Pb thin films prepared by the nanosecond pulsed laser deposition technique for photocathode application

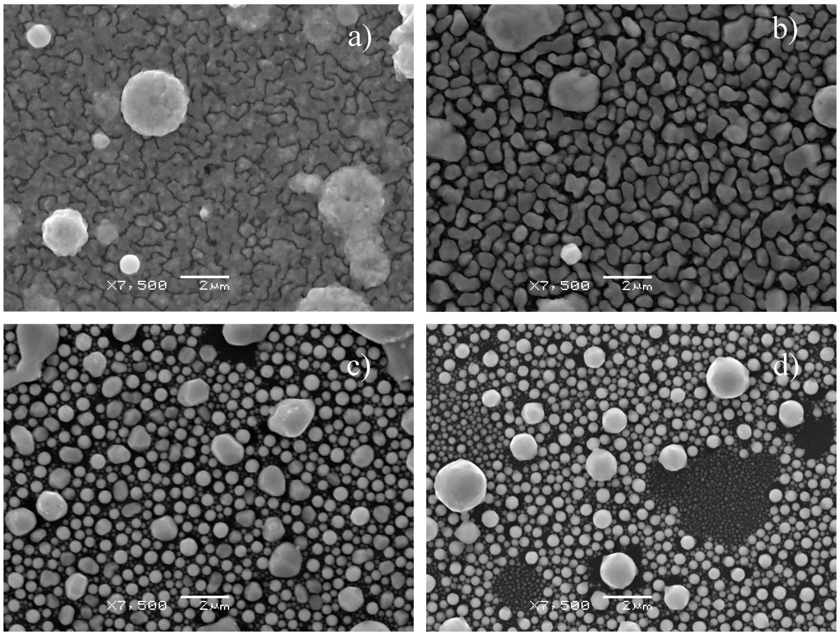
F. Gontad [a b], A. Lorusso [a b], A. Perrone [a b]

[a]Dipartimento di Matematica e Fisica, Università del Salento, Italy

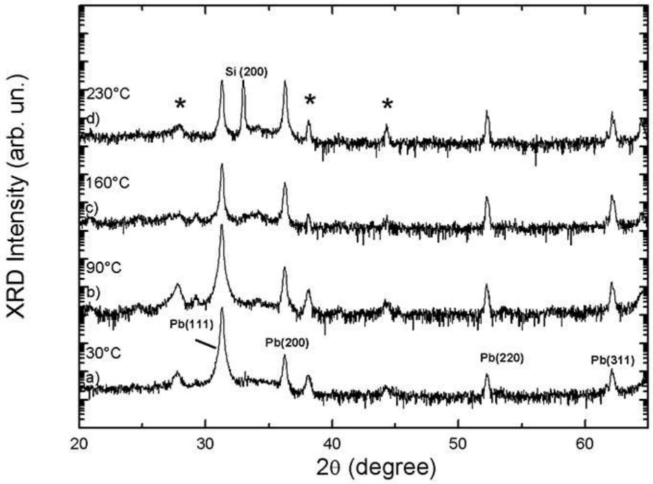
[b]Istituto Nazionale di Fisica Nucleare sez. di Lecce, Italy

Since 2003 our research group has been interesting on the production, development and characterization of thin metallic photocathodes prepared by Pulsed Laser Deposition (PLD) to get high brightness electron beams which are very useful for the development of new generation of X-FEL. The group has been involved in the past to synthesize metallic photocathodes based on thin films of magnesium and yttrium, because they are very interesting for the conventional rf-guns Ref.[1–3]. In the last times the group has been working on the synthesis of lead thin films. Such material, indeed, is very promising for its use in the photoinjectors with superconductive radiofrequency cavities made of niobium Ref.[4,5].

It is well known that the quality of the deposited films is strongly related to the laser parameters as well as to the substrate temperature Ref.[6]. For the deposition of Pb films, it was convenient to fix the laser fluence as closely as possible to the ablation threshold value in order to reduce the thermal effects on the target during the ablation process decreasing, in this way, the formation of the melted material which is responsible of the presence of droplets on the film surface. The substrate temperature was changed as effort to improve the homogeneity of the Pb thin films which is very important for the application of such device as photocathode. Figure 1 shows the SEM micrographs of Pb thin films deposited at substrate temperatures of 30, 90, 160, and 230^0 C. At room temperature the film morphology presented interconnected grains (Fig. 1a) while the increment of the substrate temperature favoured the formation of non-wetting clusters (Figs. 1 b-d).



Moreover, at the highest substrate temperatures (Figs. 1 c and d), the film growth was characterized by the formation of sub-micrometric spherical islands, which tend to increase in height, while their cross section decreased with the temperature. XRD patterns of Pb thin films at different substrate temperatures are reported in Fig. 2.



Several Pb peaks were ascribed to (111), (200), (220) and (311) planes of fcc Pb. The polycrystallinity of the films could be attributed to the energetic particles of the plasma plume, which promote the atom mobility and their rearrangement at the substrate surface. The appearance of some weak diffraction peaks located at 27.68^0, 38.12^0 and 44.04^0, indicated with an asterisk (*) in the d pattern of Fig. 2, could be provoked by the formation of lead silicates (most likely PbSiO3) during the first steps of the deposition process. However, the most interesting feature of the XRD pattern of the deposited films was the strong evolution of relative peak intensities of Pb (111) and Pb (200) with the substrate temperature. At 30^0 C (a pattern of Fig. 2), the contribution of the (111) crystalline planes of the Pb network was more pronounced with respect to the others, showing a preferential orientation along those planes typical of polycrystalline fcc metallic thin films. Nevertheless, as the substrate temperature increased, the relative intensity of Pb (200) with respect to Pb (111) became greater and greater (b - d patterns of Fig. 2) showing a sort of epitaxial growth of the Pb film which followed the crystalline orientation of the Si (100) substrate.

The photoemission performances of the Pb film grown at room temperature and, for comparison, of the Pb bulk were studied. The open square data of Fig. 3 are the collected charge as a function of the laser energy. The slope of the linear fit gives the Quantum Efficiency (QE) value which is about 3×10^{-5} and 2×10^{-5} for Pb film and bulk, respectively. The low QE was associated with the absorption of contaminants due to the exposure of the photocathode in the open air before the installation in the photodiode cell. For this reason, in situ laser cleaning treatment was applied with 6,000 laser shots at 10 Hz of repetition rate and a laser energy density of about 40 mJ/cm^2 which was sufficient to remove the contamination compounds from the cathode surface but well below to the laser ablation threshold of the Pb cathode (500 mJ/cm^2). The black square data of Fig. 3 show the photoemission performance of thin film and bulk after the laser cleaning treatment. QE for the photocathode based on Pb thin film was around 8×10^{-5} and 7×10^{-5}, after the laser cleaning. It is noteworthy to observe that QE of Pb thin film photocathode is comparable to that one of Pb bulk proving the feasibility of PLD technique to realise a hybrid Pb/Nb cathode device. Moreover, the laser cleaning procedure induced a QE increment of more than 60% for both the film and the bulk cathodes.

The future research activity of the group will be devoted to optimise the performances of such metallic photocathodes based on thin films and to develop a new Nb/Pb configuration.

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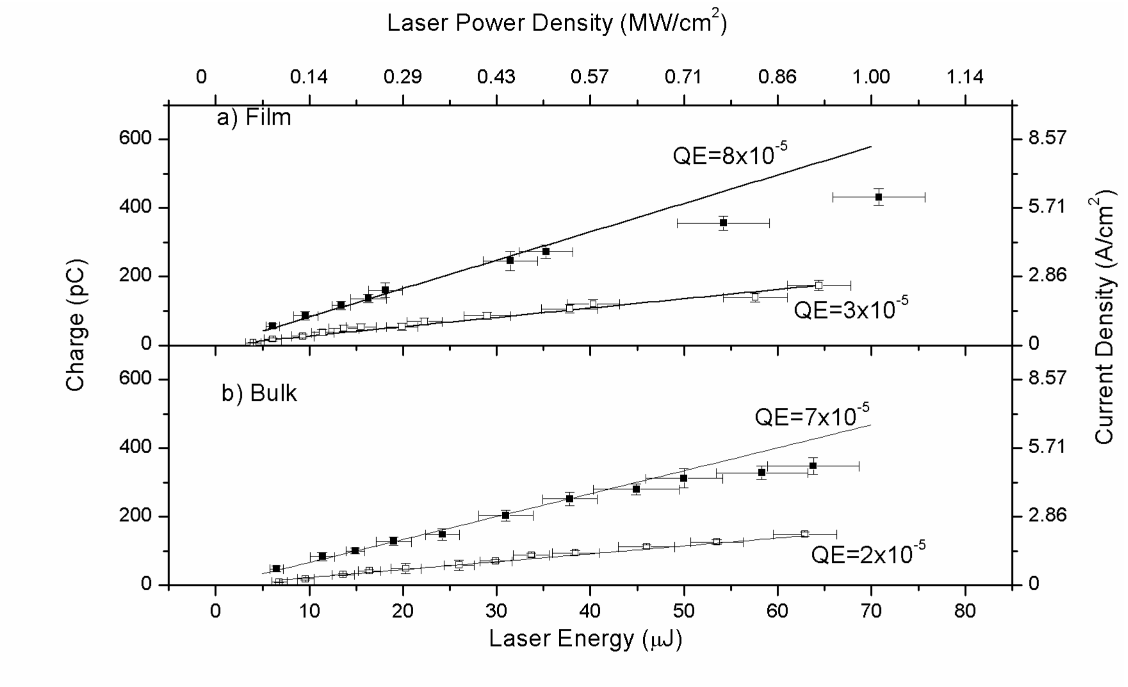

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