$CsPbX_3$ quantum dots/metal oxide inorganic nanocomposites with exceptional stability in water, light and heat

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In the last year, all-inorganic perovskite quantum dots ($CsPbX_3$ QDs with X=Br,I,Cl) have emerged as a new class of semiconductor nanocrystals with improved optical properties compared to the well-studied cadmium based QDs.[1,2] One of the issue that still remain to be addressed for implementation in optoelectronic devices and for the exploration of their properties under ambient conditions is the lack of stability with respect to temperature, moisture and light exposure. We have successfully developed a low temperature atomic layer deposition process for the deposition of a thin layer of metal oxide (MO) on a film of $CsPbBr_3$ QDs that 1) protects the perovskite QDs from water and high temperature and 2) prevents dissolution of the bottom layer or anion exchange in a multi-layering process.

First we focused on developing a protection scheme with amorphous alumina obtaining $CsPbBr_3$/AlOx inorganic nanocomposite. The structural analysis of the obtained nanocomposite was conducted by different electron microscopy techniques (STEM-HAADF, EDX, EELS) as shown in Fig.1. The combination of these techniques allowed us to confirm the complete infilling of allumina for the entrire thickness of the nanocmposite films. The latter show exceptional stability against exposure to air (over 50 days), to irradiation under simulated solar light (over 10 hours), to thermal treatment (up to 200ºC in air), and finally to immersion in water (up to a few hours) (Fig.1).[3] However ALD alumina is susceptible to hydrolysis by long term exposure to water, particularly for films deposited at low temperature. With this in mind, we are exploring the possibility to further improve the long-term stability of $CsPbBr_3$ QD film by fabricating ALD nanolaminates, specifically alumina/zirconia.[4]

The development of a general protection scheme for $CsPbX_3$ QDs is expected to impact the field tremendously by enabling fundamental studies, such as exciton diffusion transport, which require the sample to be stable during the measurements performed in air, or of size-dependent phase transitions, where decoupling of size and sintering effects is necessary. Furthermore, once stable, the implementation of these QDs in solar-driven water splitting and CO2 reduction can be foreseen.

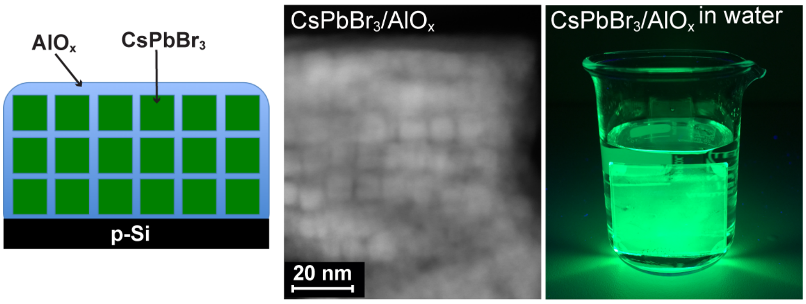

Fig. 1 From left to right: Schematic rapresentation of $CsPbBr_3/AlO_x$ nanocomposite realized in this work. Cross-sectional STEM-HAADF image of a typical nanocomposite. Photographs taken under UV illumination (λ=365 nm) after 1 h of soaking in water.

1) D. Bera, *et al., Materials,* **2010**, 3, 2260.
2) L. Portesecu, *et al., Nano Letters*, **2015**, 15, 3692.
3) A. Loiudice *et al.,* submitted.
4) A. H. Ip *et al.*, *Appl. Phys. Lett.*, **2013**, 103, 263905.