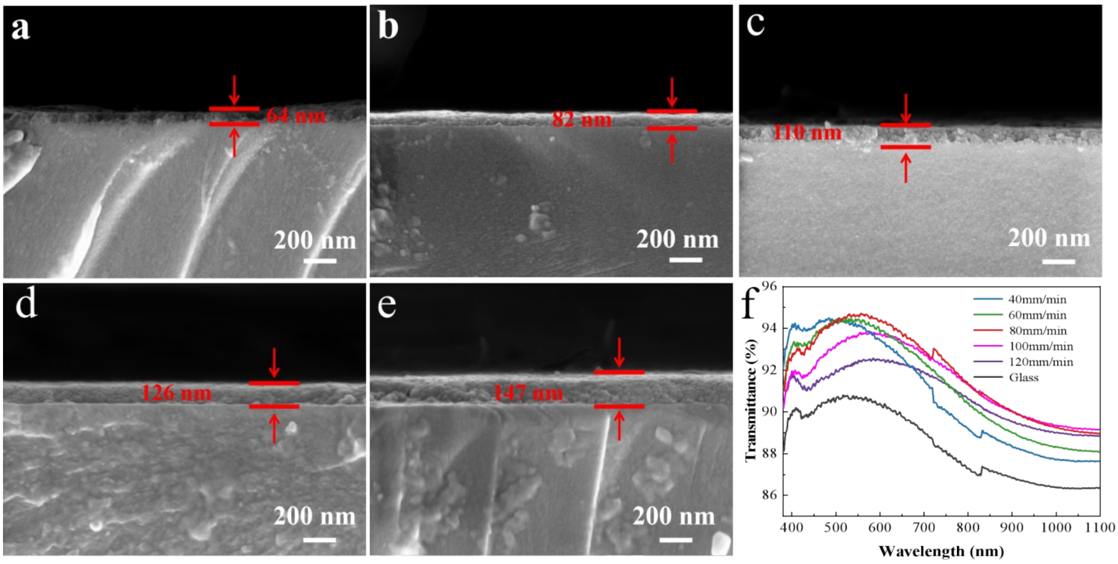

Figure S1 Effect of withdrawal speed on AR film thickness (a) 40 mm/min (b) 60 mm/min (c) 80 mm/min (d) 100 mm/min (e) 120 mm/min and (f) optical performance

Figure S2 presents the transmittance of the AR film on the coated glass with different concentrations (0.5 wt%, 1.0 wt%, 2.0 wt%, 3.0 wt%, and 5.0 wt%) of sodium silicate solution. The experiment was conducted at pH = 9.4 and a withdrawal speed of 80 mm/min. It is noteworthy that at lower concentrations of 0.5 wt % and 1.0 wt %, the generated sol viscosity was not viscous enough to form a film. However, at concentration of 2 wt% or above, nanoporous films could be formed. The size of the sol particles grew with an increase in sodium silicate solution concentration[3]. As the concentration of the sodium silicate solution increased, it was easier for silica particles to bond, producing larger silica particles. However, when the concentrations reached 3.0 wt% and 5.0 wt%, the silica particles became too large to form a rough surface, which resulted in more light scattering and reduced transmittance. The 2.0 wt% sodium silicate solution exhibits superior performance with an increase in transmittance of 4.10% at 550 nm and 3.50% in the wavelength range of 380-1100 nm compared to uncoated glass.

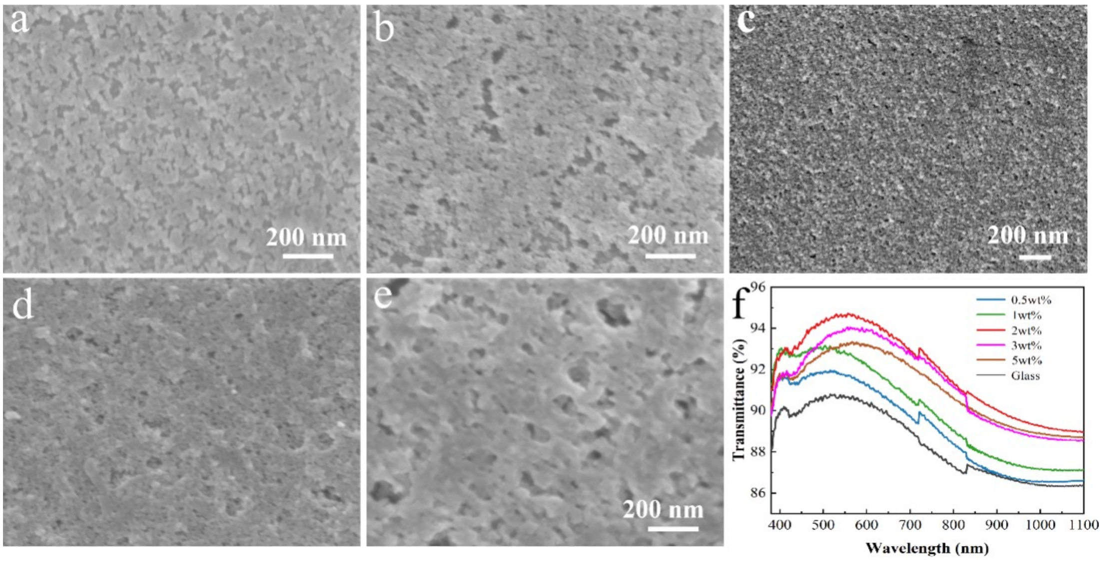

Figure S2 Effect of sodium silicate solution concentration on AR film morphology (a) 0.5 wt% (b) 1 wt% (c) 2 wt% (d) 3 wt% (e) 5 wt% and (f) optical performance

Preparation of the perovskite cells

The nickel oxide solution (15 mg/ml) was deposited on spotless ITO glass by spin-coating, followed by annealing process at 100 ℃ for 20 min. Then, 25 μL $(FAPb_{I3})_{0.95}(MAPbBr_3)_{0.05}$ perovskite precursor solution and 120 μL ethyl acetate was uniformly spin-coated onto the nickel oxide substrate in a first-come-first-served order. Subsequently, the as-mentioned film was annealed at 100 ℃ for 1 h. Consequently, the film was placed into vapor deposition chamber and subjected to deposition of 20 nm of C_{60}, 8 nm bathocuproine (BCP), and 90 nm of silver to obtain perovskite solar cell modules.

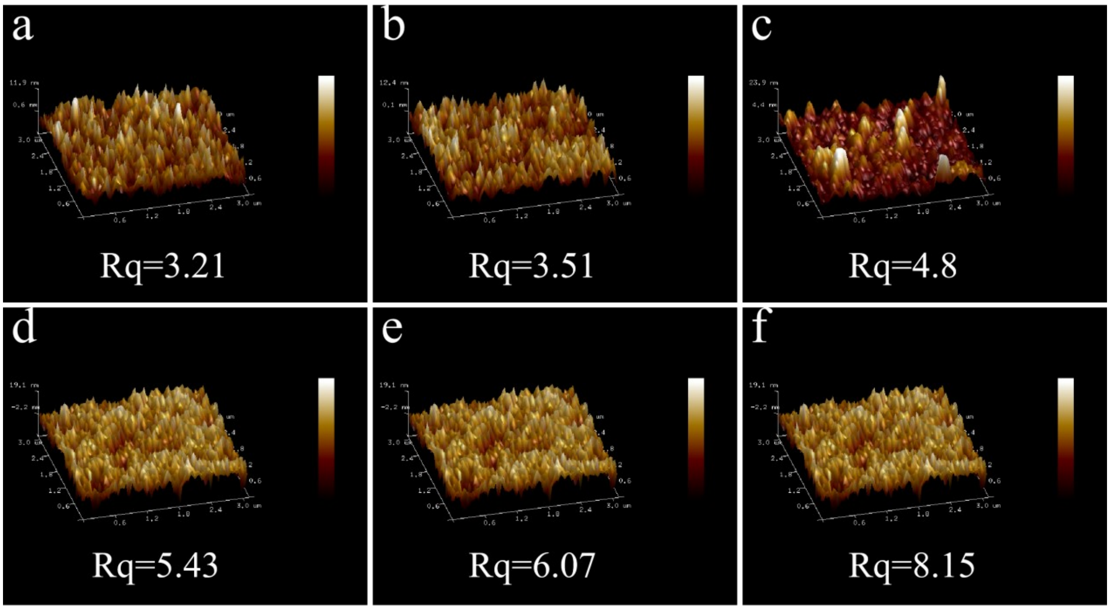

Figure S3 AFM images of aqueous SiO_2 film with different pH values: (a) pH=9.0, (b) pH=9.2, (c) pH=9.4, (d) pH=9.6, (e) pH=9.8, (f) pH=10.0

1 C. J. Brinker, G. C. Frye , A. J. Hurd and C. Ashley, Thin Solid Films, 1991, 201, 97-108.

2 T. Ganesh, K. Perumal , R. Kumar and N. Bhaskar, Nano Hybrids and Composites, 2017, 17, 171-178.

3 T. Furukawa , K. E. Fox and W. B. White, J. Chem. Phys, 1981, 75, 3226-3237.