

Highlights

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Correlation between Electronic Defect States Distribution and Device Performance of Perovskite Solar Cells

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In this study random current fluctuations, measured at different temperatures and for different illumination levels, are used to understand the charge carrier kinetics in methylammonium lead iodide $\text{CH}_3\text{NH}_3\text{PbI}_3$ -based perovskite solar cells. A model, combining trapping/detrapping, recombination mechanisms and electron-phonon scattering, is formulated evidencing how the presence of shallow and deeper band tail states influences the solar cell recombination losses. At low temperatures, the observed cascade capture process indicates that the trapping of the charge carriers by shallow defects is phonon assisted and directly followed by a recombination. By increasing the temperature, a phase modification of the $\text{CH}_3\text{NH}_3\text{PbI}_3$ absorber layer occurs and, for temperatures above the phase transition at about 160 K, the capture of the charge carrier takes place in two steps. The electron is first captured by a shallow defect and then it can be either emitted or thermalize down to a deeper band tail state and recombines subsequently. This result reveals that in perovskite solar cells the recombination kinetics is strongly influenced by the electron-phonon interactions. A clear correlation between the morphological structure of the perovskite grains, the energy disorder of the defect states, and the device performance is demonstrated.

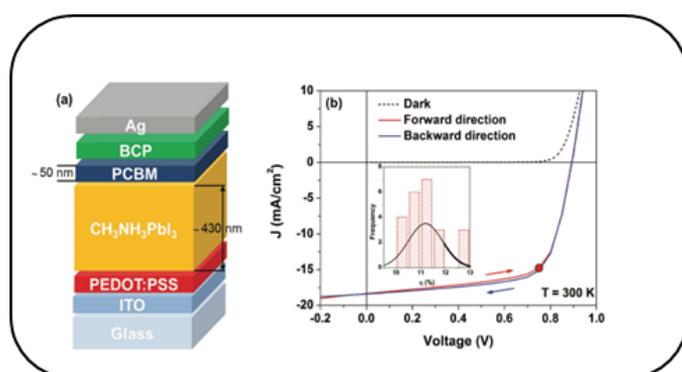


Fig.1: (a) Schematic illustration of the cross-section of the device structure. (b) Current density–voltage characteristics at 300 K in dark (dashed line) and under illumination (solid lines). The inset shows a histogram of the measured efficiency of 23 processed devices.

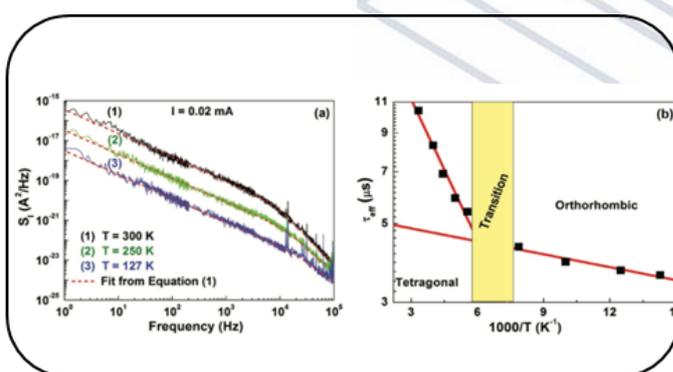


Fig.2: (a) Noise spectra of a perovskite photovoltaic device. (b) Arrhenius plot of the effective lifetime coefficient τ_{eff} . Two distinct behaviors are observed in the tetragonal and orthorhombic phases of the perovskite.