Structural study of CsI photocathode under impact of humidity

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Introduction

In the recent past, the interest with Alkali Halides (A-H) thin films has been increased due to their potential use as a photocathode in particle detectors using the Ring Imaging Cherenkov Technique [1]. Out of these A-H materials, CsI is the most preferred one because of its high Quantum Efficiency (QE) [2]. However, very few of the earlier studies in this field deal with characterization of CsI film structure. In this work, we have studied the impact of humidity on the CsI film structure.

Experimental Setup

The film deposition takes place in a high vacuum 18" diameter stainless steel evaporation chamber. In this work, the deposition has been done on a polished Stainless steel (S.S) substrate. A small amount of CsI powder from ALFA ASER has been added to a tantalum (Ta) boat. The Ta boat is kept away from the sample holder about 20 cm. A turbo-molecular pump (model : TMU 521 P, Pfeiffer) having a pumping speed of 510L/s for N2 gas has been used to creat a high vacuum about 5×10^{-7} Torr. The residual gas analyzer (SRS RGA 300) has been used to monitor the residual components inside the vacuum chamber. In order to start deposition, the Ta boat has been heated carefully by applying a high current. The rate of evaporation is kept at 1-2 nm/sec. The required film of thickness 100 nm was deposited on the substrate with the deposition rate being controlled by the quartz crystal thickness (Sycon STM 100). After the CsI film preparation, the chamber was opened under a constant flow of dry nitrogen (N_2) gas in order to avoid the interaction of CsI film with water present in the humid air. Immediately, the freshly evaporated CsI thin film is extracted and placed into a vacuum desiccator, containing fresh silica gel, for its transport to the XRD characterization setup.
The crystallographic studies have been performed by X-ray diffraction technique (XRD) in the Bragg-Brentano para focusing geometry using PAN alytical X Pert PRO XRD system. The incident beam optics consists of a CuKα radiation source (λ= 1.5406 Å) and a nickel (Ni) filter. XRD measurements have been performed in continuous scan mode in the range $2\theta = 10^\circ - 80^\circ$ for both cases; "as deposited" and "humid air aged".

Structural Properties

Fig. 1 shows the XRD patterns of CsI film in case of "as deposited" and "humid air aged". In both cases the most intense peak (110) followed by (220). One can notice the sharpness in XRD peaks of CsI film, which indicates to its crystalline nature. The intensity of the appeared peaks has been increased after exposing to humidity. Also, all the appeared peaks are attributed to body center cubic (bcc) structure. The lattice plane (110) corresponds to Bragg's angle at $2\theta \sim 27.81^\circ$ *and* 27.77° in case of "as deposited" and "humid air aged" respectively. The lattice plane (220) appeared at $2\theta \sim$

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57.14° in case of "as deposited" and at $2\theta \sim$ 57.11° in case of "humid air aged".

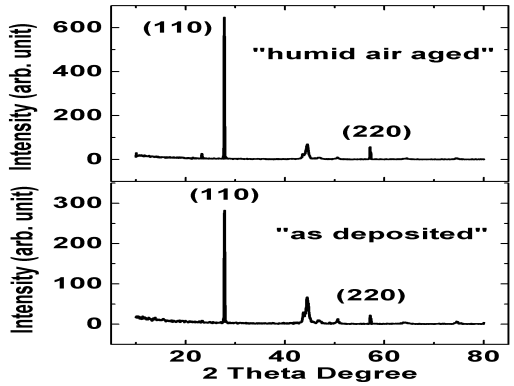

FIG. 1: XRD pattern of 100 nm thick CsI film, in case of "as deposited" and "humid air aged".

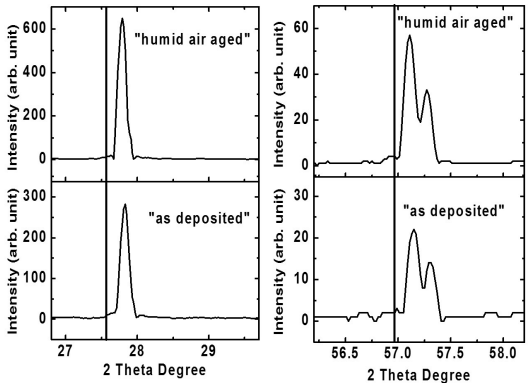

FIG. 2: Shifts in the (110) (left panel) and (220) (right panel) peaks as compared to a single crystal shown with sharp solid line before and after aging.

The peak position of (110) and (220) lattice planes matches with those listed in JCPDS card number 060311 ($2\theta\, of\, (110) = 27.59^o$, $2\theta\, of\, (220) = 56.97^o$), but with small shift to the right (higher angles of 2θ), see Fig. 2. The shift to the right indicates a decrease in d-spacing which means compressive stress acting in the film. These stresses acting in the film appears due to the difference methods of film preparation and can cause significant effects on the properties of the materials.

The d-spacing of a single crystal as reported in JCPDS (d_{stand}) and the calculated one (d_{exp}) can be used to determine the stress in the films as it is illustrated in equation (1):

$$\mathbf{stress} = \frac{\mathbf{\Delta d}}{\mathbf{d}} = \frac{\mathbf{d_{exp} - d_{stand}}}{\mathbf{d_{exp}}} \qquad (1)$$

The crystallite size (D) of CsI film has been calculated using the classical scherrer's formula as in equation (3) [3]:

$$\mathbf{D} = \frac{\mathbf{k}\ \lambda}{\beta\ \cos\theta} \qquad (2)$$

where k is the shape factor (0.89), λ is the X-ray wavelength, β is the full width at half maximum and θ is the Bragg's angle. The quantitative values of stress and crystallite size are tabulated in Table 1. It can be noticed that the crystallite size has been increased after exposing to humid air for (110) lattice plane and decreased for (220) lattice plane. This can be explained by the inverse relation between the crystallite size (D) and full width at half maximum (β). Furthermore, the stress has been decreased after exposing to humidity.

TABLE I: Values of stress, crystallite size and FWHM of "as deposited" and "humid air aged" (shown in brackets) CsI film analyzed by XRD.

(hkl)	Stress ($\times 10^{-4}$)	D (nm)	FWHM (Degree)
(110)	69.77	82.25	0.0984
	(57.26)	(137.16)	(0.0590)
(220)	27.25	124.25	0.0720
	(22.02)	(93.17)	(0.0960)

References

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