Main results and achievements of thin film metallic photocathodes prepared by PLAD

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The research activity carried out in 2011 at Radiation Physics Laboratory of the Physics Department is strongly related to the national project *SPARC-SPARX* financed by National Institute of Nuclear Physics. The main purpose of the project is the production of laser radiation in the X-ray range (1.5-13.5 nm) by SASE-FEL technique. To reach this goal, the development of new photocathodes is mandatory to produce high brightness electron beams. The research group is involved in the production and developing of metallic photocathodes based on thin films prepared by 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 with high current and low thermal emittance. Based on the current results obtained in different laboratories, the most promising metals that can be used as sources for primary electron beams in RF photo-injector are copper, yttrium, lead and magnesium [1–4]. Moreover, due to its superconducting properties and high chemical stability, lead has been also indicated as one of the best photocathodes in hybrid superconducting lead-niobium RF guns. It should be also stressed that the superconducting temperature of lead is quite similar to that of niobium. Copper is the most used metal since a long time ago as source for photoelectrons in RF-guns. That choice is principally due to the fact that a photocathode based on this metal is, in principle, easy to be prepared. 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 type of cathode was successfully operated during the commissioning of SPARX photo-injector. Nevertheless, the quantum efficiency (QE) of such metal is quite low, about 10^{-5} at 266 nm of wavelength. The main advantage of photocathodes based on magnesium with respect to those based on lead, copper and yttrium lies with the higher QE that they offer. In particular recent results show that QE higher than 10^{-3} can be obtained in low DC electric field with photons at 266 nm [5]. On the contrary, the very low value of yttrium work function (2.9 eV) makes this material very interesting because the extraction of photoelectrons may be achieved even with photons at 400 nm (3.1 eV). This wavelength corresponds, in fact, to the 2^{nd} harmonic of a Ti:Sapphire laser. The opportunity to drive the photoemission in RF guns by the 2^{nd} harmonic, instead of the 3^{rd} one, presents obvious advantages in terms of the final energy deliverable to the cathode even after spatial-temporal manipulation.

Another advantage of Y-based photocathodes consists on reducing the thermal emittance increasing the brightness of the electron beams. Interesting results have been carried out in 2011, testing the Y thin film based photocathodes by CW laser diode in the blue region of 406 nm [6,7]. Figure 1 shows the photoemitted current as a function of the laser power. As one can observe, the QE increases from a value of 7.6×10^{-7} till a value of 1.1×10^{-5} after a laser cleaning process for removing the contamination layers from the cathode surface. The research experience, acquired during these years in our group, was useful to understand that in- situ laser cleaning processes of the cathode surface are mandatory to improve the photoemission performances of cathodes.

In 2011 important parametric studies have been also carried out to optimize the deposition process of Pb thin film on Nb substrate with the challenge to test it in hybrid superconducting lead-niobium RF guns. In light of our last 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 optimization of the laser irradiation conditions was demanded in order to reduce the density of droplets on the surface of Pb films and to improve its morphology [8]. Preliminary results have showed that the morphology of Pb films is not homogeneous but characterized by grains (Fig. 2a). Deposition of Pb films at different substrate temperatures showed also that the grain size increases with the temperature revealing also the presence of big voids (Fig. 2b).

For the current year, 2012, we have planned to improve the Pb thin film deposition. Testing of

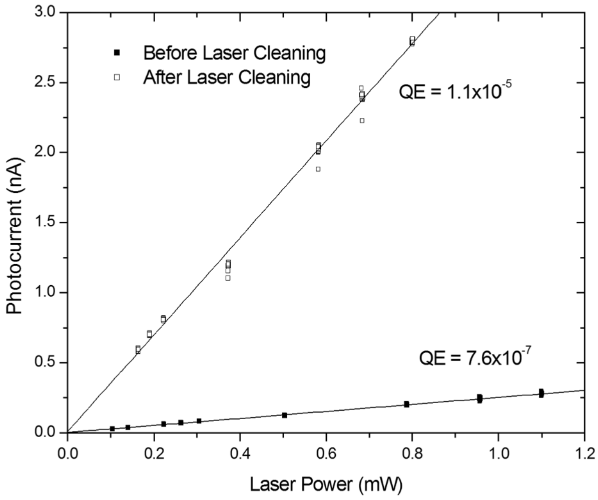

Figure 1. Photocurrent of Y photocathode as a function of laser power before and after in-situ laser cleaning treatment with photons at 406 nm.

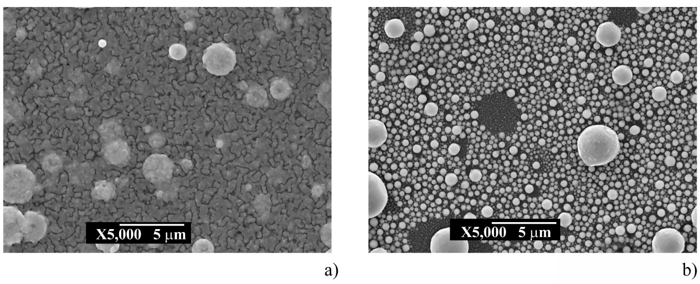

Figure 2. Pb thin film deposited at room temperature a) and at about 200^{o} C b) of substrate temperature.

photoemission performance will be also planned in hybrid superconducting lead-niobium RF guns with photocathodes based on Pb thin films deposited on Nb by PLAD technique.

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