Perovskite Light Emitting Diodes with Record High-radiance Operational Lifetime by Phenylalkylammonium Passivation

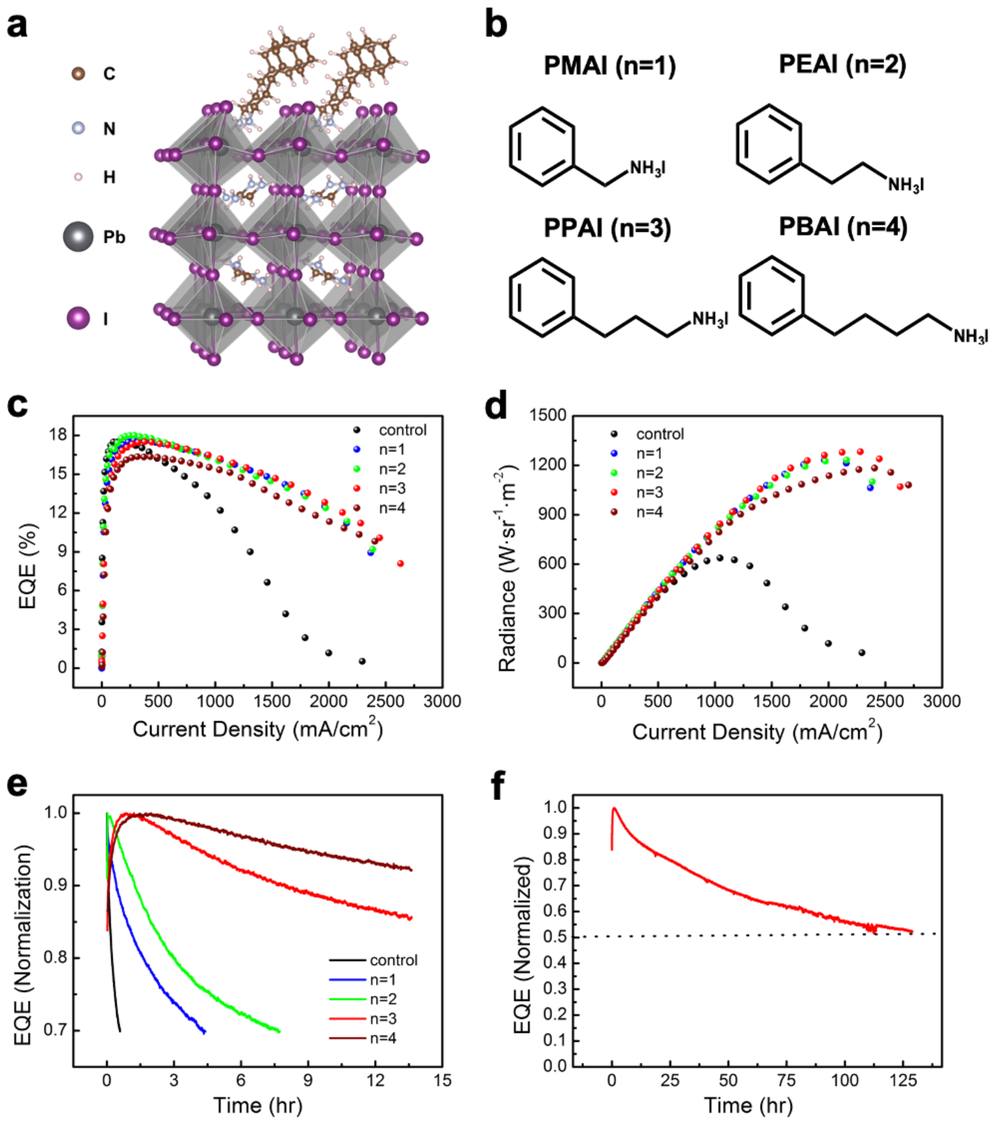
香港中文大學
The Chinese University of Hong Kong

Yuwei Guo[1], Sofia Apergi[2,3], Nan Li[1], Mengyu Chen[1,4], Chunyang Yin[5], Zhongcheng Yuan[5], Feng Gao[5], Fangyan Xie[6], Geert Brocks[2,3,7], Shuxia Tao[2,3]*, Ni Zhao[1]*

Introduction

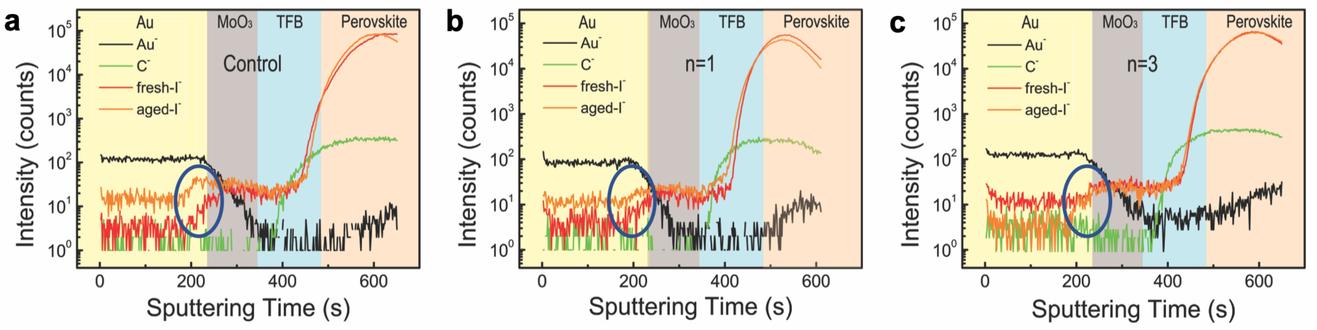
Perovskite-based light emitting diodes (PeLEDs) display has a great potential in the display field. The past few years have seen a significant improvement in the efficiency of PeLEDs. However, the poor operation stability of the devices still hinders the commercialization of this technology in practical applications, exhibiting a rapid decay of external quantum efficiency (EQE) within minutes to hours during operation. To address this issue, we explore surface treatment of perovskite films with phenylalkylammonium iodide molecules of varying alkyl chain lengths.

Device Characterization



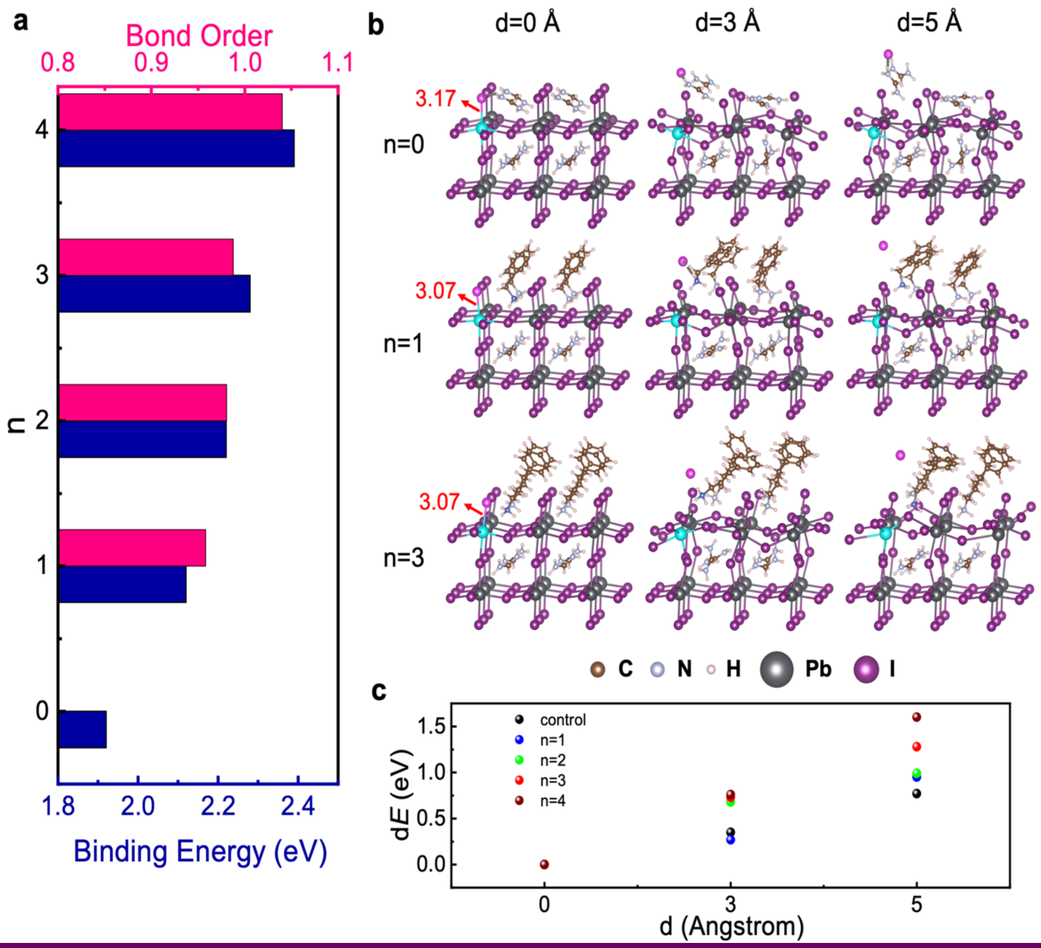
a) Schematic diagram of a molecular passivated perovskite surface; **b**) structures of the passivation molecules; **c**) EQE as a function of current density for the control and treated devices; **d**) Radiance as a function of current density for the control and treated devices; **e**) Stability test under a constant bias current density of 100 mA cm^{-2} for the control and treated devices; **f**) T_{50} measurement under a constant current density of 100 mA cm^{-2} by PPAI passivation

ToF-SIMS Characterization



The iodide ion migration has been suppressed with the chain length increases by testing the devices after 16 hrs operation with a constant current density of 100 mA cm^{-2}

DFT calculation



a) Binding energy and bond order of the passivation molecules on the $FAPbI_3$ perovskite surface; **b**) Schematic pathway of iodide migration on the passivated perovskite surfaces. From left to right are configurations with zero iodide displacement (i.e., iodide ions are bonded in the lattice) and iodide displacement to distances of 3 and 5 Å away from the perovskite surface, respectively. The mobile iodide and the most affected species, such as, the surface lead and the ammonium group (the nitrogen) of the molecule are highlighted in color pink, cyan and blue, respectively. **c**) Relative energies along the iodide diffusion path for molecules with n=0, 1 to 4.

Summary

Combining experimental characterization and theoretical modelling, we show that these molecules stabilize the perovskite through suppression of iodide ion migration. The stabilization effect is enhanced with increasing chain length due to the stronger binding of the molecules with the perovskite surface, as well as the increased steric hindrance to reconfiguration for accommodating ion migration. The passivation also reduces the surface defects, using the optimized passivation molecule, phenylpropylammonium iodide, we achieve devices with an efficiency of 17.5%, a radiance of 1282.8 W sr^{-1} m^{-2} and a T_{50} half-lifetime of 130 hrs under 100 mA cm^{-2}.

Acknowledgement

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1 Department of Electronic Engineering, The Chinese University of Hong Kong, Shatin, N.T. Hong Kong SAR, China
2 Materials Simulation and Modelling, Department of Applied Physics, Eindhoven University of Technology, 5600MB Eindhoven, The Netherlands
3 Center for Computational Energy Research, Department of Applied Physics, Eindhoven University of Technology, 5600 MB Eindhoven, The Netherlands
4 School of Electronic Science and Engineering, Xiamen University, Xiamen 361005, China
5 Biomolecular and Organic Electronics, Linköping University, S-581 83, Linköping, Sweden
6 Instrumental Analysis and Research Centre, Sun Yat-sen University, Guangzhou 510275, China
7 Computational Materials Science, Faculty of Science and Technology and MESA+ Institute for Nanotechnology, University of Twente, P.O. Box 217, 7500 AE Enschede, The Netherlands