



OPEN

## Optical, electrochemical and photocatalytic properties of cobalt doped CsPbCl<sub>3</sub> nanostructures: a one-pot synthesis approach

Aadil Ahmad Bhat<sup>1</sup>, Shakeel Ahmad Khandy<sup>2✉</sup>, Ishtihadah Islam<sup>3</sup> & Radha Tomar<sup>1</sup>

The present manuscript aims at the synthesis of cesium based halide perovskite nanostructures and the effect of cobalt doping on the structural, optical, luminescent, charge storage and photocatalytic properties. In a very first attempt, we report the solvothermal synthesis of Co doped CsPbCl<sub>3</sub> nanostructures under subcritical conditions. The structural features were demonstrated by X-ray diffraction (XRD) Surface morphology determined cubic shape of the synthesized particles. Doping is an excellent way to modify the properties of host material in particular to the electronic structure or optical properties. Incorporation of Co<sup>2+</sup> ions in the perovskite structure tunes the optical properties of the nanostructures making this perovskite a visible light active material (E<sub>g</sub> = 1.6 eV). This modification in the optical behaviour is the result of size effect, the crystallite size of the doped nanostructures increases with cobalt doping concentration. Photoluminescence (PL) study indicated that CsPbCl<sub>3</sub> exhibited Blue emission. Thermogravimetric analysis (TGA) revealed that the nanostructures are quite stable at elevated temperatures. The electrochemical performance depicts the pseudocapacitive nature of the synthesized nanostructures and can be used for charge storage devices. The charge storage capability showed direct proportionality with cobalt ion concentration. And Finally the photocatalytic performance of synthesized material shows superior catalytic ability degrading 90% of methylene blue (MB) dye in 180 min under visible light conditions.

Perovskite nanostructures have revolutionized the power generation capacity of Solar plants because of their vibrant functionalities in solar cell and engineering technologies. Metal Halide Perovskites (MHP) are initially used as sensing materials for solar cells which have capability of retaining high charge transport properties<sup>1,2</sup>. The capping agents used for the synthesis of metal halide perovskite control the growth of the nanostructures. It is possible to tune the size and shape of nanomaterial so that the synthesis of bulk nanocrystals as well as nanostructures like nanowires, nanosheets and quantum dots is achieved<sup>3,4</sup>. A little bit overview of the nanocrystal size can be tuned not only during the synthesis but also by post synthesis transformation via ion exchange reaction mechanism<sup>5,6</sup>. However, Cesium based halide perovskite are considered to be the most reliable materials for perovskite solar cells (PSC), light emitting diodes (LED's) and photo detectors due to their higher thermal stability in comparison to the hybrid perovskites<sup>7,8</sup>. The performance of displaying tuneable band gap and large diffusion length along with large life time specify their valuable characteristics. These striking properties are mostly depend upon the size and morphology of the nanomaterial. Abundant attempts had been put forward to improve the efficiency and stability of Metal halide perovskite by doping various transition, post transition or lanthanoids elements for energy harvesting device applications<sup>9,10</sup>. Doping is an excellent way to modify the inherent optical, magnetic and electronic properties of the host material<sup>11,12</sup>. The photoluminescence quantum yield reaches upto 90% for CPbBr<sub>3</sub> and CsPbI<sub>3</sub>, which display green and red emission, respectively<sup>13,14</sup>. CsPbCl<sub>3</sub> has nearly 100% PL quantum yield on incorporating Cd ions in its structure<sup>15</sup>. Various transition metal and lanthanoids were reasonably doped in CsPbCl<sub>3</sub> to reduce the non radiative defects and toxicity of nanomaterial<sup>16,17</sup>. From the last several years various number of metals including Mn<sup>2+</sup>, Zn<sup>2+</sup>, Ti<sup>2+</sup> and also lanthanoids elements such as Ce<sup>3+</sup> and Yb<sup>3+</sup> have

<sup>1</sup>School of Studies in Chemistry, Jiwaji University, Gwalior, M.P 474011, India. <sup>2</sup>Department of Physics, National Taiwan University, Taipei 10617, Taiwan. <sup>3</sup>Department of Physics, Jamia Millia Islamia, New Delhi 110025, India. ✉email: shakeelkhandy11@gmail.com