Influence of humidity on KBr photocathode

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Introduction

Alkali halide photocathodes are persistently employed as a photo converter in the far ultraviolet (FUV) and soft X-ray spectral ranges. In particular, Potassium Bromide (KBr) is a good choice in the astrophysics experiments such as FUSE (The Far Ultraviolet Explorer) [1] and the extreme ultraviolet (EUV) spectrometer SUMER [2]. The sensitivity of KBr in the FUV region (<160 nm) improves the ability to reject sources of radiation and background near ultraviolet (UV) wavelength. These properties of KBr are also advantageous for soft X-ray instruments [3]. Although KBr photocathodes are less sensitive to heating and UV irradiation [4], but in the presence of moisture, its photoemissive and morphological characteristics have been altered. Therefore, in present work, the effect of humidity on photoemissive, structural and morphological properties of KBr photocathode have been investigated in detail.

The KBr film of 300 nm thickness was deposited on aluminum (Al) discs by the thermal evaporation technique, in a high vacuum environment ($4 \times 10^{-7} Torr$). The water vapor and other residual contaminants inside the chamber were monitored by a residual gas analyzer (SRS RGA 300) before the sample preparation. KBr powder of 5N purity (Alfa Aesar) evaporated with the rate of ≤ 2 nm/sec from tantalum boat. The distance between evaporation source and disc was kept about 20 cm. Thickness of the films was monitored by a quartz crystal based thickness monitor (Sycon STM-100). After film preparation, the chamber was purged with dry N_2, in order to ensure the minimum contact with atmospheric air during the sample transfer. Further, these films were placed into vacuum desiccator and transported to photoemissive, structural and morphological measurements setup.

Photocurrent of "as-deposited" and "humid air aged film" (from 1 hour to 9 hours) was measured in the spectral range of 110 nm to 160 nm, using vacuum ultra violet (VUV) monochromator (model: 234/302 VUV monochromator from McPherson), with base pressure 1.73×10^{-4} Torr. The variation of photocurrent (on wavelengths $\lambda = 125$ nm, 131 nm, 138 nm, and 144 nm) is shown in FIG.1. We observed that the photoelectron yield of KBr photocathode has been decreased with exposure to humidity (relative humidity 75%).

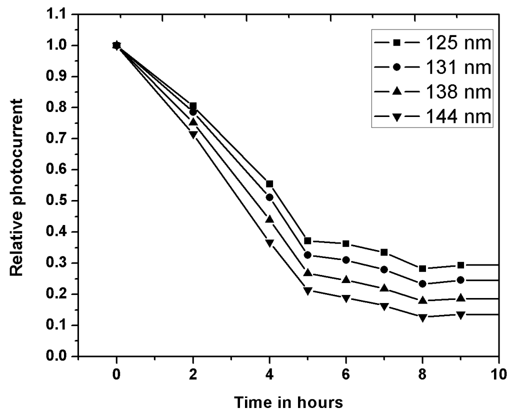

FIG. 1: Degradation in relative photocurrent as a function of time with humid air exposure on wavelengths 125 nm, 131 nm, 138 nm and 144 nm for 300 nm thick KBr film.

This detrimental effect was observed due to hygroscopic nature of KBr. When KBr film comes into contact with moisture, strong attractive force between polar water molecules and the ionic KBr crystal is formed. Due to polar nature of water molecules, it attracts more molecules and accumulated over the film surface, in which the KBr dissolves. The degradation of photoemissive properties is more pronounced due to the solubility of alkali halides in water [5].

In order to examine the crystallographic nature of KBr film, X-ray diffraction (XRD) technique has been adopted. The XRD line profile data is recorded in continuous scan mode ($2\theta = 10^0$-85^0) using X'Pert PRO $\theta/2\theta$ (PANanalytical) diffractometer in the Bragg- Brentano parafocusing configuration with CuKα (λ=0.15406 nm) radiation. To minimize the instrumental contribution in XRD line broadening, diffractometer has been calibrated with standard silicon (Si) crystal. The XRD pattern (FIG.2) exhibit sharp peaks, which attributes to crystalline nature of KBr film. The most intense peak corresponds to (200) crystallographic plane at $2\theta = 27.1453$, followed by (400) and (440) at $2\theta =$

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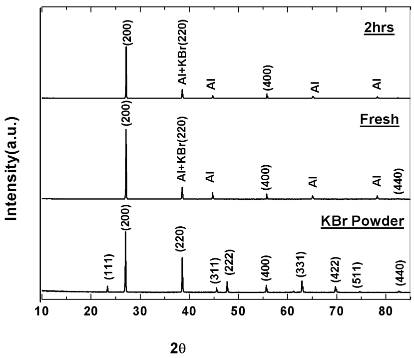

FIG. 2: XRD pattern of "as-deposited", "2 hours humid air aged" 300 nm thick KBr film deposited on Al disc and of KBr powder.

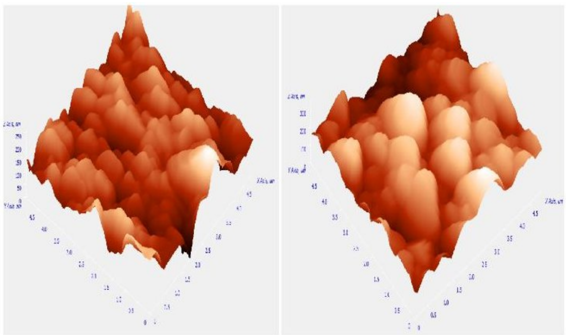

FIG. 3: 3-Dimentional atomic force microscopy (AFM) image of "as-deposited" (left panel) and "2 hours humid air exposed" (right panel) of KBr thin film photocathode.

55.7677 and 82.4375 respectively. These peak positions are matched with ASTM card data (PDF no.-730831).

The value of lattice constant, in case of "as-deposited" and aged film, is obtained and comes out to be about 6.57016 Å, 6.56372 Å respectively. We also observed that intensity of peaks has been decreased with ageing. The average crystallite size, corresponding to most intense peak (200), is calculated by Scherrer relation [6]:

$$D = \frac{k\lambda}{\beta_{hkl} cos\theta} \quad (1)$$

where D is the crystallite size, k is a shape factor(0.9), λ is the wavelength of CuKα radiation, β_{hkl} is full width at half maximum (FWHM) of particular peak and θ is the diffraction angle. The average crystallite size has been increased from 69 nm ("as-deposited" film) to 83 nm (after 2hour exposure to humid air).

The morphological study was done by atomic force microscopy (AFM) Technique. The AFM images of "as-deposited" and "2 hours humid air aged" (relative humidity 75%) film are shown in FIg.3. It is observed that average grain size has been increased from 332 nm to 477 nm in the case of aged film. This effect may be arisen due to coalescence process due to humid ageing, in which neighboring grains are merged and form a bigger grain. Further, average peak to valley height decreases while, root mean square (rms) roughness increases with humid ageing.

In summary, Photoemissive and crystallographic properties of "as-deposited" and "humid air exposed" KBr photocathode has been investigated. It is found that Photocurrent of KBr photocathode is decreased, once film is exposed to humid air. The degradation in photocurrent is observed due to interaction of KBr molecules with polar water molecules. XRD patterns of "as-deposited" as well as "humid air exposed" KBr thin film photocathode, show a most intense peak at (200) crystallographic plane followed by two other peaks at (400) and (440) plane, indicating a crystalline face centered cubic (FCC) structure. The average crystallite size was estimated from well known Scherrer's formula. The average crystallite size of "2 hours humid air exposed" KBr thin film photocathode has been increased from 69 nm ("as-deposited") to 84 nm. Average grain size and rms roughness have been increased after exposure to humid air exposure.

Acknowledgments

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References

[1] H. W. Moos, et al., ApJ 538, L1-L6 (2000).
[2] U. Feldman et al., ApJS, 113, 195 (1997).
[3] Oswald H. W. Siegmund, et. al., Appl. Opt. 27,1568 (1988).
[4] Juan I. Larruquert, et. al., Appl. Opt. 41, 2532-2540 (2002).
[5] Y. Xie, et. al., Nucl. Instrum. Methods Phys. Res. A689, 7986 (2012).
[6] P. Scherrer, Nachr. Ges. Wiss. Gttingen. 26 98 (1918).
[7] Triloki, B. Dutta, B. K. Singh, Nucl. Instrum. Methods A 695 (2012).