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The role of the adsorbed gases on the photoelectron performance of Mg-based photocathodes

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Abstract

The influence of the adsorbed gases on the photoelectron performance of Mg thin film-based photocathodes was investigated. Mg thin films were deposited on Silicon and Copper substrates by pulsed laser ablation technique. The samples deposited on Silicon substrate were used to deduce the morphology, the structure and the thickness by using different diagnostic techniques. On the contrary, the samples deposited on Copper substrate were tested as photocathodes in a DC photodiode cell. The quantum efficiency of the Mg photocathodes was systematically improved by laser cleaning treatments, which appears to be necessary before any use of a metallic photocathode. The role of the hydrogen and oxygen absorption process on the emission properties is presented and discussed.

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1. Introduction

In recent years, metallic photocathodes have emerged as a valid alternative to semiconductor photocathodes due to their superior robustness and long lifetime, even if they have high work functions and relatively low quantum efficiency (QE). Although a very large number of metallic photocathodes has been prepared and extensively studied [1–7], only a few of them could find significant technological applications. The Mg photocathode has been the most studied due to its respectable QE [8]. It has been prepared by different methods, namely sputtering [9], ion implantation [10], pulsed laser deposition (PLD) [11], friction welding [12,13], evaporation [14], hot isostatic pressure [15], and, in bulk disks, press fitting [16]. Much research still must be done to understand the role of the adsorbed gas on the photoelectron performance of metallic emitters. We describe our progress in the basic understanding of the influence of the gas absorption on the QE of metallic cathodes. Moreover, we outline the importance of the laser cleaning treatments to improve their photoemissive properties.

2. Experimental apparatus

Several Mg thin films have been prepared by the PLD technique using the UHV system that has been described elsewhere [17]. Some samples were selected for the present investigations.

The QE is defined as the ratio of the number of photoemitted electrons, N_e, to incident photons, N_p:

$$QE = \frac{N_e}{N_p}.$$

The QE can also be expressed as follows:

$$QE = \left(\frac{q}{e}\right) \Big/ \left(\frac{E}{h\nu}\right)$$

where $\nu = c/\lambda$, q is the collected charge, E is the energy incident on the cathode, e is the electron charge, and ν is the laser frequency.

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After some calculation we obtain the following expression:

$$\mathrm{QE} = \frac{I}{P}\frac{hc}{\lambda e}$$

where $I = q/t$ and $P = E/t$, with t the time.

The QE measurements were performed in a photodiode cell under UHV conditions. The cathode and the anode separated at a distance of 3 mm were placed inside the photodiode cell (Fig. 1). The Mg film occupied the cathode position and was electrically grounded. The anode plate was biased with high DC voltages up to 5 kV thus allowing the generation inside the gap of an intense electric field of about 1.7 MV/m.

To illuminate the cathode and for precise alignment of UV laser beam on cathode surface, the anode plate was machined with two symmetric holes. They have a diameter of 4 mm and form an angle of 72° with respect to the normal of the cathode surface. This particular geometry was chosen for two main reasons:

- The first was to avoid the use of a metallic grid usually present in such experiments. Our previous experimental results clearly indicated that the light distribution on the cathode surface, in the presence of a metallic grid, was affected by diffraction features and hampered uniform illumination of the cathode surface [8].
- Secondarily, the angle of 72° was chosen in order to perform experiments with the same geometrical configuration used in the last generation of the BNL/SLAC/UCLA 1.6 cells S-Band RF gun [12].

The vacuum chamber in which the photodiode cell was inserted was evacuated to a base pressure of about 2×10^{-7} Pa by means of an ion pump. The quality of the vacuum was monitored by a quadrupole mass spectrometer.

Laser cleaning and QE measurements of the Mg films were performed using the UV radiation of the 4th harmonic of a Q-switched, mode-locked Nd:YAG laser (QUANTEL YG-501) able to deliver up to 300 μJ at 266 nm with a pulse duration of 30 ps.

The optical transfer line and the photodiode cell structure are reported in Fig. 1. The 4th harmonic of the laser beam was reflected by a mirror mounted on a gimbal for fine alignment; a variable aperture iris was used to select the central part of the beam and to align it. A beam splitter was used to sample the beam energy by means of a calibrated fast photodiode. When needed, a series of neutral density filters was used to decrease the laser energy down to a fraction of nJ. A couple of cylindrical lenses allowed us to transversely shape and collimate the beam to obtain a circular laser spot on the cathode. The laser beam was, when considered necessary, focused with a fused silica plano-convex lens (focal length 30 cm) mounted onto an xyz translational stage driven by stepper motors controlled by a computer (x and z movements were linked in order not to change, once fixed, the distance between the lens and the illuminated area of the cathode). Another beam splitter sampled the laser beam to illuminate a Ce-doped YAG screen used as virtual photocathode. Another variable aperture iris has been used to facilitate the alignment of the laser beam before its entry into the vacuum chamber through a quartz window in order to illuminate the cathode surface. A triggered CCD camera (Basler mod. 301) was used to observe the laser spatial distribution over the cathode surface.

The laser energy measurements were performed by integrating the signal of the calibrated fast photodiode, while the charge measurements were done using a charge integrator.

The laser cleaning procedure was performed by scanning the focused laser beam over an area of about $2.4 \times 2.4\,\mathrm{mm}^2$. The laser beam had a diameter on the cathode surface of about 300 μm and energy of about 25 μJ per pulse (power density and laser fluence were about

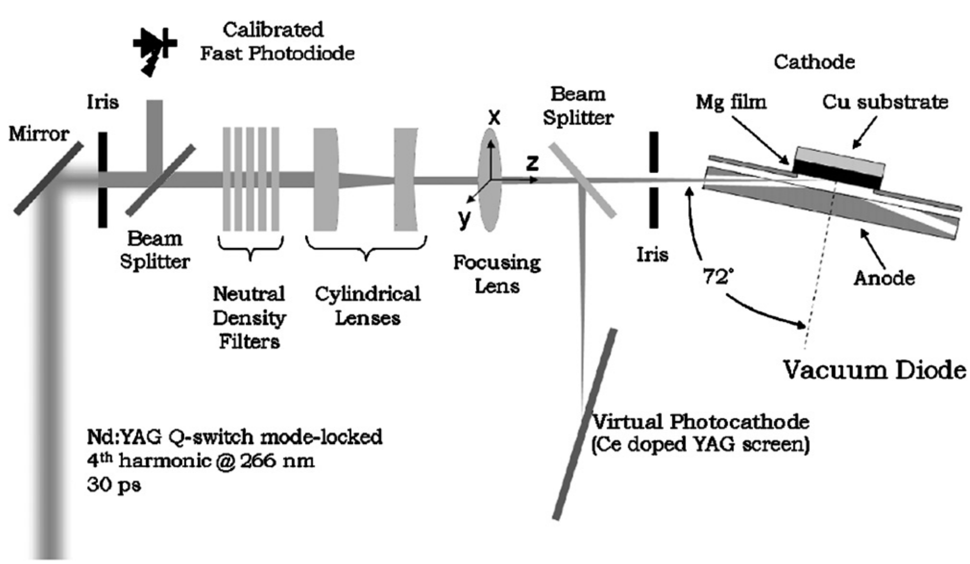

Fig. 1. The scheme of the experimental apparatus for laser cleaning and QE measure is here reported.