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## Oriented transition dipole moments for high-efficient perovskite light-emitting diodes

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Metal halide perovskite light-emitting diodes (PeLEDs) are regarded as alternative candidates for next-generation display technologies due to their high efficiency, superior color purity and tunable bandgap. However, PeLEDs based on isotropic perovskite emitting layers with randomly oriented emissive transition dipole moments (TDMs) remain to be inefficient to get upper limit efficiencies of planar PeLEDs. In general, horizontal emissive TDMs parallel to the device substrate are suitable for light out-coupling, while emitted light from vertical TDMs is mostly trapped in the device. Therefore, an emissive layer with high ratios of horizontal TDMs is expected to enhance the efficiency of PeLEDs. A high proportion of horizontal TDMs can be obtained by adjusting the thickness and crystal orientation of the perovskite film. Here, we mainly use grazing-incidence wide-angle X-ray scattering (GIWAXS) to study a series of additives, and explore the effect of additives on the crystal orientation of the two-dimensional perovskite films.

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