# Anisotropic Electronic State of $CsPbBr_3$ Cubic Colloidal Nanocrystals

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Perovskite nanocrystals (NCs) have attracted significant attention due to their exceptional optoelectronic properties and their potential applications in diverse fields. One of the challenging tasks is the selective modification of a specific crystal facet of cubic perovskite NCs because all six facets of the NCs are chemically equivalent. Here, we report the symmetry-broken electronic state of $CsPbBr_3$ perovskite NCs by their deposition onto surface-modified substrates and their anisotropic optical properties. We utilized a dip-coating technique to fabricate a self-assembled monolayer of $CsPbBr_3$ NCs on a quartz substrate. To modify the surface of the quartz substrate, silane-coupling agents were used. The silane-coupled layer was prepared by hydrolyzing 3-aminopropyltrimethoxysilane (APS) or trimethoxy(octadecyl)silane (TODS) on the quartz substrate (Figure 1a). Scanning electron microscopy (SEM) images revealed a densely packed monolayer arrangement of $CsPbBr_3$ NCs. APS-treated quartz substrate exhibits the highest coverage, reaching as high as 98% compared to untreated quartz substrate. In the $CsPbBr_3$ NCs monolayer film, four crystal facets perpendicular to the substrate are surrounded by the NC itself, while the other two facets are parallel to the substrate, with one facing the air and the other facing the substrate. Consequently, the symmetry of the cubic $CsPbBr_3$ NCs is disrupted in the in-plane and out-of-plane directions to the substrate. By angle-resolved absorption and photoluminescence (PL) measurements, peak shifts with varying detection angles are observed, indicating the formation of anisotropic electronic states of the cubic NCs in in-plane and out-of-plane directions to the substrate (Figure 1b). On the other hand, when the quartz substrate is treated with the long-chain alkylsilane coupling agent (TODS), the absorption and PL exhibit no angle dependence, suggesting the disappearance of the anisotropy. These results suggest that the symmetry of the electronic states in the cubic NCs can be controlled by the polarity of the underlying substrate.

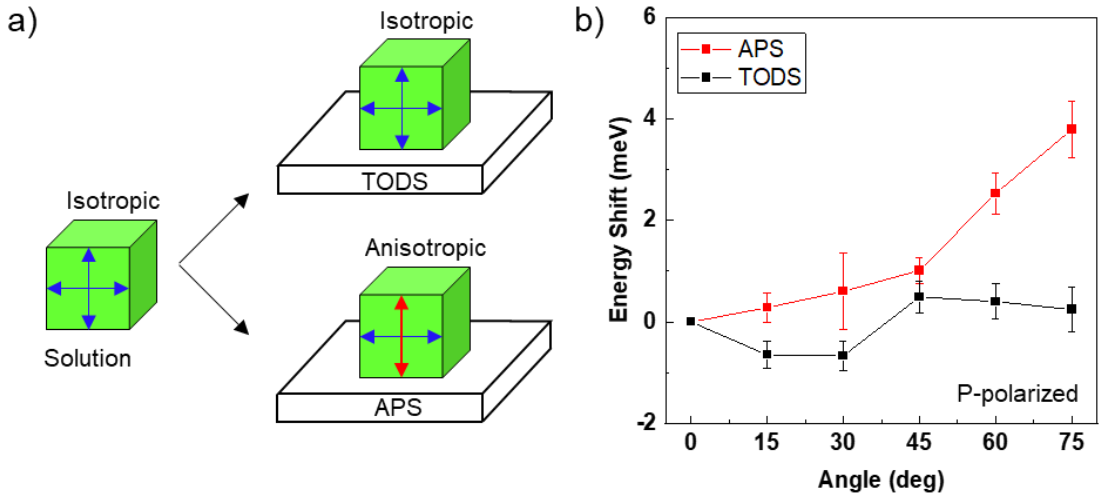


**Figure 1**. (a) Schematic of anisotropic electronic state of $CsPbBr_3$ NCs. (b) Angular dependence of UV absorption of the $CsPbBr_3$ NCs monolayer on APS and TODS treated substrate.