Pulsed laser deposition of thin film metallic photocathodes

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Our research group has been involved in the production, development and characterization of thin film metallic photocathodes prepared by Pulsed Laser Deposition (PLD) with the aim of improving the current electron beam sources. Such aim has been pursued by two main paths: the improvement of Pb/Nb photocathodes for superconductive radiofrequency guns (srf-guns) and the improvement of Y photocathodes for the actual radiofrequency guns (rf-guns) through a new conceptual idea. The main advantage of srf-guns lies on their suitability for the production of near continuous wave electron sources at high accelerating gradients with a lower dissipated power and also lower thermal emittance [1]. However, superconducting cavities (sc) are mainly made of niobium, which has a low Quantum Efficiency (QE) that creates difficulties for the fabrication of an efficient srf-gun. This drawback can be overcome by incorporating an alternative material that improves the QE of the photocathode and, at the same time, preserves the quality factor of the sc cavity. Different studies [2,3] have pointed out lead as a promising solution for the photocathode material in srf-guns for several reasons: a similar superconducting temperature to Niobium, a higher QE, high chemical stability and finally, its inclusion in niobium cavities allows the preservation of their sc properties [4].

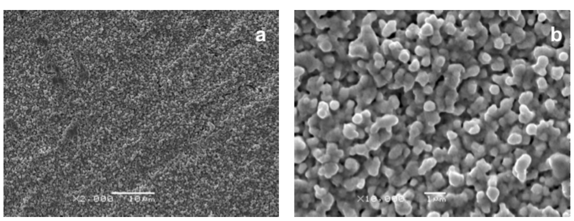

Figure 1.

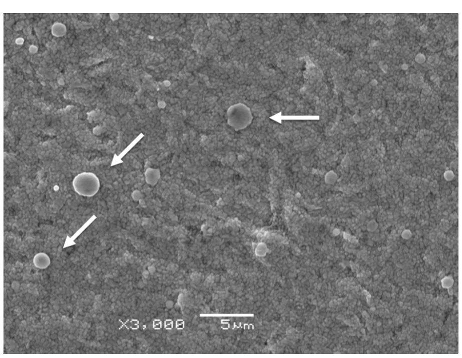

Figure 2.

On the other hand, the research on conventional rf-guns is still of great interest in the scientific community involved on the development of electron beams of great coherence. Still, a similar problem needs to be faced when the photoemission performance of rf-guns requires to be enhanced: the QE of the main material used for the fabrication of the conventional cavities (copper) is quite low [5]. Up to now, big effort has been focused on the deposition of metallic thin films that can improve the photoemission performance of Cu rf-guns (specially Y and Mg), providing a higher QE and a lower work function [6]. In our work, we have explored a new approach: the deposition of a Cu thin film near the circular area of photocathodes made of metals such as Y or Mg (with well-performing QE and work function) in order to improve the electrical and thermal conductivities of the whole cavity.

In 2013, a large number of experiments were performed in order to optimize the deposition parameters of Pb on Nb substrates. Part of the experiments was carried out at the European Laboratory of FORTH, in Crete, taking advantage of their ultrafast lasers. In this way, the improvement on the adherence, deposition rate and density of droplets was studied when the PLD was performed with pulse lengths of 5 and 0.5 ps.

Figure 1 shows the Scanning Electron Microscopy (SEM) images of a Pb thin film deposited on a Nb substrate with an energy density of 0.09 J/cm^2, pulse duration of 0.5 ps and a wavelength of 248 nm at (a) low magnification and (b) high magnification [7]. It is clear that the deposition of lead films with ultrashort pulses avoids the presence of large droplets, which was evident on the ns regime (Figure 2), even if the film still presents a granular structure [7]. Additionally, a new set of experiments was performed for evaluating the deposition of Cu thin solid films on Y substrates (Figure 3) [8]. The main aim of these experiments was the fabrication of a photocathode with good quantum efficiency and low resistivity. With that goal in mind, Cu thin films were deposited over Y substrates but leaving uncovered the central area of the photoemitting substrate. The resistivity of those Cu thin films was found to be quite close to the Cu bulk resistivity, revealing that this new idea represents a valid method for the fabrication of well performing photocathodes in terms of both photoemission and electrical performances.

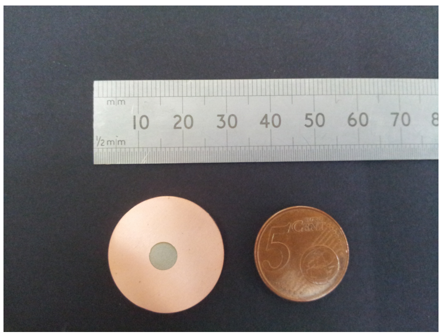

Figure 3.

Finally, in order to analyse the photoemission performance of the photocathodes, a new setup was prepared and developed in the Laboratorio di Fisica delle Radiazioni, according to the design described in Figure 4. The apparatus, consisting in a copper ring working as the anode and a steel holder for the photocathode, was built at the mechanical workshop of the university and installed inside a high vacuum chamber. This setup allowed us the measurement of the photoemission performance of the deposited films and bulk material. The photoemission performance of Pb films deposited by thermal evaporation was compared to the one measured for thin films deposited through PLD with different pulse length, founding similar QE (even if PLD provided films with a slightly better photoemission performance) [9].

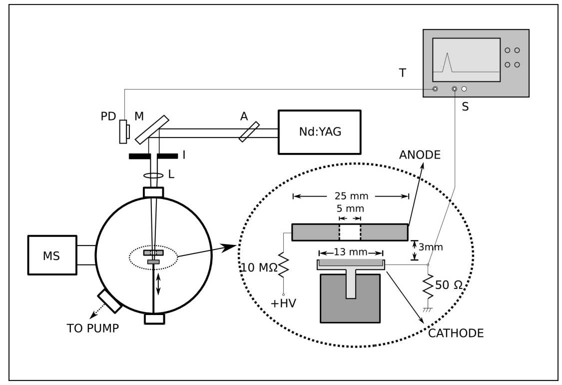

Figure 4.

For 2014, we have planned to optimize the fabrication of Cu/Y or Cu/Mg photocathodes following the new concept idea started in 2013, studying the deposition of Cu thin films by sub-ns PLD.

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