Ultrathin Oxygen Deficient SnO_x Films as Electron Extraction Layers for Perovskite Solar Modules

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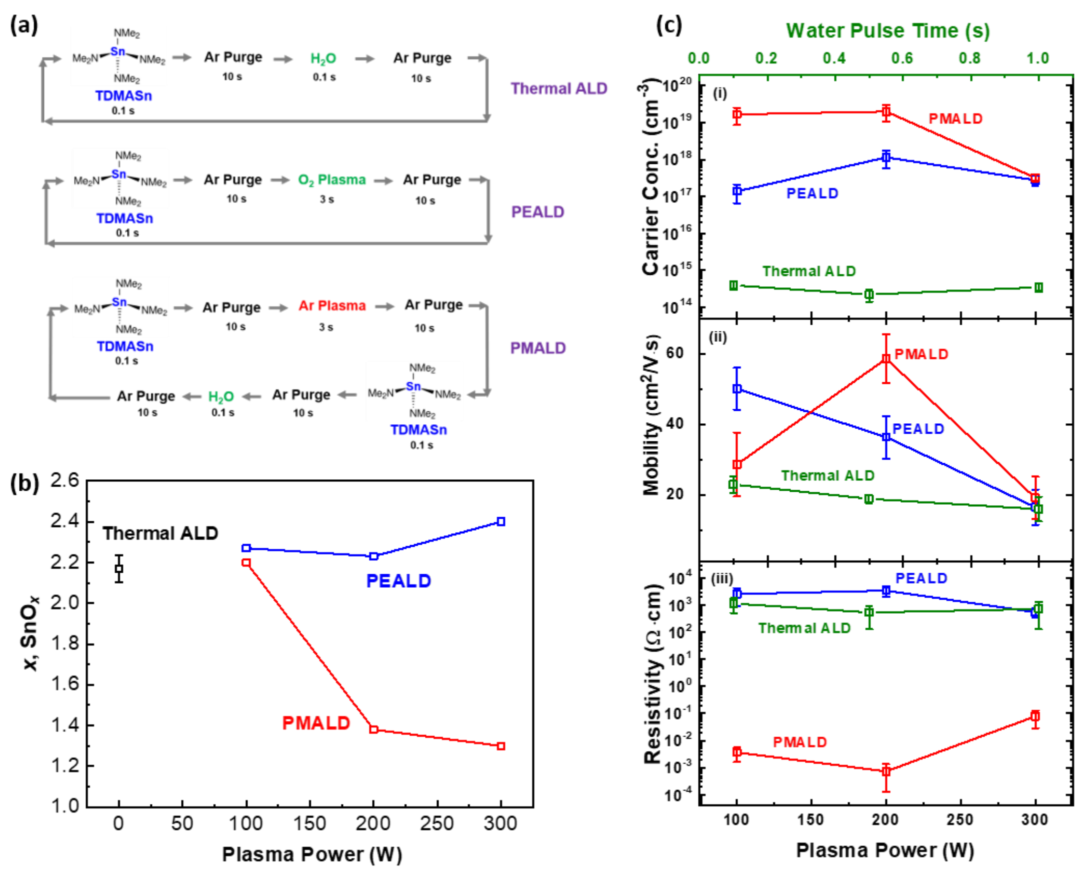

Figure 1. Composition and carrier transport properties of SnO_x films obtained by various ALD approaches. (**a**) Comparison of growth sequence for SnO_x by thermal ALD, plasma enhanced ALD (PEALD), and plasma-modified ALD (PMALD). (**b**) O/Sn ratio in SnO_x thin-films obtained by the various ALD routes as a function of the plasma (O or Ar) power. (**c**) Carrier concentration, mobility, and resistivity, as probed by Hall measurements, in terms of water pulsing time for thermal ALD, oxygen plasma in PEALD and argon plasma power in PMALD.

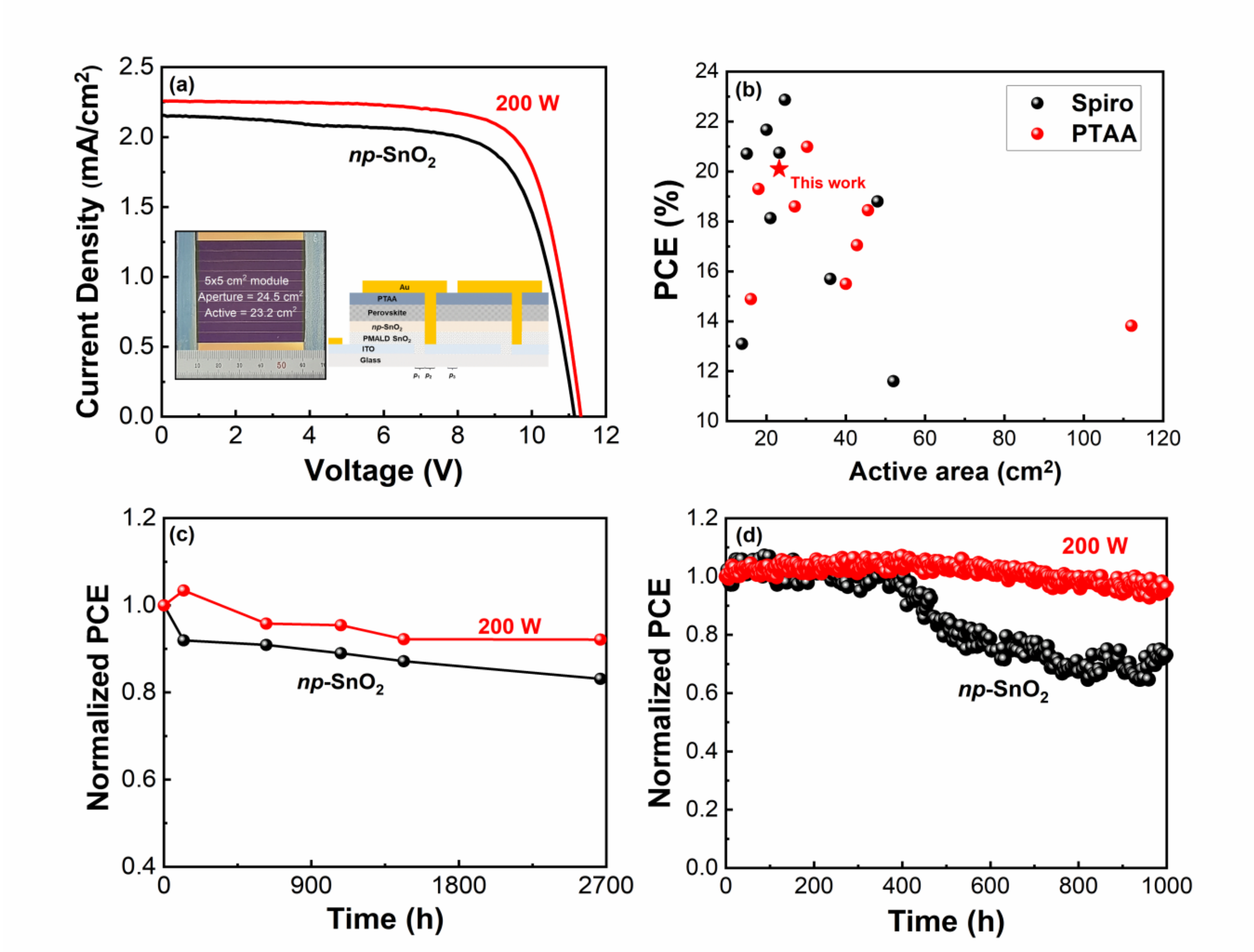

Figure 2. Module performance and stability. (a) Illuminated *J*-*V* characteristic of 5 cm × 5 cm modules with a *np*-SnO_2 layer (Reference) and upon including a 200W PMALD SnO_x electron extraction layer under 1 SUN. (**b**) PCE values of the highest performance perovskite modules as a function of the device area, including this work. (**c**) Long-term damp-heat stability tests at 85°C and 85% relative humidity. (**d**) Maximum power point tracking measurement of the reference device and device with PMALD SnO_x (200 W) under continuous LED illumination.