Photoemission and morphological studies of KBr thin film photocathode for astrophysics application

R. Rai, Triloki, and B. K. Singh*
High Energy Physics laboratory, Department of Physics, Institute of Science, Banaras Hindu University, Varanasi-221005, INDIA

Introduction

The application of photocathode with the high photoejection probability is an effective means of obtaining increased quantum detection efficiency (QDE) of an astroparticle and high energy detectors. Single-photon sensitivity, excellent time resolution, low signal to noise ratio and most important, high QE, are some essential precondition for an ideal photocathode based device. Alkali halide photocathodes are persistently employed as a photo converter in the extreme ultraviolet (EUV, 10 nm $<\lambda<$100 nm) and vacuum ultraviolet (VUV, 100 nm $<\lambda<$200 nm) spectral ranges. In particular, Potassium Bromide (KBr) is a good choice in the astrophysics experiments such as FUSE (The Far Ultraviolet Explorer) [1] and the extreme ultraviolet (EUV) spectrometer SUMER [2]. The sensitivity of KBr in the FUV region ($\lambda<$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]. In current work, the photoemissive and morphological behavior of KBr thin film photocathodes have been investigated in detail. We also reported a brief study on the influence of substrate reflectivity on photosensitivity of KBr thin film photocathode.

The KBr films are deposited by the thermal evaporation technique in a high vacuum environment (5.6×10^{-7} Torr). The water vapor and other residual contaminants inside the chamber are monitored by a residual gas analyzer (SRS RGA 300) before the sample preparation. KBr powder of 5N purity (Alfa Aesar) is evaporated with the deposition rate of $\leq$ 2 nm/sec from a tantalum boat, which is kept at the 20 cm distance from the substrate. Thickness of the films is monitored by a quartz crystal based thickness monitor (Sycon STM-100). After film preparation, the chamber is purged with dry N_2, in order to ensure the minimum contact with atmospheric air during the sample transfer. Further, these films are placed into vacuum desiccator and transported for the photoemission and morphological measurements.

*Electronic address: bksingh@bhu.ac.in

Photoemissive properties are evaluated by measuring the photocurrent from KBr films under UV illumination. VUV monochromator (Model: 234/302, Mcpherson), with base pressure 6.82×10^{-5} Torr, is exploited to generate a monochromatic light of spectral range of 110 to 180 nm. This VUV monochromator was equipped with a 30 W magnesium fluoride (MgF_2) windowed deuterium (D_2) lamp. The stability of D_2 lamp was monitored during the entire experiment by Hamamatsu's made PMT (Model: 658). A positive voltage (+200 V) was applied on a grid (anode) kept at a 2 mm distance from KBr photocathode in order to collect the UV induced photoelectrons and resulting photocurrent was measured by a keithley picoameter (Model: 6485).

The morphological study is performed by acquiring the Scanning Electron Microscope (SEM) images of KBr films. The film Scanning has been done by FEI Quanta 200 at 10 kV accelerating voltage with secondary electron detector in 5×10^{-4} Torr vacuum environment.

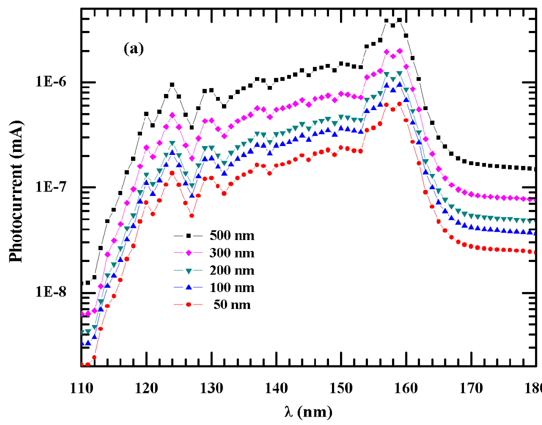

FIG. 1: Photocurrent as a function of wavelength with varying film thickness.

The photocurrent measurements have been performed in 110 to 180 nm spectral range and obtained results are shown in FIG. 1 and 2. FIG 1. depicts, the photocurrent as function of wavelength for 50, 100, 300 and 500 nm thick SS deposited KBr films. From the analysis, it is found that thicker film have higher value of photocurrent than thinner one and photoemission properties of KBr films is deteriorated with decreasing film thickness. This detrimental effect may be observed due to reduction in the escape length of photoexcited electrons with decreasing film thickness. Earlier, it was reported that the film crystanality has been improved with increasing film thickness and 500 nm film have largest coherency domain size and smallest strain [4]. Therefore, the film with a better crystal structure and fewer impurities have a higher probability that the ejected photoelectron will survive through transport towards the vacuum interface and contribute in the photocurrent. FIG. 2 illustrates, the effect of substrates reflectivity on the photosensitivity of 300 nm KBr film. It is evident that the highest photocurrent is achieved when KBr film is deposited on Au substrate. One of the possible explanation for this is as, due to high metallic lustre, Au substrate have high reflectivity than others and therefore, the photoemission of KBr film is enhanced. However, in the case of Al and stainless steel (SS) substrate almost same photocurrent is found. Owing to lower metallic luster of SS and Al substrates, the respective photocurrent is smaller than that of the film deposited on Ag and Au substrates.

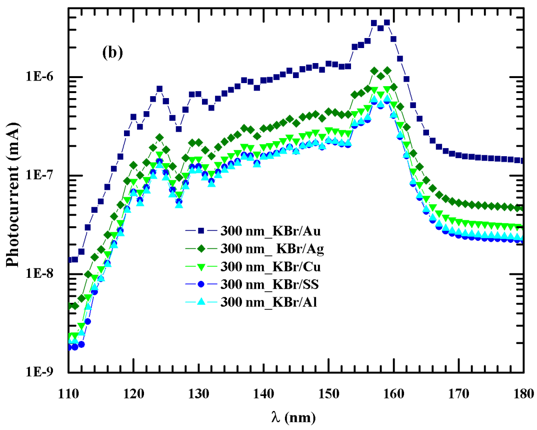

FIG. 2: The influence of substrates reflectivity on the photosensitivity of 300 nm KBr film.

SEM images of 50, 100, 300 and 500 nm KBr films are shown in FIG. 3. We found that the average grain size as well as total area coverage and grain density have been increased with increasing film thickness. The extension in grains, with increasing film thickness is observed due to coalescence process. Prior to coalescence, there was a collection of various grains of different sizes and with increasing film thickness due to the continuous deposition of KBr molecules on the substrate, the larger grains grow at the expense of the smaller ones. The time evolution of the distribution of grain sizes can be derived by a desire to minimize the surface free energy through a decrease in surface area of the grain structure. Several mechanisms are available for mass transport, two most likely ones involve self diffusion through a bulk or via the surfaces of the grains. Diffusion will proceed from the smaller grain to larger grain until the former disappears entirely [5].

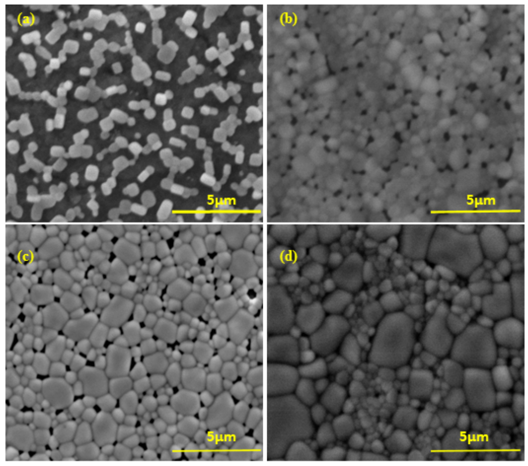

FIG. 3: SEM images of (a) 50, (b) 100, (c) 300, (d) 500 nm KBr films.

In summary, photoemissive and morphological properties of KBr thin film photocathodes have been investigated. We have derived on the basis of theory of photoemission that thicker KBr film deposited on high metallic lustre substrate, shows high photon sensitivity. This result is also supported by morphological studies of KBr thin films.

Acknowledgments

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