Electronic Supplementary Information (ESI)

Mechanism of Non-Catalytic Chemical Vapor Deposition Growth of All-Inorganic $CsPbX_3$ (X=Br, Cl) Nanowires

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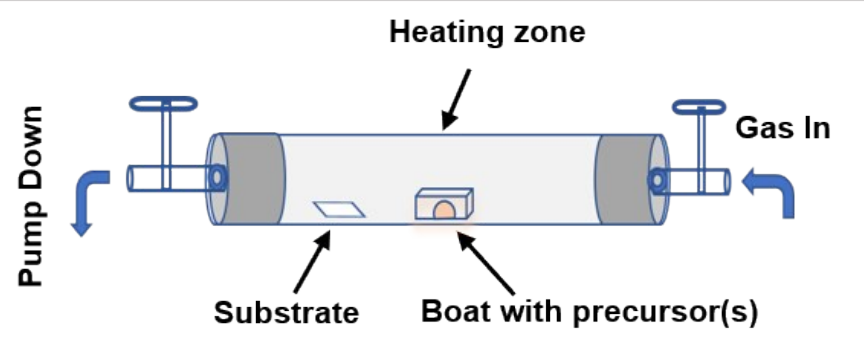

Fig. S1 Schematic diagram of the chemical vapor deposition (CVD) setup used for growing all-inorganic $CsPbX_3$ (X = Br, Cl) NWs in the non-catalytic chemical vapor deposition (NC-CVD) synthesis.

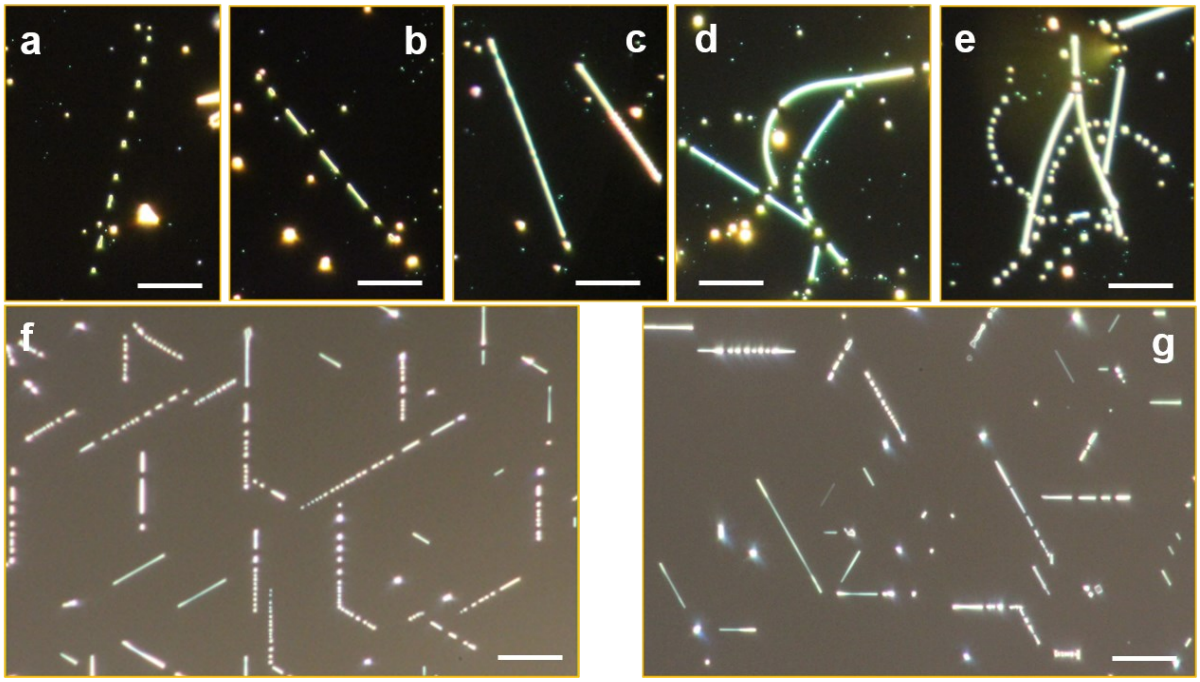

Fig. S2 Dark field (DF) optical microscopy images showing self-assembly of the all-inorganic $CsPbBr_3$ particles in growing $CsPbBr_3$ nanowires (NWs) in the non-catalytic chemical vapor deposition (NC-CVD) synthesis. NWs' growth on (a-e) SiO_2/Si and (f-g) c-Al_2O_3 substrates. Scale bar is 20 µm.

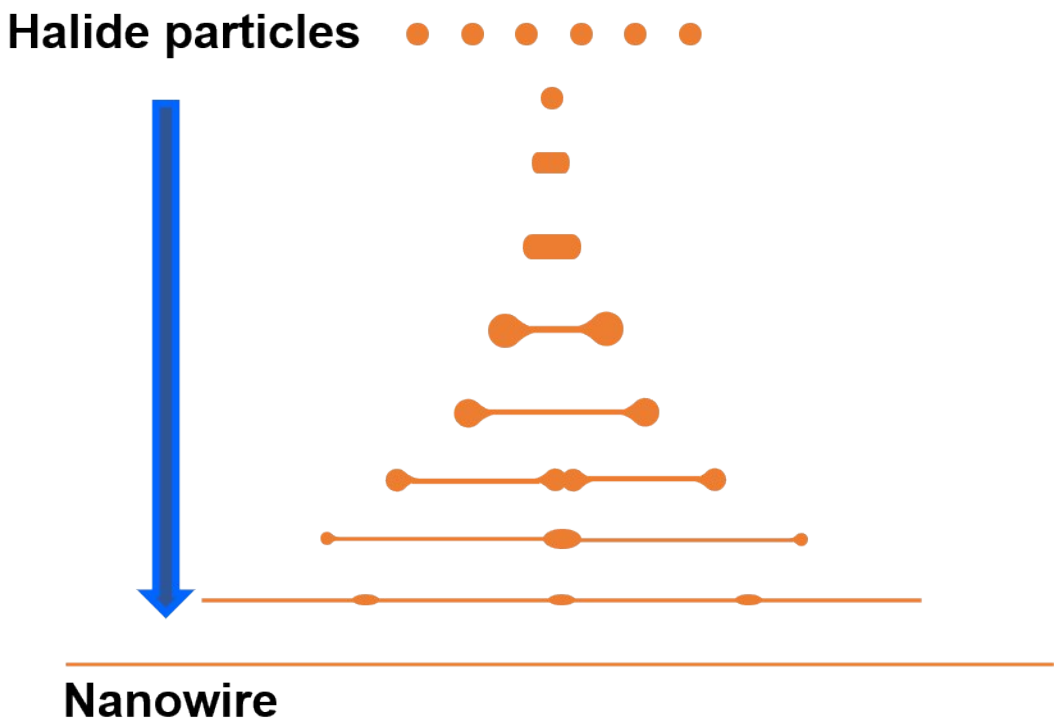

Fig. S3 A schematic illustration of the steps involved in the self-assembly mechanism in the non-catalytic chemical vapor deposition (NC-CVD) synthesis of all-inorganic $CsPbX_3$ (Br, Cl) nanowires.

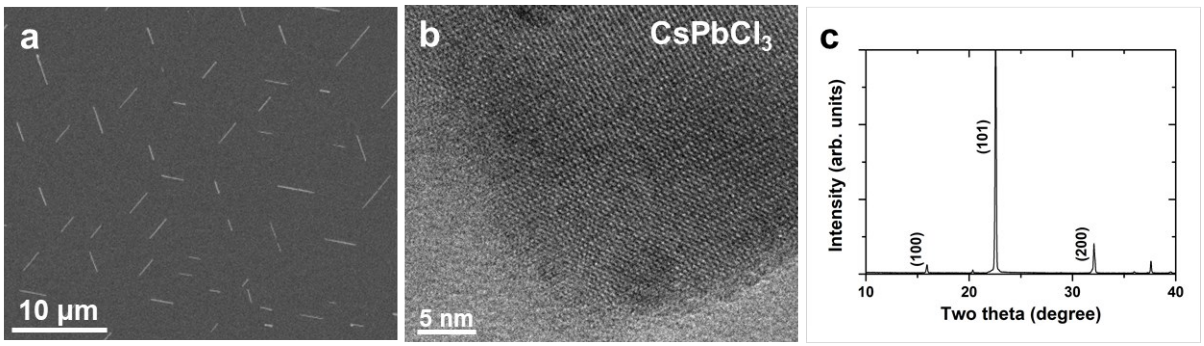

Fig. S4 Morphology and Microstructural analysis. (a) Field emission scanning electron microscopy (FESEM) image of $CsPbCl_3$ NWs grown on c-Al_2O_3. (b) HRTEM image and (c) X-ray diffraction spectra of $CsPbCl_3$ NWs grown on c-Al_2O_3.

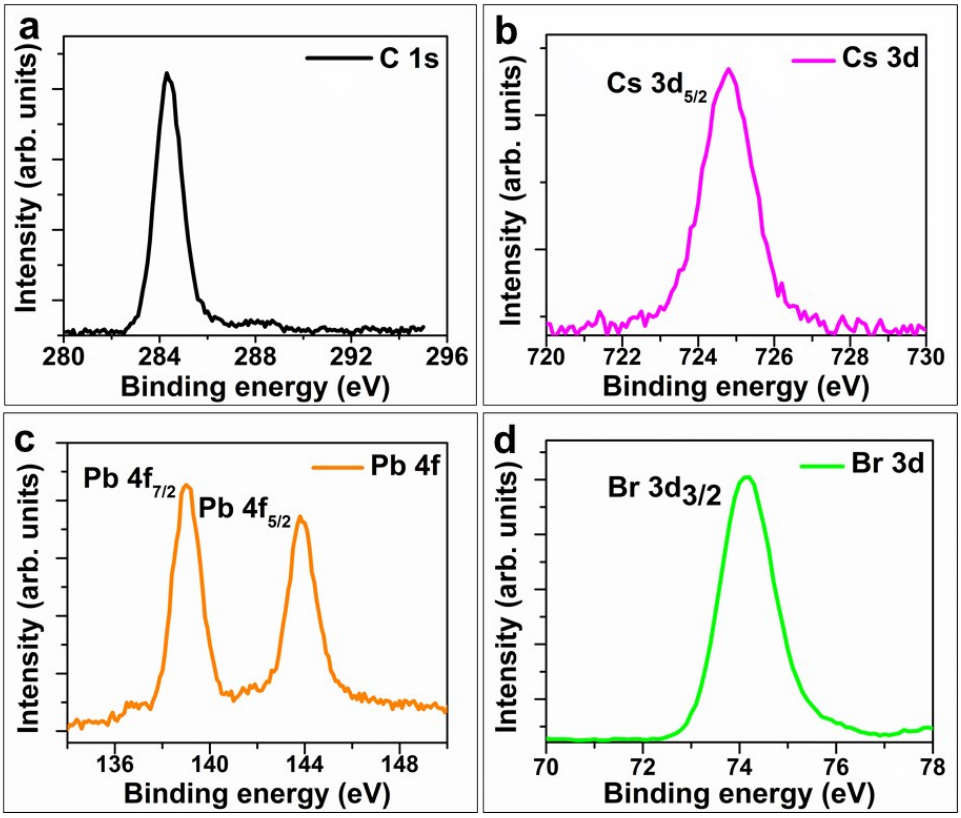

Fig. S5 High resolution X-ray photoelectron spectroscopy (XPS). (a) Calibration spectrum of C 1s. The core level spectra of (b) Cs $3d_{5/2}$; (c) Pb $4f_{7/2}$ and Pb $4f_{5/2}$; and (d) Br $3d_{3/2}$ obtained from a self-assembled $CsPbBr_3$ perovskite nanowire grown by the non-catalytic chemical vapor deposition (NC-CVD) process.

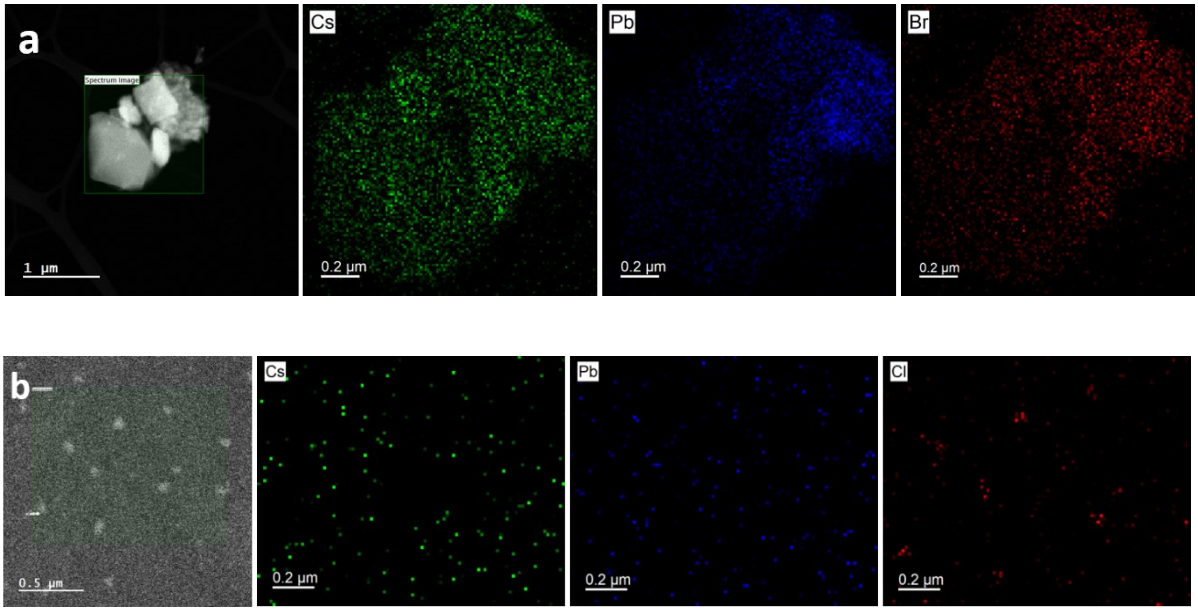

Fig. S6 Energy dispersive X-ray spectroscopy (EDS) maps showing the distribution of various elements in $CsPbX_3$ (X = Br, Cl) NWs. These elemental maps were taken in a TEM (a) A dark field image of $CsPbBr_3$ structures drop casted on C coated Cu grid and corresponding elements maps (b) A TEM image of $CsPbCl_3$ structures drop casted on C coated Cu grid and the corresponding elements maps.

Here, it is important to mention that the NWs were found to be very sticky on the Al_2O_3 substrates and was very difficult to transfer a complete NW structure. Therefore, EDS studies were performed on the structures available on the copper (Cu) grid obtained from the drop casting of the sonicated extracts of the self-assembled $CsPbBr_3$ and $CsPbCl_3$ NWs grown on sapphire followed by a hot plate drying.

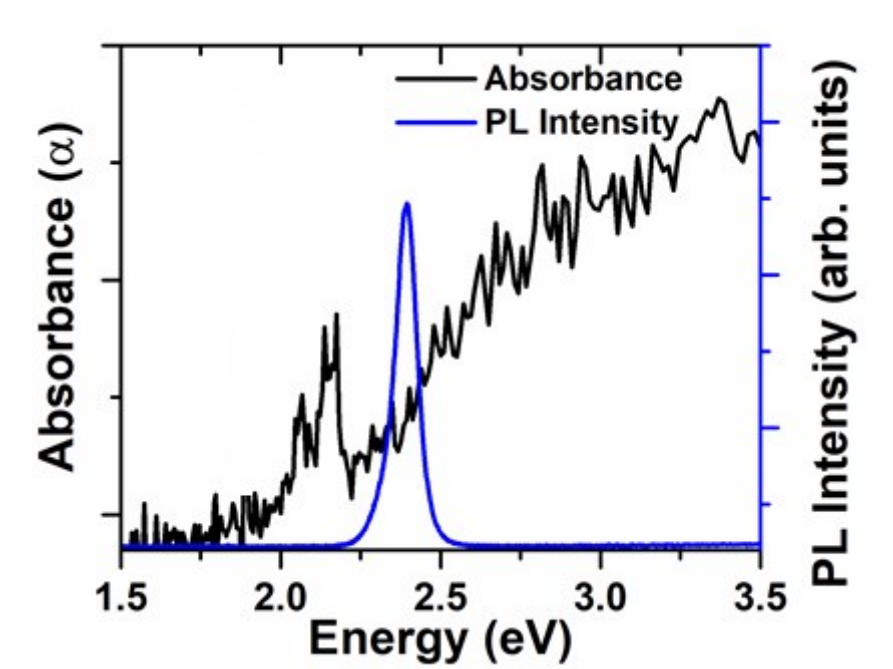

Fig. S7 Room temperature absorbance and photoluminescence spectra of $CsPbBr_3$ NWs grown on c-Al_2O_3. The close proximity of the absorption edge and the PL peak indicates that the PL emission corresponds to the band edge emission of the self-assembled $CsPbBr_3$ NWs.

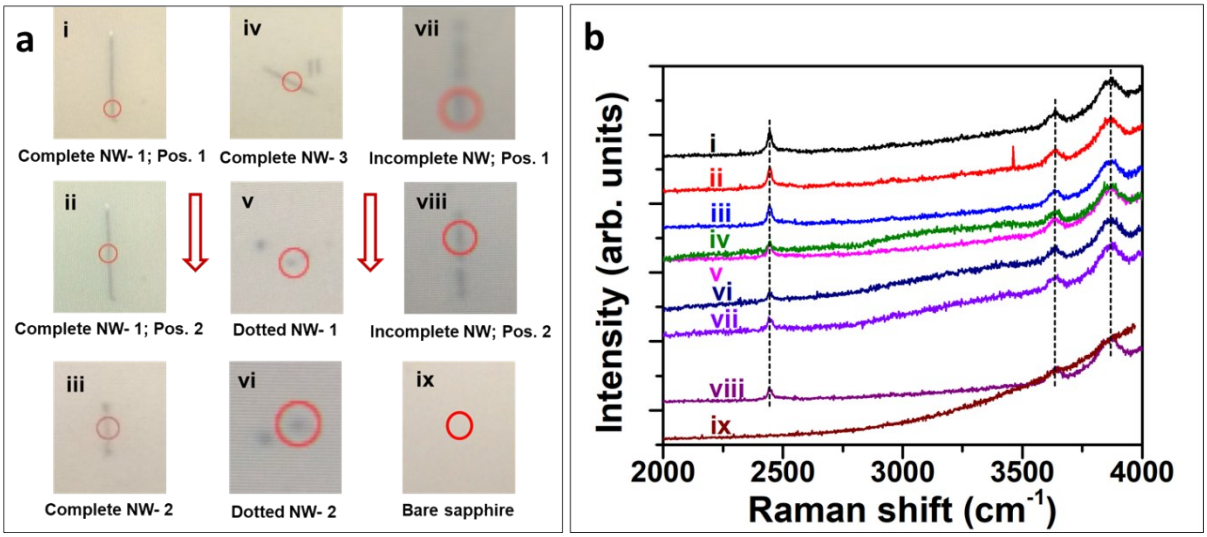

Fig. S8 Confocal micro-Raman characterization of various morphological features of self-assembled $CsPbBr_3$ halide perovskites. (a) Low resolution camera images of the studied $CsPbBr_3$ structures including complete nanowires, dots and incomplete nanowires; (b) the corresponding Raman spectra. No spectral shift is observed for the various structures under investigations showing their crystalline homogeneity.

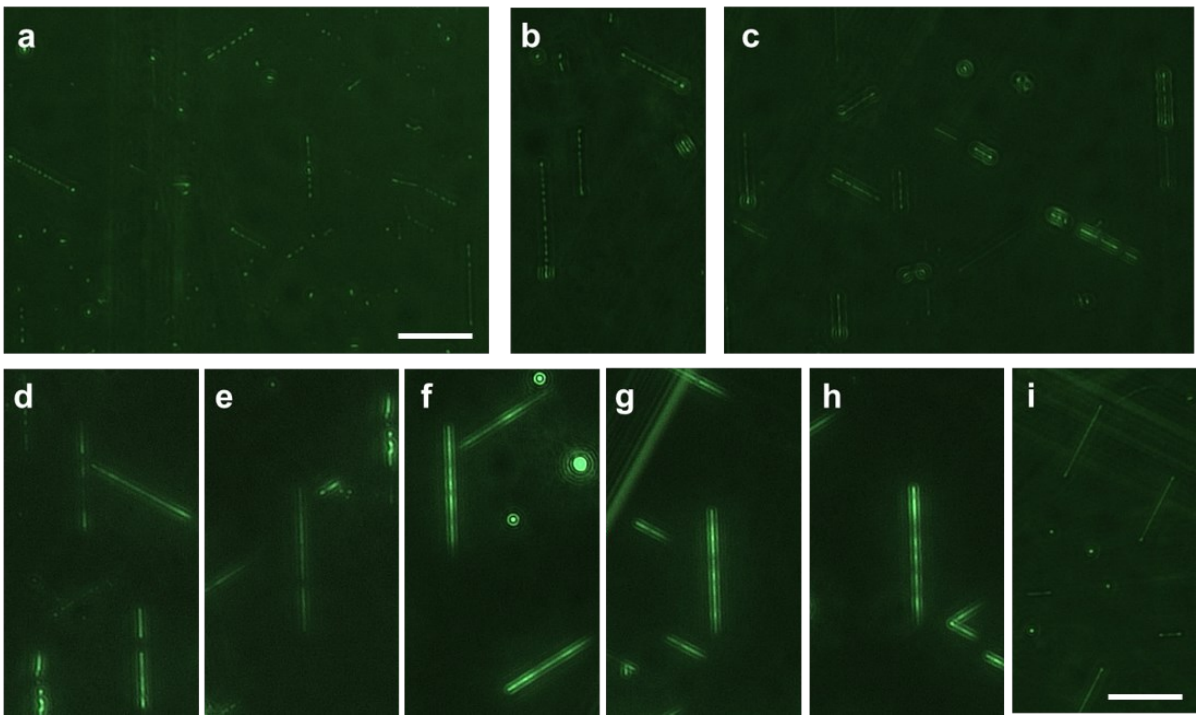

Fig. S9 Fluorescence microscopy images obtained from a Nikon ECLIPSE TS 100. (a-i) Different stages of self-assembly process of the $CsPbBr_3$ nanowire formation. Nanowires are grown on c-plane sapphire by non-catalytic chemical vapor deposition (NC-CVD) method. Same fluorescence from $CsPbBr_3$ dot like spherical halide particles, incomplete/ fragmented

nanowires and complete nanowires resembles the same material composition in all different nanoscale features. Difference in the fluorescence intensity may arise from the size and thickness of the structures. Scale bar (a-c) 50 µm and (d-i) 10 µm.

Verification of Surface Guiding or Graphoepitaxial Effect of c-Al_2O_3 on Halide NWs Growth

Surface guiding and graphoepitaxial effects have been reported for the vapor growth of IHP NWs on sapphire substrates.[1-3] Following the faceted growth of $CsPbCl_3$ and $CsPbBr_3$ NWs on c-Al_2O_3, we performed a systematic study to see if there is any surface guiding or graphoepitaxial effect of the sapphire substrate on the faceted growth of the halide nanowires. Two pieces of cleaned sapphire substrates were annealed at the same CVD growth environment maintaining the same maximum growth time (60 mins) and temperature (500°C), similar to those for halide nanowires growth. AFM measurement was performed on the sapphire substrates just before and after annealing. No morphological change with any nanogroove was noticed on the substrates. This confirms that there was no guiding or graphoepitaxial effect on growing the NWs on c-Al_2O_3 substrate. The self-induced assembly of the halide particles was, therefore, taken place following the inherent hexagonal crystal facets of the c-Al_2O_3 substrate.

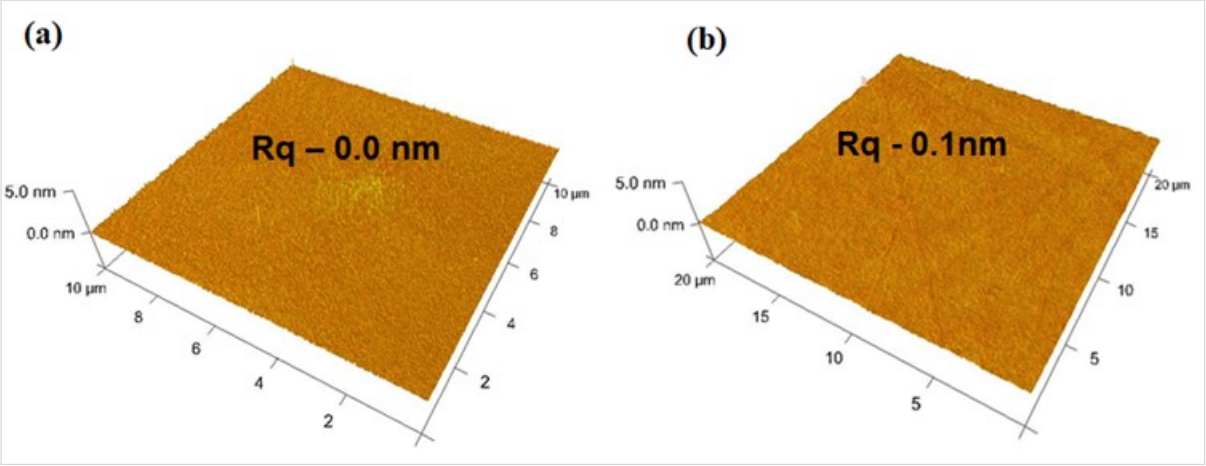

Fig. S10 AFM measurements of clean-bare sapphire substrate- (a) before annealing and (b) after annealing. Annealing was performed using the same time (60 min) and temperature (500ºC) as that of the NC-CVD growth of $CsPbX_3$ NWs.

References

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