New Results on Optical, Crystallographic and Morphological Properties of CsI Photocathode

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Introduction

Alkali halide materials are of technological importance due to their excellent electron-emitting properties in the ultraviolet (UV), vacuum ultraviolet (VUV), extreme ultraviolet (EUV) and X-ray energy ranges. Among alkali-halide photocathodes, CsI is the best choice, owing to its high quantum efficiency (QE) in the VUV wavelength range [1, 2]. Due to the importance of CsI photocathodes, several thin film preparation methods, such as thermal evaporation [3], ion beam sputtering [4], pulsed laser deposition [5], are used to study the various physical and chemical properties of CsI. However, it has been observed that the thermal evaporation is the best choice forming a stoichiometric Cs:I ratio [6] as well as the highest absolute quantum efficiency (QE) compared to other preparation techniques. In the present work the optical absorbance and transmittance have been investigated by UV-Vis, the structural properties have been studied by XRD and the morphological analysis has been done by AFM.

Experimental Setup

CsI thin film of 500 nm thickness was prepared by using thermal evaporation technique. Deposition was done on quartz and stainless steel substrates. The substrates were cleaned by water then by alcohol after that by acetone. Tiny amount of CsI powder of 5N purity from alfa aeser has been placed into the tantalum (Tu) boat. The distance between substrate and Tu boat was kept about 20 cm. The residual gas analyzer (SRS RGA 300) monitored the water vapor and other residual gases inside the chamber, when the vacuum was $1*10^{-6}$ Torr inside the chamber, the boat heated carefully to allow outgassing from the outer surface of the crystals to start deposition. The deposition rate was between 1nm to 2nm per second. The thicknesses of the film and deposition rate were controlled by a quartz crystal thickness monitor (Sycon STM 100). Immediately after preparing the film, nitrogen N_2 gas was purged inside the chamber, in order to protect the prepared samples from the interactions with atmospheric air, then the samples extracted directly to the vacuum desiccator to transfer it to the characterization setup. The optical properties of CsI thin film was carried out in the UV-Vis measurement by a Perkin Elmer UV/Vis spectrometer (model: λ-25) in the wavelength 190-900 nm. The crystallographic studies were performed by X-ray diffraction technique (XRD) in the Bragg-Brentano para focusing geometry using PAN alytical X Pert PRO XRD system. In order to study the surface morphology, Atomic Force Microscopy (AFM) was used. The AFM scanning was done by NEXT ND-MDT atomic force microscope, which provides a high resolution two dimensional (2-D) and three dimensional (3-D) surface images.

Optical Properties

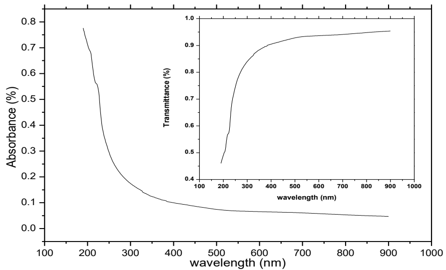
The Optical properties of 500 nm CsI thin film was measured in the range 190-900 nm by UV-Vis spectrophotometer. The film has been deposited on quartz substrate due to it's transparency in this spectral range. Fig (1) shows the absorbance and transmittance (inset image) of the film "as deposited" CsI film. It is observed that the absorbance various between 0-0.8 in the UV spectral range and the absorbance decreases with increasing the wavelength. The transmittance (T) has been calculated by using the formula **T= exp(-A)** where A is the absorbance of the film [7]. It is observed that, 500 nm thick CsI film is almost transparent in the visible spectral range and having transparency more than 90 %.

Structural Properties

In order to investigate the structural properties and the orientation of 500 nm thick CsI film deposited on stainless steel substrate, X-Ray Diffraction technique (XRD) has been used. Fig (2) shows the typical XRD pattern that indicates the CsI thin film is purely crystalline in nature due to the sharpness of the peaks. The most intense peak is found at Bragg's angle 2θ=27.8 corresponds to (110) crystallographic plane and also four other XRD peaks are found at Bragg's angles 2θ= 48.97, 57.14, 71.7 and 78.36 assigned to (211), (220), (222) and (321) crystallographic planes respectively attributed a body center cubic (bcc) structure.

Morphological analysis

The surface morphology of 500 nm thick CsI film deposited on stainless steel substrates has been studied by AFM technique. In order to observe the surface morphology of CsI film, few regions were scanned; one of them is shown in Fig (3) which has topological scale (5*5) µm because it has better resolution as compared to higher order scale (10*10) µm or (20*20) µm. The morphology shows granular structure with having an average roughness of about 16.09 nm, and average grain size about 627 nm.



Fig(1) The optical absorbance and Transmittance(inset) of 500 nm thick CsI film

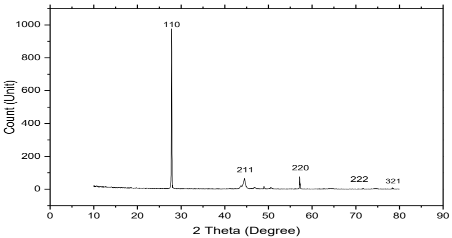


Fig. 2. The XRD pattern of 500nm thick CsI film deposited on stainless steel substrate.

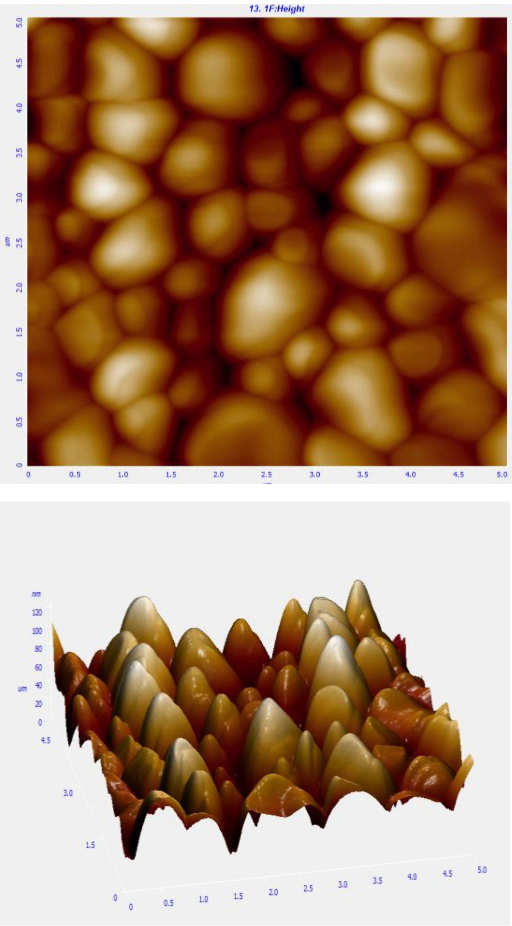


Fig (3) 2D (top image) and 3D (bottom image), AFM image of 500 nm thick CsI film

References

[1] A. Breskin, Nucl. Instrum. Methods A 387, 1 (1997).
[2] A. Breskin, Nucl. Instrum. Methods A 367, 326 (1995).
[3] V. Dangendorf, et al., Nucl. Instrum. Methods A 289, 322 (1990).
[4] M.A. Nitti, et al., Appl. Phys. A 80, 1789 (2005).
[5] S.B. Fairchild, et al., J. Vac. Sci. Technol. A 29, 031402 (2011).
[6] B.K. Singh, et al., Nucl. Instrum. Methods A 610, 350 (2009).
[7] C. Lu, et al., Nuclear Instruments and Methods in Physics Research A 343 (1994).