Mobile Ions Determines Multiphase Performance Dynamics of Perovskite LEDs

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Metal-Organic Perovskite Light Emitting Diodes (PeLEDs) currently reaching more than 20% external quantum efficiency1–3 are a promising technology for display and lighting applications. Unfortunately, many questions regarding their performance are still not completely understood, especially those related to the device stability, operation in non-stationary regimes, and efficiency roll-off at high current densities. In this work, we try to address some of those issues in MAPbI3 hybrid perovskite LEDs. By analysing electroluminescence (EL) and current dynamics after the abrupt application of pumping voltage at different temperatures it was showed that EL intensity and current of PeLED exhibits complex growth kinetics after the application of constant pump voltage. The initial EL intensity of the pristine sample is very weak and continue to grow from milliseconds to tens of minutes. Subsequent application of voltage after the device "rests" for tens of minutes or hours creates a much stronger initial EL signal, which increases by tens of per cent during additional seconds. This EL growth process was analysed using several spectroscopic techniques that enabled us to study changes of EL intensity, current, and EL spectrum taking place during applied bias stressing, relaxation after bias stressing, negative voltage or light soaking. Additionally, we investigated stressing-induced changes of the samples photoluminescence, electroabsorption and capacitance.

Analysis of the experimental results together with mathematical modelling revealed that the complex operation dynamics on time scales from sub-seconds to minutes and hours is caused by redistribution of single type mobile species - iodine ions, which changes the carrier injection, spatial electric field and carrier density distributions and density of nonradiative recombination centres. These novel results provided a deeper understanding of the processes taking place in operating PeLEDs and will be highly important for their optimization directed to the more efficient performance of the perovskite devices.

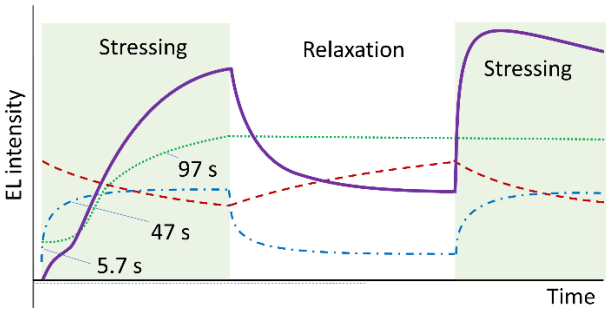

Figure 1. Major stressing-induced processes. EL development kinetics (solid magenta line), bi-exponential current growth causing fast reversible EL growth component (dash-dot blue line), slow irreversible EL growth component (dot green line), and reversible EL decay (dash red line). The numbers show time constants of various processes at room temperature at 2 V stress voltage obtained from exponential fitting.

Keywords: perovskite, LEDs, mootion of ions, crystal defects.

References:

[1] Cao, Y. *et al.* Perovskite light-emitting diodes based on spontaneously formed submicrometre-scale structures. *Nature* **562**, 249–253 (2018).
[2] Xu, W. *et al.* Rational molecular passivation for high-performance perovskite light-emitting diodes. *Nat. Photonics* **13**, 418–424 (2019).
[3] Chiba, T. *et al.* Anion-exchange red perovskite quantum dots with ammonium iodine salts for highly efficient light-emitting devices. *Nature Photon* **12**, 681–687 (2018).