Metallic thin films grown by pulsed laser deposition for photocathode application

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R&D of photocathodes is of great interest for the production of high brightness electron beam sources which are demanded, for example, for the new generation of X-ray free electron lasers and laser-plasma accelerators [1–3]. The radiofrequency (RF) and superconducting radiofrequency (SRF) cavities are usually made of copper (Cu) and niobium (Nb), respectively. However, their relatively high work function and low quantum efficiency (QE) urge the search of alternative substances that may substitute them as the photoemitting material. Among the alternative candidates, yttrium (Y) and lead (Pb) seem to be the more adequate choices due to their lower work functions and superior quantum efficiencies, with respect to Cu and Nb, respectively. The insertion of a small photo-emitting spot made of an alternative material with better photoemissive properties, such as Y or Pb, seems to be a very noteworthy method to improve the photoemission performances of the cathode preserving the electrical properties of the cavity, i.e. its quality factor. Pulsed laser deposition (PLD) technique got very interesting results for photocathode synthesis based on metallic thin films. In the last times the group has been working on the synthesis of lead and yttrium thin films by PLD for studying their potentiality application as photocathodes [4–6]. Figure 1a) shows a SEM micrograph of a top view of the Y film characterized by a uniform and percolated morphology. It is worth to note that the droplets density on the film surface is very low. Figure 1b) reveals an interconnected and discontinue grain morphology of Pb thin film with the presence of several droplets on the film surface deriving directly from the melting material of the target.

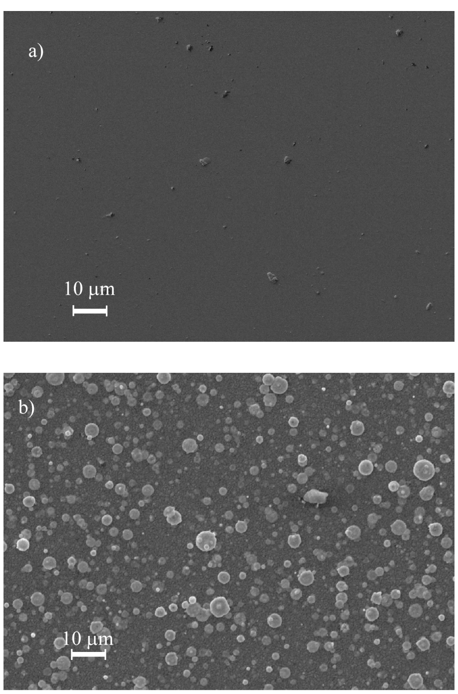

Figure 1. Plan-view SEM micrographs of (a) Y film and (b) Pb film on Si (100) substrates.

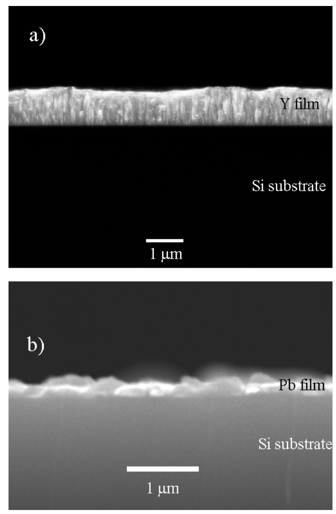

Figure 2. Cross sectional SEM images of (a) Y film and (b) Pb on Si (100) substrates. The Y and Pb thicknesses are about 1.2 m and 300 nm, respectively.

Figure 2 displays the cross sectional images of

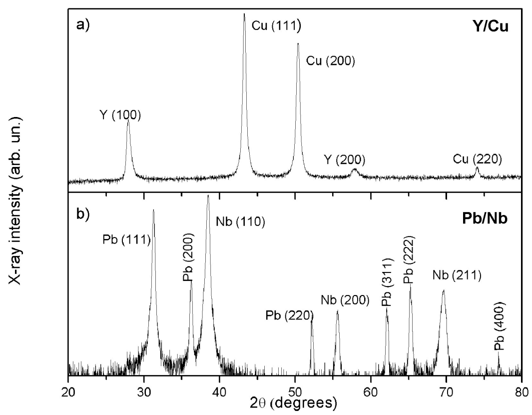

Figure 3. $\theta - 2\theta$ XRD patterns of (a) Y film and (b) Pb film on Cu and Nb polycrystalline substrates, respectively.

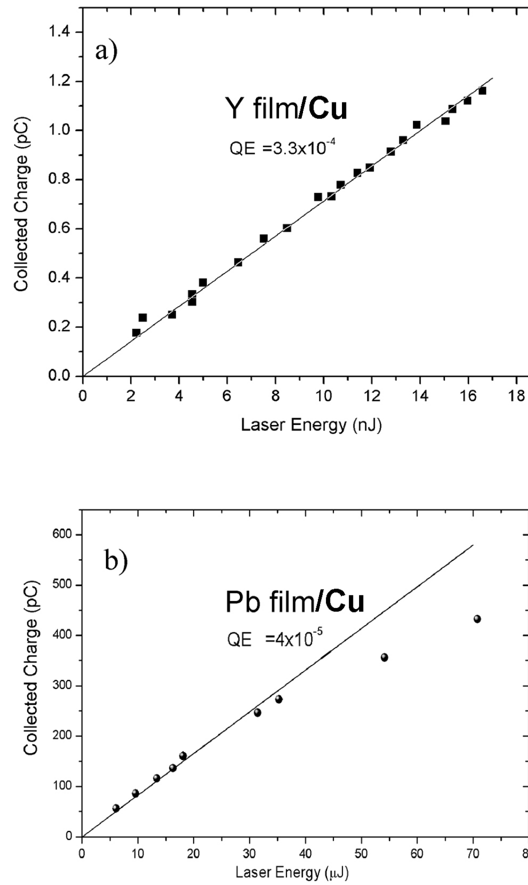

Figure 4. Collected charge as a function of laser energy for (a) photocathode based on Y thin film and (b) photocathode based on Pb thin film. The continuous lines are the data fitting curves to estimate the QE.

the Y and Pb thin films from which it is possible to estimate the Y film thickness of about 1.2 μm (Figure 2a) while the Pb thickness is about 300 nm (Figure 2b). Moreover, the images show that the Y film growth is characterized by a densely packed columnar structure with a very low RMS roughness value of about 2.0 nm, while for Pb film the RMS roughness is evaluated of about 60 nm. Photocathodes with a very low surface roughness are demanded for the production of high brightness electron beams. XRD patterns of Fig. 3 reveal a polycrystalline structure for both Y and Pb films. The XRD pattern of Fig. 3a) shows the polycrystallinity of the Y film which is typical of the hexagonal structure of Y as indicated by the clear presence of Y (100), Y (200) and Y (204) peaks. The other peaks are attributed to the Cu substrate. Figure 3b) shows the XRD pattern of the Pb film deposited on Nb. In addition to the (110), (200) and (211) peaks of the Nb polycrystalline substrate, the figure shows a relatively intense peak at an angle of 31.30, along with weaker peaks at 36.26^o, 52.24^o, 62.14^o, 65.24^o and 76.95^o ascribed to the Pb deposit in the cubic crystalline form. The peaks can be ascribed to the (111), (200), (220), (311), (222) and (400) planes of cubic Pb respectively. Since Y and Pb are interesting for their photoemission performances, we studied QE of the photocathodes based on Y and Pb thin films.

Figure 4 shows a linear relationship between the collected charge as a function of the laser energy for both photocathodes. The laser wavelength, for inducing the photoemission, was 266 nm. The continuous lines are the data fitting curve from which a QE of 3.3×10^{-4} was estimated for Y thin film photocathode (Fig. 4a) and a QE of 4×10^{-5} for Pb thin film photocathode (Fig. 4b). It is interesting to note in Fig. 4b) the data saturation, after about 250 pC of collected charge, due to presence of space charge effects.

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