Supporting information for

Substrate Effects on Structural and Optoelectronic Properties of Quasi-2D Perovskite Films

Chenyu Hu[†], Zhenmei He[†], Shuochen Wang[‡], Lixuan Kan[†], Sanfeng Lei[†], Xixiang Zhu[†], Jinpeng Li[†], Kai Wang[†], and Haomiao Yu[,†]*

[†]Key Laboratory of Luminescence and Optical Information, Ministry of Education, School of Physical Science and Engineering, Beijing Jiaotong University, Beijing 100044, China

[‡]The High School Affiliated to Renmin University of China, Beijing 100080, China

Corresponding Author

Haomiao Yu* yuhaomiao@bjtu.edu.cn

Experimental section

Materials: PEN substrates were purchased from Peccell Technologies, Inc., PDMS substrates were purchased from Dow Corning Corp. Methylammonium iodide (MAI) and lead iodide (PbI$_2$) were purchased from Xi'an Polymer Light Technology Corp, 2-phenylethylamine hydroiodide (PEAI) was purchased from Liaoning Preferred New Energy Technology Corp. The organic solvents include dimethyl sulfoxide (DMSO, 99.9%), chlorobenzene (CB, 99.9%) were purchased from Sigma Aldrich. All reagents and chemicals were used as received without further purification.

Perovskite precursor solutions: 0.8 mmol of PbI$_2$, 0.6 mmol of MAI, 0.4 mmol of PEAI were dissolved in 1.2 ml of a mixed solution of DMF and DMSO (9:1 volume ratio). The prepared quasi 2D perovskite precursor solution was stirred at 50°C for 12 hours. Care was taken to store it away from light using a brown bottle. Prior to spin-coating, the solution was filtered through a 0.22 µm polytetrafluoroethylene (PTFE) needle filter tip into a clear white bottle to obtain a clear, yellow solution of the perovskite precursor.

Sample preparation and device fabrication: Silicon, glass, PEN, and PDMS substrates were first meticulously cleaned through ultrasonic washing in distilled water, isopropanol, and ethanol, followed by treatment with UV-ozone plasma to enhance surface properties. In order to avoid large movement and deformation of the flexible substrate and maintain a stable temperature during the film preparation process, the flexible PEN and PDMS substrates are supported by rigid glass substrate. The PEN substrate is fixed on the glass by double-sided tape, and the PDMS substrate is directly

attached to the glass due to its good adhesion. These prepared substrates were subsequently coated with a perovskite precursor solution using a spin-coating technique. The process involved heating the substrate on a hotplate at 100°C for 3 minutes to ensure proper adhesion and film formation. This was followed by a precisely controlled spin-coating step at a speed of 4000 rpm for 30 seconds. A volume of 90 μL of the perovskite precursor solution was accurately dispensed onto the substrate using a pipette, and immediately after the spin-coating process, the substrate was transferred to a hotplate set at 100°C for annealing over 10 minutes to crystallize the film. The fabrication of the devices was finalized by depositing 80 nm thick gold electrodes through thermal evaporation under a high vacuum of 5×10^{-5} Pa at a deposition rate of 0.1 Å/s, establishing the electrical contacts. The active area of the resulting vertical structure devices was meticulously defined to be 0.038 mm^2.

Device characterization: Grazing incidence wide-angle X-ray scattering (GIWAXS) analyses of the films were performed using a Xeuss 2.0 system from Xenocs, France, with a wavelength of 1.54189 Å and an incident angle of 0.3°. X-ray diffraction (XRD) measurements were conducted using a Smart Lab 3kW X-ray diffractometer. The films' surface morphologies were examined via scanning electron microscopy (SEM) using a Zeiss EVO 18 SEM. Absorption spectra were acquired with a Shimadzu UV-2600 spectrophotometer. Steady-state and time-resolved photoluminescence (TRPL) measurements were conducted using a Fluorolog-3 fluorescence spectrophotometer from Horiba Scientific. The photoluminescence quantum yield (PLQY) of the thin films was determined using a SpectrumTEQ-EL electroluminescence quantum efficiency

measurement system (Ocean Optics) under 375 nm excitation. The current-voltage (I-V) characteristics of the devices were recorded with a Keysight B2912A source meter. Low-temperature PL spectroscopy and I-V measurements were performed using a cryostat system in conjunction with a Fluorolog-3 fluorescence spectrophotometer and a Keysight B2912A source meter, respectively.
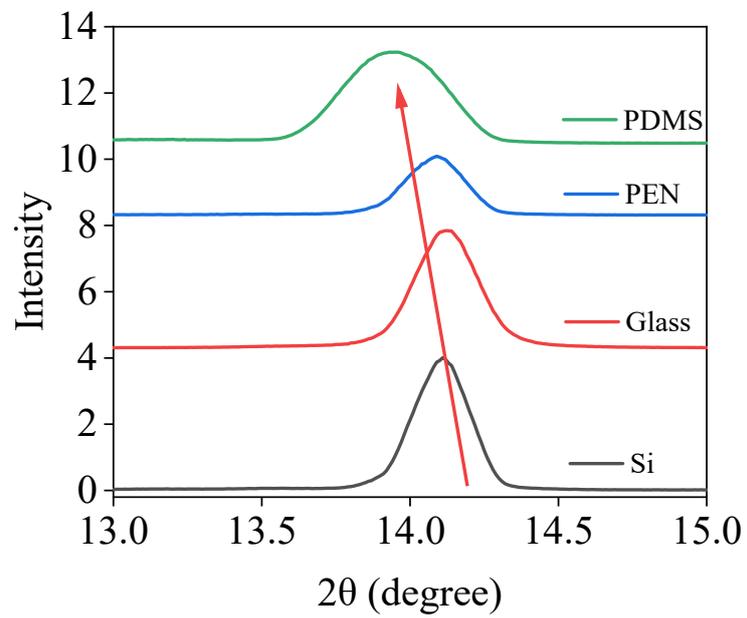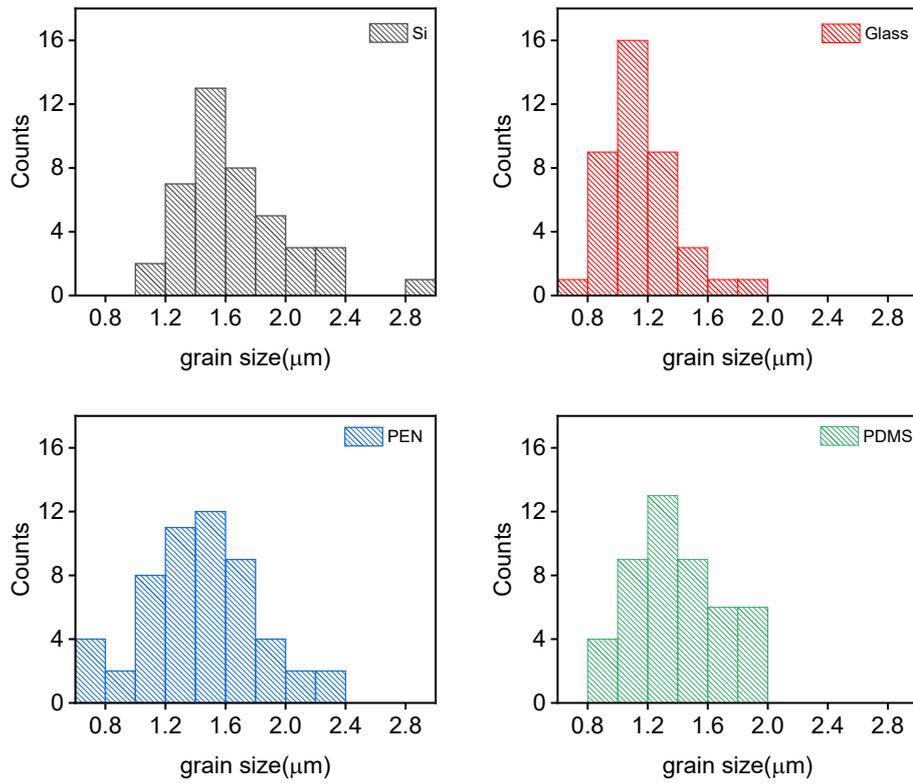
Figure S1. XRD patterns of quasi-2D perovskite films deposited on four different substrates, indexed by the (110) plane.

a

Si

300μm

Glass

300μm

PEN

300μm

PDMS

300μm

b

Si

10μm

Glass

10μm

PEN

10μm

PDMS

10μm
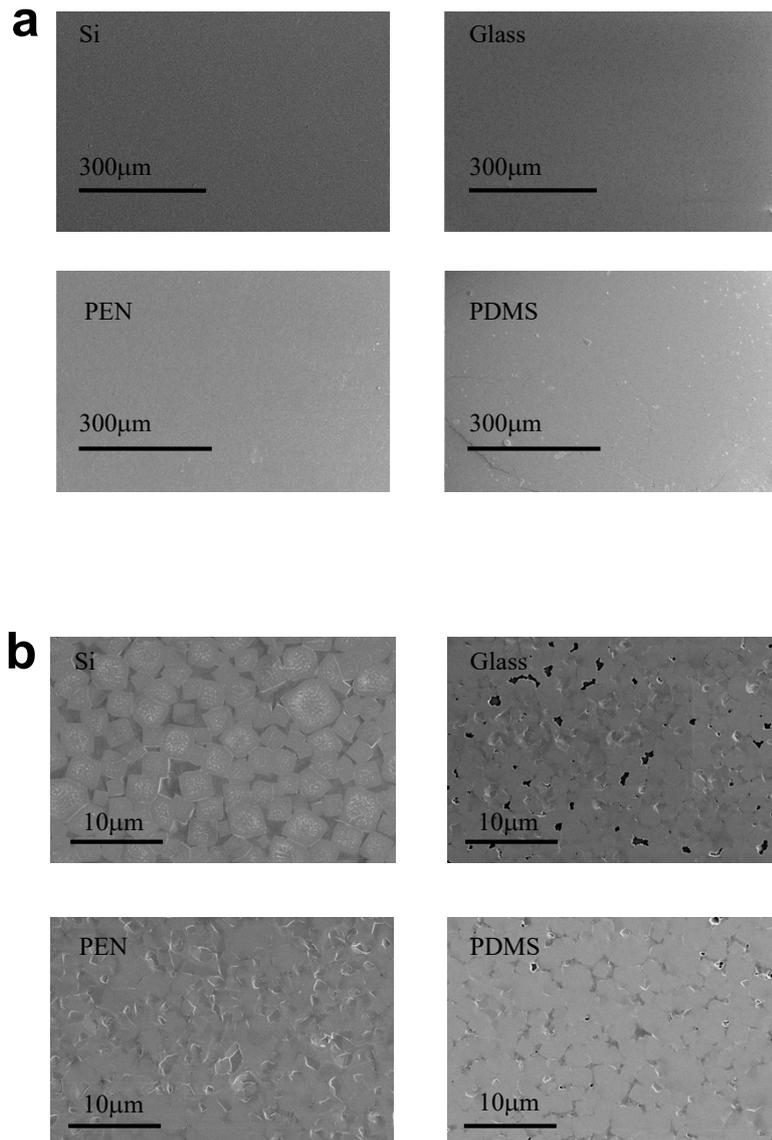
**Figure S2.** SEM images of perovskite on four different substrates, magnification at (a) 500x and (b) 10000x.

Figure S3. Grain size distribution in quasi-2D perovskite films on four different substrates, as derived from SEM images.
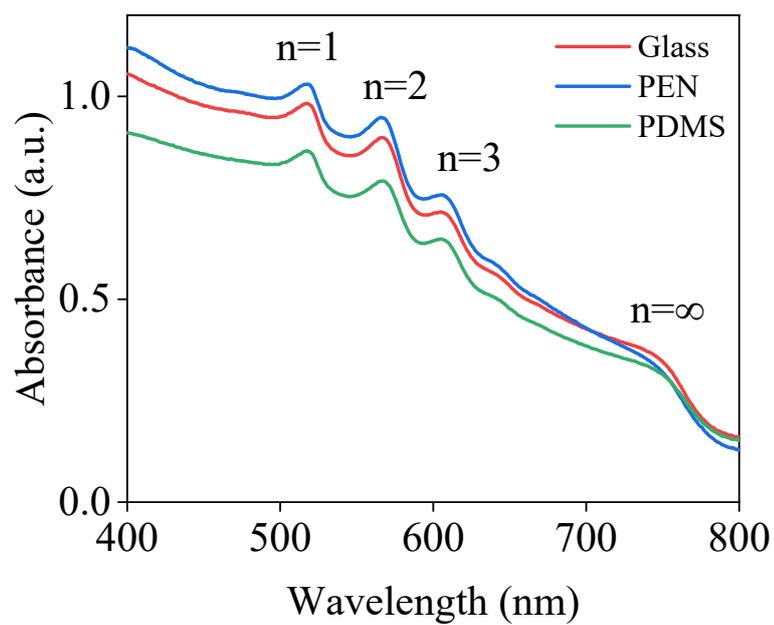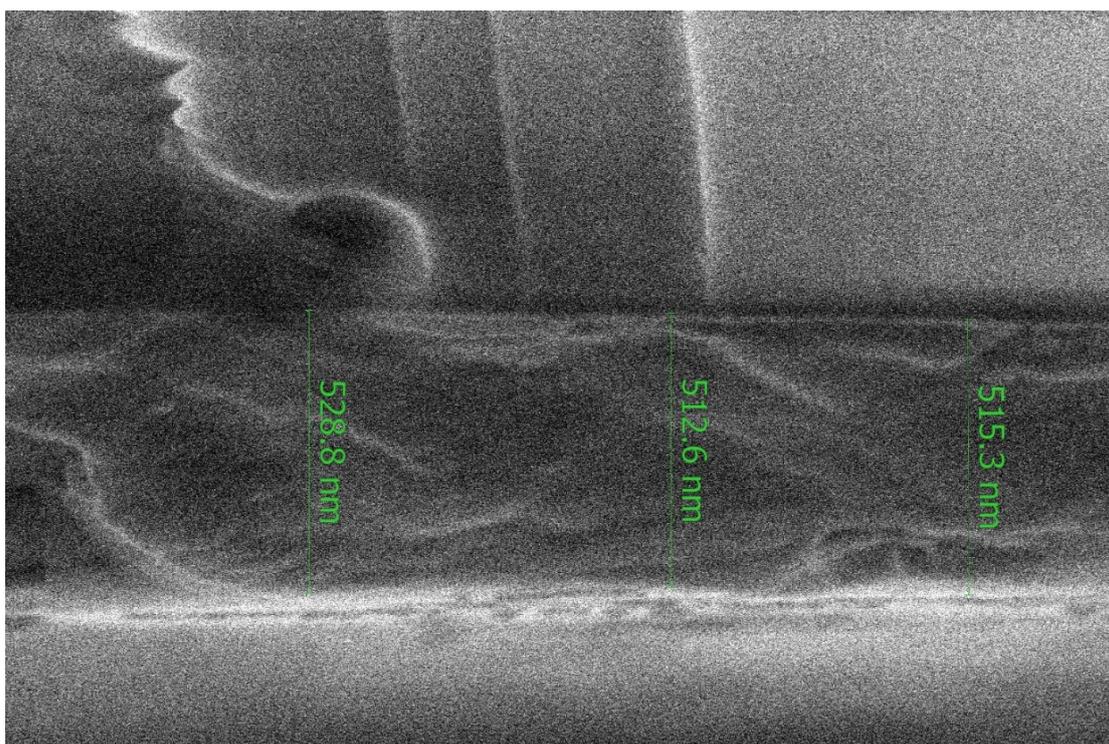
Figure S4. UV-vis absorption spectra of quasi-2D perovskites deposited on glass, PEN, and PDMS substrates.
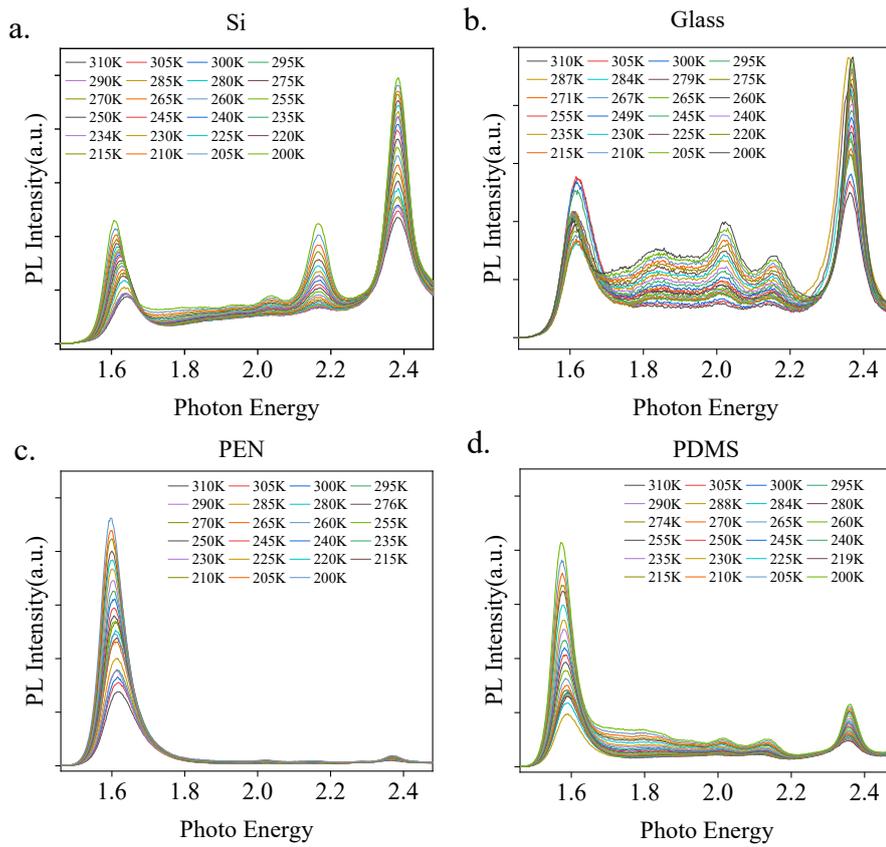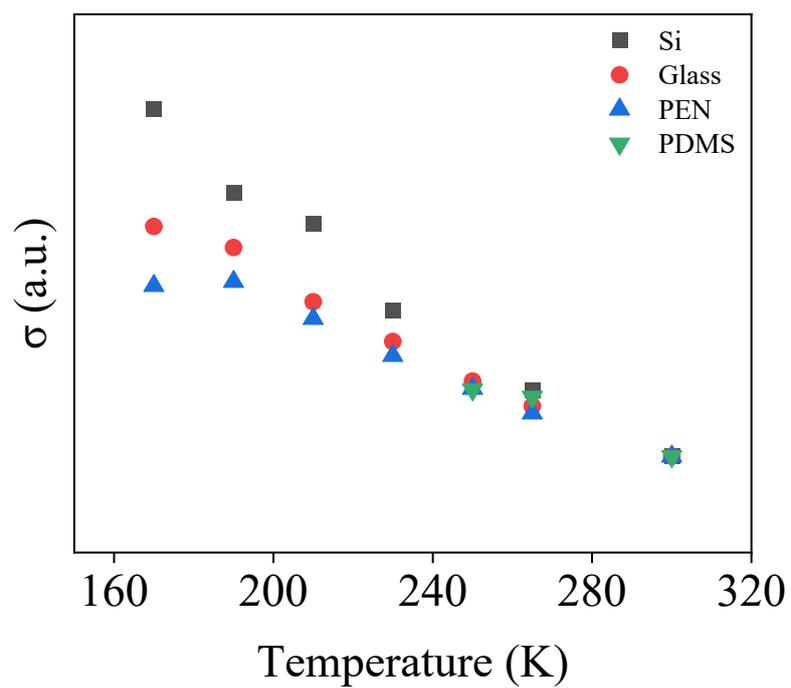
**Figure S5.** PL spectra of quasi- 2D perovskites on four substrates measured at various temperatures.
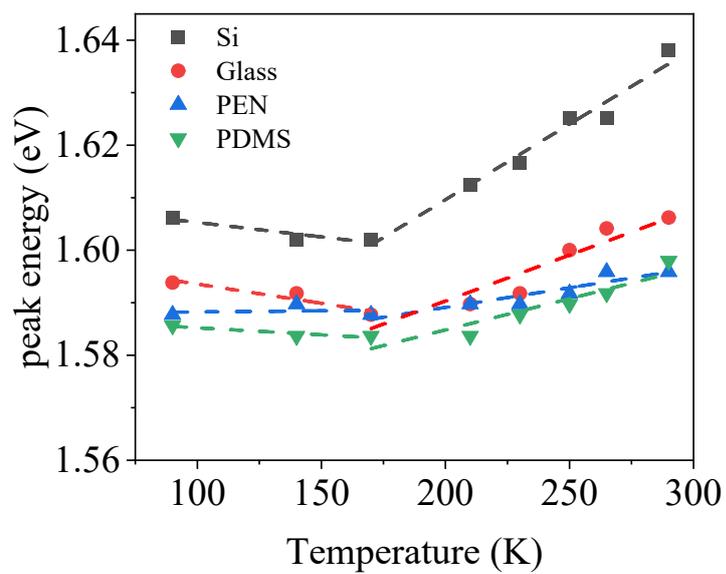
Figure S6. Variation of perovskite peak energy, corresponding to 3D-like phases, with temperature for quasi-2D perovskites on four substrates.
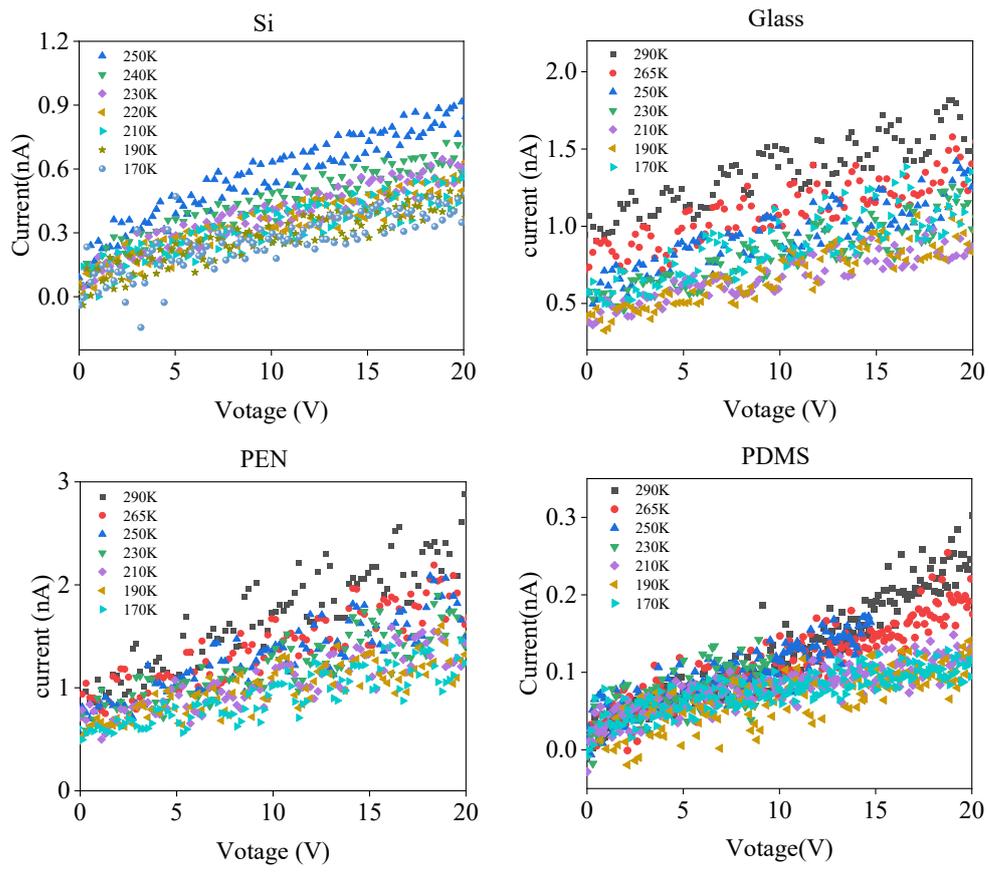
Figure S7. Cross-sectional SEM image of a quasi-2D perovskite film prepared using the described experimental method.

Figure S8. Variation of conductivity with temperature for Au/perovskite/Au vertical structure devices on four different substrates.
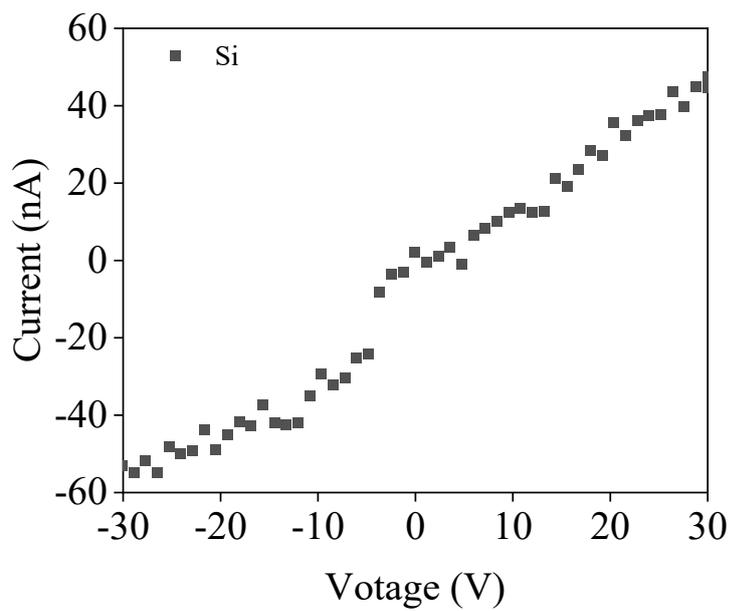
Figure S9. *I-V* curve of Au/perovskite/Au lateral device on silicon substrate.

Figure S10. Variation of conductivity with temperature for Au/perovskite/Au lateral structure devices on four different substrates.

Table S1: Determination of time constants in PL decay kinetics through tri-exponential fitting of TRPL spectra.

Substrate	t_1(ns)	t_2(ns)	t_3(ns)	A_1	A_2	A_3	t_{aver}(ns)
Si	17.0	564.7	1.8	124	264	255	235.7
Glass	32.6	521.6	1.5	67	65	236	99.4
PEN	14.8	782.6	1.6	54	221	228	346.1
PDMS	23.6	342.9	1.7	35	112	270	95.7