$CH_3NH_3PbI_3$ Perovskite Light Emitting Field-Effect Transistor

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Hybrid organic-inorganic perovskites have emerged as excellent solution-processable materials for photovoltaic applications [1]. Recently, their light emission properties have also attracted considerable attention for light-emitting devices [2,3]. Here we demonstrate $CH_3NH_3PbI_3$ light emitting field-effect transistor (LE-FET), a new device concept in perovskite-based optoelectronics.

In LE-FET devices, ambipolar channels are formed simultaneously by proper source-drain and gate biasing. Under perfectly balanced conditions, holes and electrons injected from opposite electrodes recombine in the middle of the FET channel, thus defining a very narrow radiative emission zone [4]. Compared to conventional LED devices, LE-FETs can achieve brighter and fast-switchable electroluminescence thanks to optimized carrier injection.

Solvent engineering was used to spin coat high-quality perovskite films on top of a bottom-gate, bottom contacts Si substrates, resulting in ambipolar FET devices. We show that typical screening effects associated to ionic transport in $CH_3NH_3PbI_3$ can be effectively eliminated by lowering the operating temperature. Field-effect carrier mobility is found to increase by almost two orders of magnitude below 200 K, consistently with phonon scattering limited transport. Under balanced carrier injection, gate-dependent electroluminescence is observed from the transistor channel (Figure 1a). Electroluminescence brightness and the spatial location of the emission zone can be controlled by tuning the biasing conditions.

Electroluminescence emission is characterized by two distinct peaks appearing within specific temperature ranges (Figure 1b), which stem from the known tetragonal to orthorhombic structural phase transition of $CH_3NH_3PbI_3$ [5]. This is in excellent agreement with the electronic structure of the two phases predicted by our first-principle calculations.

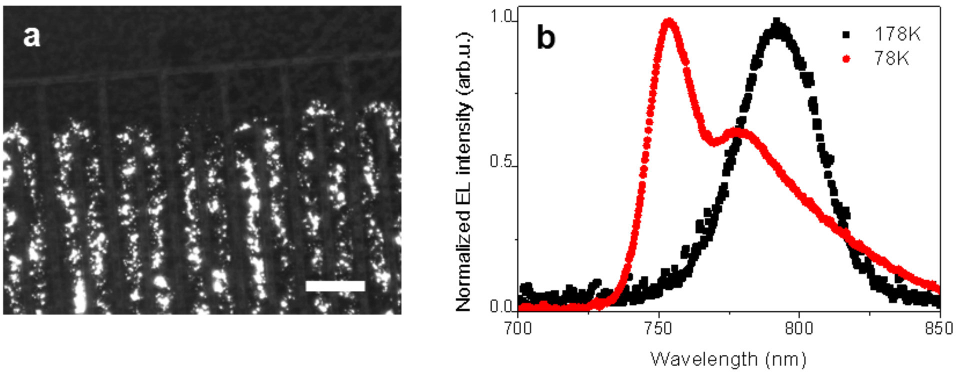

Fig. 1 (a) Optical image of the $CH_3NH_3PbI_3$ LE-FET emission zone recorded at T=158 K shows light emission from the middle of the interdigitated drain and source electrodes. (b) Normalised electroluminescence spectra recorded at 178 and 78 K show two distinct emission peaks corresponding to the high-temperature tetragonal and low-temperature orthorhombic crystallographic phases of $CH_3NH_3PbI_3$. All data were obtained with gate bias of V_{gs}=100 V and source-drain bias of V_{ds}=100 V.

This first demonstration of $CH_3NH_3PbI_3$ LE-FETs proves the potential of perovskite materials for low cost, large area light emitting electro-optic devices such as gate-assisted light emitting diodes and electrical-injection lasers.

References

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