AC-Driven Perovskite Light-Emitting Field-Effect Transistors

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In recent years, hybrid organic–inorganic perovskites has drawn great attention towards applications in light-emitting devices such as light-emitting diodes [1], X-ray scintillators [2] and lasers [3]. Recently we have demonstrated a perovskite light-emitting field-effect transistors (PeLEFETs) [4] operating at low temperatures, with gate-controlled carrier injection and recombination zone. Despite the balanced carrier injection provided by the FET configuration, the performance of these devices is strongly affected by ionic transport effects which cause large hysteresis and hinder operation at room temperature.

In this work we present an improved $CH_3NH_3PbI_3$ PeLEFET with bottom gate, top contact configuration (Fig. 1a), which, compared to the previously reported bottom gate bottom contact configuration [4], yields a tenfold improvement of the field-effect electron mobility, up to 0.1 $cm^2V^{-1}s^{-1}$ and 0.01 $cm^2V^{-1}s^{-1}$ for holes. Furthermore, we show that AC-driven gate bias modulation, allows minimizing the ionic drift within the perovskite channel, hence reducing the effects of the ionic screening and increasing the brightness of electroluminescence compared to its DC-driven counterpart at comparable voltages.

Figs. 1b and 1c compare the low temperature (T= 78 K) emission of a DC-driven (V_{DRAIN}= 100 V and V_{GATE}= 50 V) and AC-driven (V_{DRAIN}= 100 V and V_{GATE}= ±50 V, frequency= 10 kHz) PeLEFET at similar voltages. Besides showing brighter and more uniform emission compared to the DC-driven device, tuning the gate and drain voltages in AC-driven mode allows achieving bright emission from the entire FET channel by alternated injection of electrons and holes from both electrodes (Fig. 1d, V_{DRAIN}= -80 V and V_{GATE}= 125 V peak-to-peak, Frequency: 10 kHz).

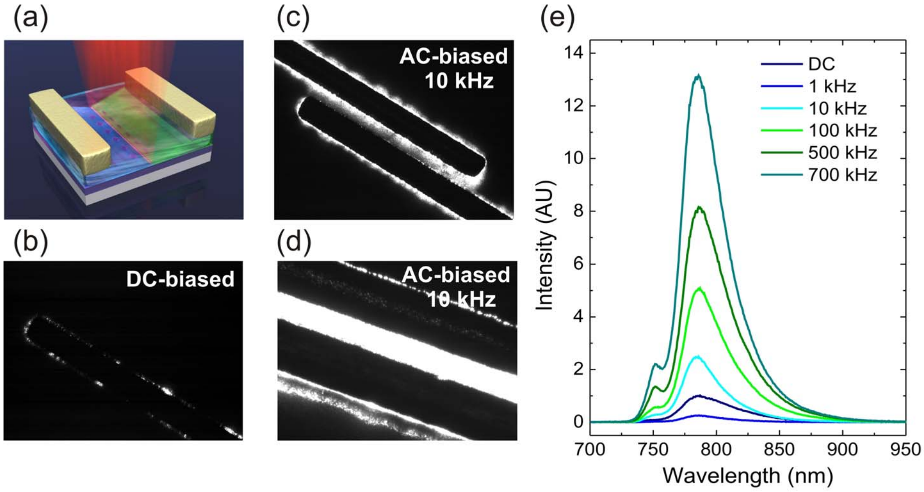

Fig. 1 (a) Schematic structure of the PeLEFET. (b) Emission of the DC-driven PeLEFET (V_{DRAIN}= 100 V and V_{GATE}= 50 V) (c) Emission of the AC-driven PeLEFET (V_{DRAIN}= 100 V and V_{GATE}= 100 V peak-to-peak at 10 kHz) (d) Emission from the whole FET-channel in the AC-driven PeLEFET achieved by tuning the drain- and gate-bias (V_{DRAIN}= -80 V and V_{GATE}= 125 V peak-to-peak at 10 kHz). (e) Spectra of the light emission for the DC-driven (V_{DRAIN}= 150 V and V_{GATE}= 100 V) and AC-driven (V_{DRAIN}= -100 V and V_{GATE}= 125 V peak-to-peak) PeLEFET at different modulation frequencies. The peaks are normalized on the emission of the DC-driven device.

At the constant gate bias amplitude investigated (125 V peak-to-peak), the AC-driven PeLEFET electroluminescence was found to increase with the modulation frequency up to 700 kHz (Fig. 1e), limited by the breakdown of the device at high current density. More significantly, AC operation enables electroluminescence emission at significantly higher temperatures, approaching room temperature.

These results constitute a significant leap forward towards the realization of a stable perovskite PeLEFET devices, with electroluminescence efficiency surpassing that of standard LED configurations and controllable emission pattern to be used in active-matrix displays and solid state lighting.

References

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