Metallic photocathodes based on thin films prepared by pulsed laser ablation deposition

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As was the case in 2011, scientific activity carried out at the Radiation Physics Laboratory in 2012 has been strongly related to the INFN national SPARC-SPARX project. The present project primarily focuses on the production of laser radiation in the X-ray range (1.5 - 3.5 nm) by the SASE-FEL technique. Therefore, the development of new and performable photocathodes is mandatory in order to produce high brightness electron beams. Our research group has been involved in the production and development of metallic photocathodes based on thin films prepared by the pulsed laser ablation deposition (PLAD) technique. These photocathodes will be installed in radio frequency (RF) photo-injector guns, as well as in hybrid superconducting lead-niobium RF guns, to produce electron beams of high current and low thermal emittance. Based on current results, obtained in different laboratories, the most promising metals, that could be used, as sources for primary electron beams in RF guns are copper, yttrium, lead and magnesium Ref.[1–4]. Moreover, because of its superconducting properties and high chemical stability, lead has been identified as one of the best cathodes in hybrid superconducting lead-niobium RF guns. It is worth noting that the superconducting temperature of lead is quite similar to that of niobium. For a long time copper has been the metal most often used as a source for photoelectrons in RF guns. That choice is principally because a photocathode based on this metal is, in principle, easy to prepare. Moreover, the chemical reactivity of the Cu with residual gases is quite low and thus, the stability of its photoemissive properties should be preserved at the operational vacuum level of RF guns (10^{-8} Pa). Such a type of cathode was successfully operated during the commissioning of the SPARX photo-injector. Nevertheless, the quantum efficiency (QE) of such metal is quite low; about 10^{-4} at wavelength of 266 nm. The main advantage of photocathodes based on magnesium with respect to those based on lead, copper or yttrium lies with the higher QE that they offer. In particular, recent

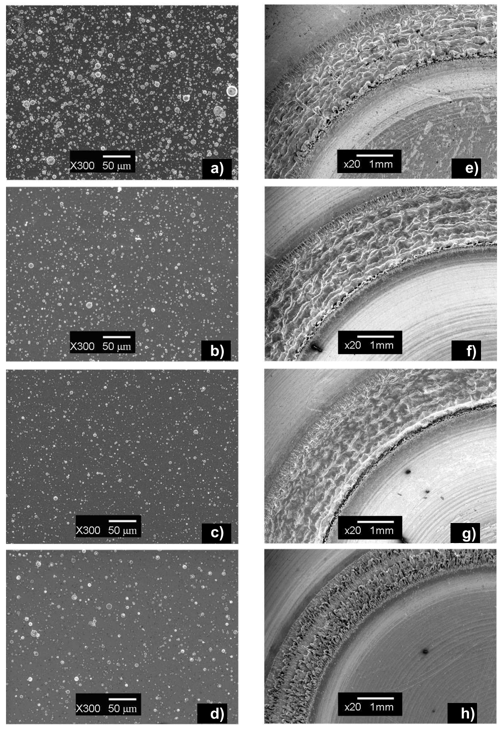

Figure 1. SEM images of the Pb film and target surfaces at different laser fluences. Film: a) 2 J/cm^2, b) 3 J/cm^2, c) 4 J/cm^2 and f) 8 J/cm^2. Target: e) 2 J/cm^2, f) 3 J/cm^2, g) 4 J/cm^2 and h) 8 J/cm^2.

results show that QE higher than 10^{-3} could be obtained with photons at wavelength of 266 nm in low DC electric fields Ref.[5]. In contrast, the very low value of yttrium's work function (3.0 eV) makes this material very interesting, because the extraction of photoelectrons might be achieved even with photons at a wavelength of 400 nm (3.1 eV). This wavelength corresponds to the 2nd harmonic of a Ti:Sapphire laser. The opportunity to drive photoemission in RF guns by the 2nd harmonic, instead of the 3rd, presents obvious advantages in terms of the final energy deliverable to the cathode, even after spatial-temporal manipulation. Another advantage of Y-based photocathodes is the reduction of the thermal emittance by increasing the brightness of the electron beams. Interesting results obtained in 2011 were confirmed in 2012 with the use of ultrashort pulsed lasers Ref.[6]. The research experience acquired during these years by our group was useful in understanding that the in-situ laser-cleaning processes of the cathode surface are mandatory in order to improve the photoemission performance of cathodes. In 2012, important parametric studies were carried out to optimise the deposition process of Pb thin film on Si and then on Nb substrates with the challenge of testing it in hybrid superconducting lead-niobium RF guns. In light of our recent achievements, we assume that electron beams produced by hybrid superconducting lead-niobium RF guns based on Pb thin film are promising, not only for its chemical stability and hence, for its longer lifetime but also for its superconducting performance. The optimisation of the laser irradiation conditions was required in order to reduce the density of droplets on the surface of the Pb films and to improve its morphology Ref.[7]. Figure 1 shows the scanning electron microscopy (SEM) images of the Pb film and target surfaces at different laser fluences ($\lambda = 1064$ nm). It is clear that the droplets density decreases with the laser fluence.

Deposition of Pb films at different substrate temperatures also showed that the grain morphology changes with the temperature (Fig. 2).

Finally, some deposition experiments were carried out with ultrashort pulsed lasers at the European Laboratory of FORTH in Crete. Characterisation and testing of the samples prepared in Crete are in progress. For 2013, we have planned the optimisation of the Pb thin film deposition process and testing of photoemission performance is planned in hybrid superconducting lead-niobium RF guns with photocathodes based on Pb thin films deposited on Nb by PLAD technique.

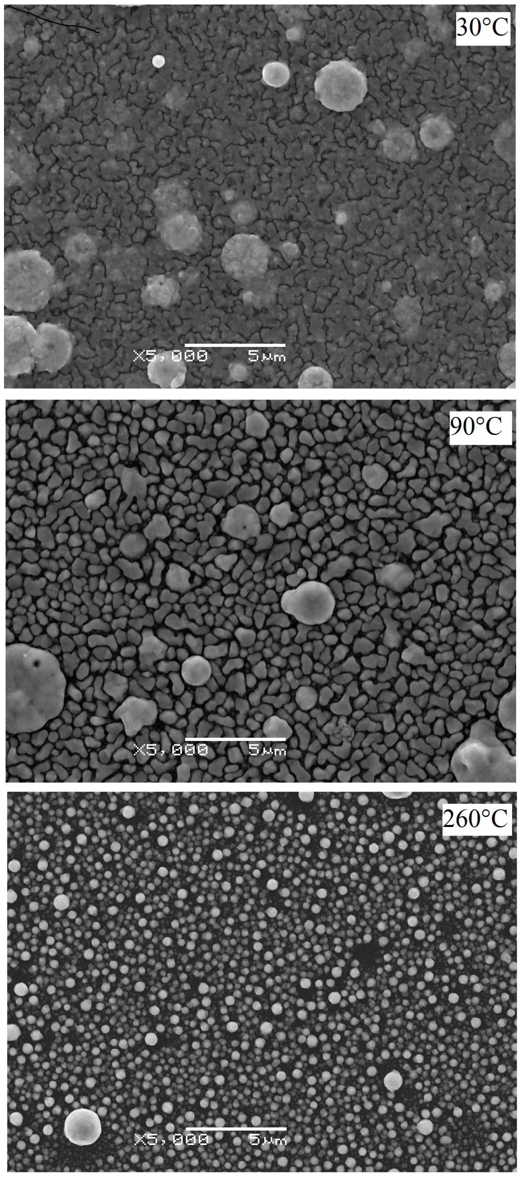

Figure 2. SEM images of the Pb films at different substrate temperatures and at 0.5 J/cm^2.

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