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Supplementary information

Solution-processable nickel-chromium ternary oxide as an efficient hole transport layer for inverted planar perovskite solar cells

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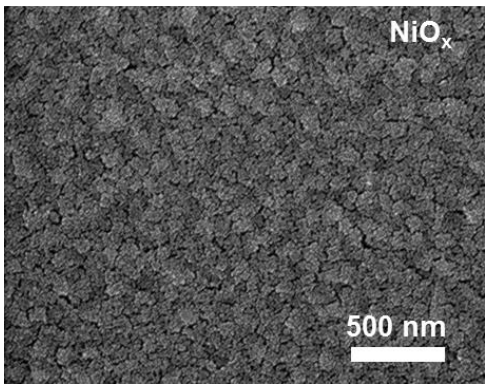

Fig. S1. Top-view SEM image of as-deposited NiO_x film. The film is not as compact as $NiCrO_3$ film shown in Fig. 1a.

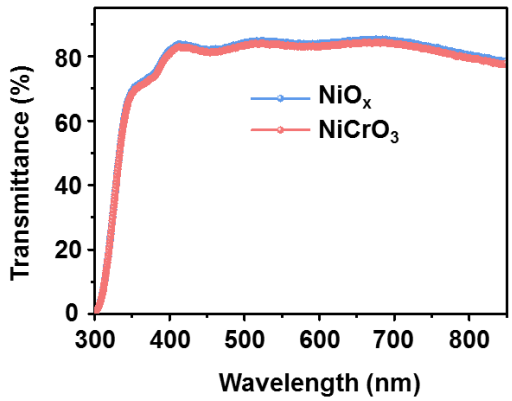

Fig. S2 Transmittance spectra of NiO_x and $NiCrO_3$ films coated on the FTO substrates. Both films have similar transparency which is highly transparent in the visible range from 300 to 850 nm.

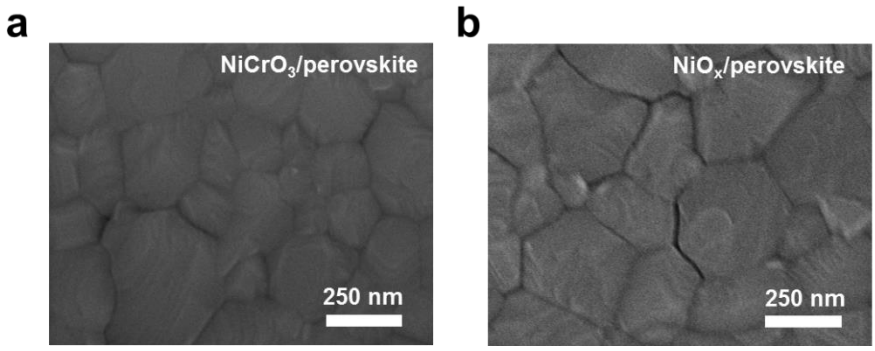

Fig. S3 Top-view SEM images of $MAPbI_3$ perovskite films deposited on (a) NiO_x and (b) $NiCrO_3$ films. A similar morphology of perovskites was observed for both samples.

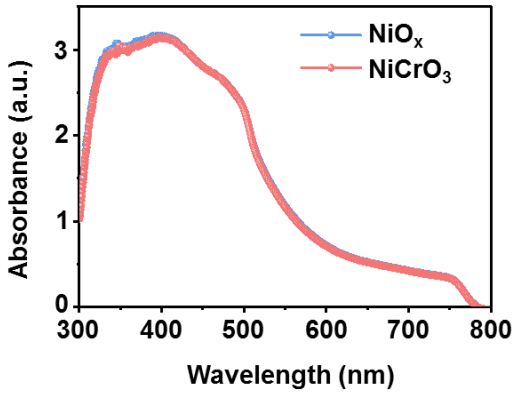

Fig. S4 UV-vis absorption spectra of $MAPbI_3$ perovskite films coated on NiO_x and $NiCrO_3$ films. Both perovskite films can harvest a wide range of UV and visible light up to 780 nm.

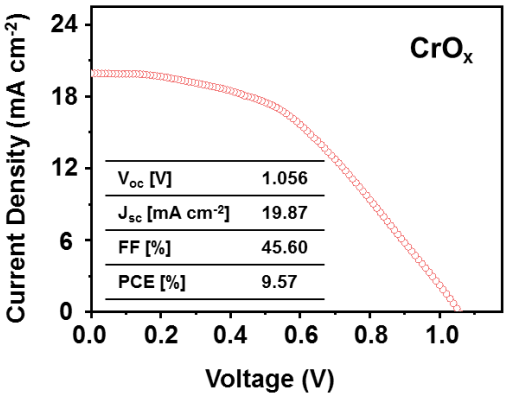

Fig. S5 J-V characteristics of CrO_x HTL based PSC and corresponding photovoltaic parameters. The device was measured under AM 1.5G illumination with a scan rate of 0.15 V s^{-1}.

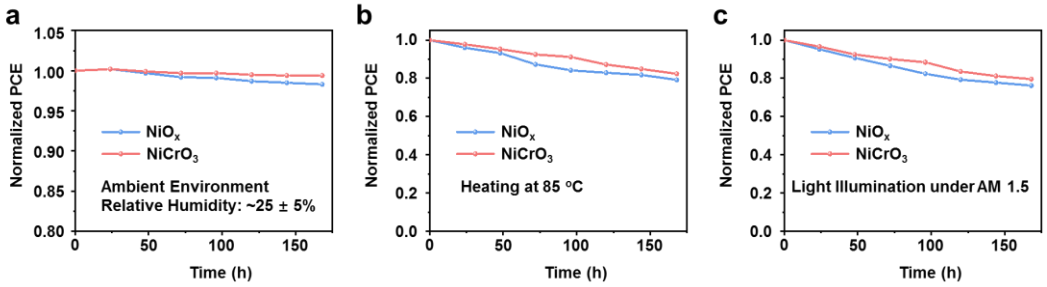

Fig. S6 Stability metrics of unencapsulated $MAPbI_3$ PSCs based on NiO_x and $NiCrO_3$ HTLs under different environments: (a) ambient air with ~20 ± 5% relative humidity at 25 °C, (b) 85 °C in nitrogen atmosphere, and (c) AM 1.5G irradiation of ~100 mW cm^{-2}.

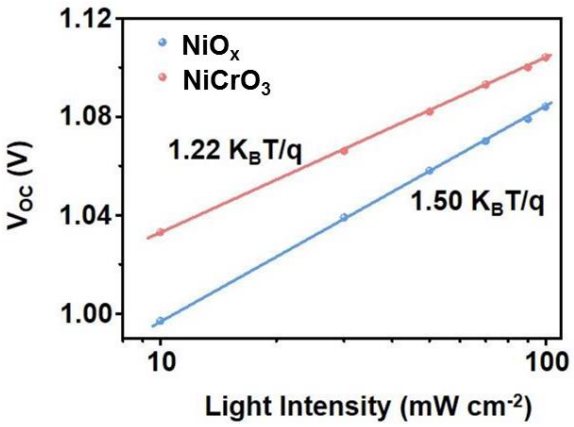

Fig. S7 V_{OC} values of the PSCs based on NiO_x and $NiCrO_3$ HTLs as function of light intensity. The correlation between V_{OC} and light intensity (I) is described as $dV_{OC}/dlnI = nk_BT/q$, where n, k_B, T, and q are the ideality factor, Boltzmann constant, room temperature, and elementary charge, respectively.

Table S1 Summary of photovoltaic performances of perovskite solar cells based on ternary inorganic HTLs.

Device	V_{OC} [V]	J_{SC} [mA cm^{-2}]	FF [%]	PCE [%]	Ref
$NiCrO_3$	1.104	23.07	78.30	19.93	**This Work**
$NiCo_2O_4$	1.063	23.02	78.60	19.24	*Adv. Funct. Mater.* **2019**, *29*, 1904684
$LiCoO_2$	1.060	22.50	80.00	19.05	*J. Mater. Chem. A* **2018**, *6*, 13751-13760
$CuCrO_2$	1.070	21.94	81.00	19.00	*Adv. Energy Mater.* **2018**, *8*, 1702762
$CuGaO_2$	1.110	21.66	77.00	18.51	*Adv. Mater*. **2017**, *29*, 1604984
$NiCo_2O_4$	1.070	21.86	78.00	18.23	*Adv. Energy Mater.* **2018**, *8*, 1702722
$CuFeO_2$	1.010	23.60	65.00	15.60	*ACS Appl. Mater. Interfaces* **2019**, *11*, 45142-45149