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PULSE LASER DEPOSITION METHOD FOR UV-PHOTOCATHODE PRODUCTION

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Abstract

Production method of alkali halides UV-photocathodes durable to environment exposure was proposed. Photocathodes with high homogeneous and adhesion photoemission layer were made. Quantum yield measurements results of manufactured photocathodes are presented. Developed method is promising for creation of high aperture electron injectors and detectors.

Introduction

UV-photocathodes have wide application as UV-detectors, electron injectors for acceleration facilities an etc. Especially actual problem is creating wide aperture UV-photocathodes with homogenous photoemission layer, which can withstand exposure to air without degradation of quantum yield.

Pure metals have low quantum efficiency even after laser cleaning of emitting surface [1]. Common method to improve quantum efficiency is to cover metal surface by alkali halides. This method uses complex and expensive vacuum equipment, but still to get good homogenous film with good adhesion and quantum yield one should to have enormous experience in such technologies.

In paper [2] pulse laser deposition (PLD) method was used to cover metal substrate by Mg thin film. Pure film with high homogeneity and adhesion was achieved. It is known that alkali halides films considerably improve quantum efficiency of pure metal [3]. Also such coatings can withstand exposure to air, that allows creating wide aperture UV-photocathodes without requirement oversized high vacuum chamber and sophisticated soldering techniques.

Production

PLD has long been known and used for various applications. This technique particularly effective for production of films with complex stoichiometry, growth speed is high, mechanical parameters also are very good. The disadvantages of PLD are: the availability of large-sized particles on the surface at the wrong laser regime and poor controllability of the process. Fig. 1 shows schematic of the film growth.

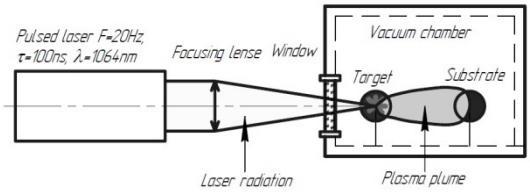


Figure 1. PLD process of UV-photocathode production.

To implement the PLD film growth of halide compounds we developed and manufactured vacuum chamber and pulsed solid state laser. The chamber had a few quartz windows to enter laser radiation, gauge Edwards WRG-S, fore line pump, turbo molecular pump Varian S.P.A, noncontact target heater (808nm 7W laser diode with collimator), focusing lens with F=50mm. We made lamp pumped Nd:YAG solid-state laser with passive Q-switching based on LiF saturable absorber. The laser parameters are: pulse duration – 100ns, wavelength – 1064nm, frequency < 20Hz, pulse energy < 1J, TEM00 beam quality. Fig. 2 shows schematic of designed laser.

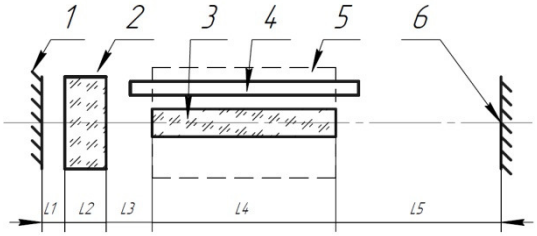


Figure 2. Schematic of designed pulsed laser. 1 – rear flat mirror, 2 – saturable absorber LiF, Nd:YAG rod 6.3x100mm (1.1% doping), Xe pump lamp, 5 – elliptical reflector, 6 – flat output coupler 40% transmission. L1=65mm, L2=40mm, L3=130mm, L4=100mm, L5=145mm.

Laser power and frequency controlled by power source. It's important that pulsed laser should work in threshold regime, when plasma plume exist, but not much power putted into each pulse. Otherwise film can be damaged by big fragments of target and droplets. Deposition time was picked experimentally to get optimal 0.5um thin film [3].

Deposition was lasted for 15-16min (20Hz frequency) depending on the material. Thickness was controlled by interferometer.

As substrate we used Cu and Ni flat disks 1.5mm thickness and 20mm diameter. Our preliminary tests showed that quality of produced films greatly depend on target and substrate preparation. We had pure CsBr compound in powder form, so we pressed it into dense tablet, CsI compound was in crystal form so any additional preparation was not required. Substrate preparation was: mechanical cleaning by fine grinding paper, laser cleaning, chemical cleaning in hydrochloric acid solution, washing in distilled water, drying at room temperature.

After all preparations target and substrate were placed into vacuum chamber, fore line pump and turbo molecular pump produced vacuum about 10^{-5} torr and then pulsed laser turned on. The substrate and the target should be set normal with respect to each other, incidence angle of laser radiation is about 45 degree to normal of target, see fig. 3. When PLD process was over, substrate was annealed for 3 hours in 60deg C and then got out from vacuum chamber to environment.

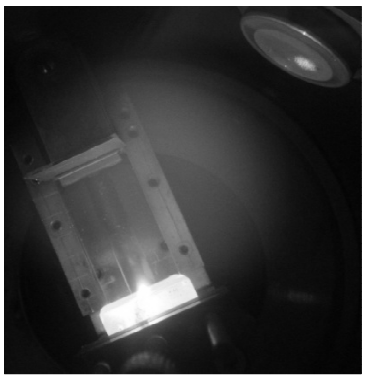


Fig. 3. Deposition in process.

Quantum yield measurements

Experimental studies of quantum yield of produced photocathodes were made by measuring the total charge accumulated from measuring capacity. Photocurrent flow between anode mesh and photocathode after UV laser short pulse exposition cause the charge. Fig, 4 represent measuring set up.

We applied DC high voltage 0-20kV between mesh and photocathode (SRS PS375 power source was used), distance was set 0-5mm. Measuring capacity C=10nF also protects oscilloscope from high voltage gap breakdown. Total charge was gained from area under voltage pulse of cable capacity recharge to measuring capacity through measuring resistor (oscilloscope input resistance, Tektronix TDS 2022B or LeCroy WaveRunner 62Xi) R=1MOmh. Cable capacity was much lower than measuring capacity so recharge pulse form did not distort respect to case then measuring capacity was shorted circuit. To make sure all emitted electrons reach anode mesh we adjusted laser pulse energy and applied DC voltage. By achieving saturation voltage at which a linear relationship ceases and emitted charge practically independent of the applied voltage, we can indirectly determine the quantum efficiency. But this is true only if the time of flight of the electrons from the cathode to the grid is much greater than the laser pulse duration. This condition is satisfied for picosecond laser sources, but not satisfied for UV eximer lasers with pulse duration 5-7ns. For longer laser pulses measuring result provides lower QY relatively direct QY measurement techniques.

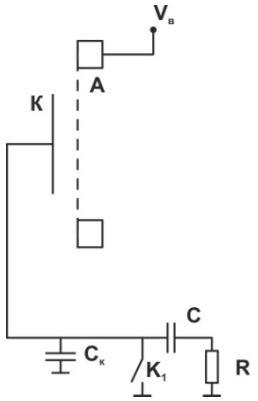
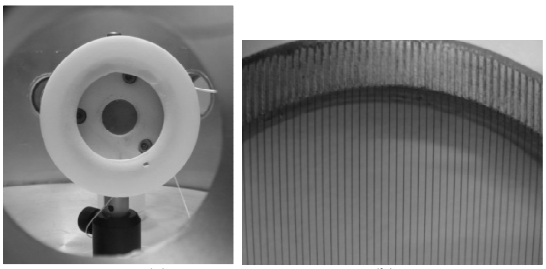


Figure 4. Quantum yield measurement circuit. A – anode mesh, K- photocathode, C_k=100pF – cable capacity, K_1 – discharge switch, C=10nF – isolate capacity, R= 1MΩ – measurement resistor, Vb=0-20kV HV.

After 10minutes exposure to air, we mounted photocathode and tungsten mesh (35um diameter, 520um step) into Teflon holder, distance from cathode to mesh was set to 2mm. Mesh was soldered to positive electrode of high voltage power source. Assembled unit was put into measurement vacuum chamber (10^{-7} torr). Fig. 5 shows vacuum photodiode made from developed photocathode and mesh. As UV sources we used ArF and KrF excimer lasers with wavelength 193 and 248nm respectively, pulse duration was 5ns, frequency - 100Hz, average pulse energy was less than 1mJ.



(a) (b)

Fig. 5. Photocathode testing assembly (a). Anode mesh (b).

UV laser beam was focused by CaF2 lens, spot size on cathode surface was 1-3mm diameter, regulated. In our experiments we scan with UV spot on emitting surface, to study QY homogeneity of whole surface. Response signal was broadened

because of RC constant of measuring circuit (about 100us in our case). By measuring incident light energy and calculating electrical charge from area under the response signal curve (1) we got quantum yield (2).

$$Q = \int_{-\infty}^{+\infty} I(t)dt = \int_{-\infty}^{+\infty} U(t)/R\, dt \quad (1),$$

$$Y = \frac{N_{el}}{N_{ph}} = \frac{Q}{W} \cdot \frac{h\omega}{1} \quad (2),$$

where Q – electrical charge, I(t) – current, U(t) – voltage, R – measuring resistance, Y – quantum yield, N_{el} – number of emitted electrons, N_{ph} – number of incident photons, W – UV light energy, hω – single photon energy.

Results and discussions

Better result was obtained with Cu substrates, achived quantum yield presented in Tab 1. To compare PLD technique we managed production of CsI photocathode on Cu substrate with more traditional thermal evaporation technique. PLD showed worse maximum yield, but films were very homogenous and quantum yield in different spots of photoemission area did not differ more than 20%.

Table 1. Quantum yield measurement results.

Material	Quantum yield
CsI, PLD growth, λ=193nm	$1x10^{-2}$
CsI, thermal evaporation, λ=193nm	$1.5x10^{-2}$
CsBr, PLD growth, λ=193nm	$3.3x10^{-2}$
CsBr, PLD growth, λ=248nm	$1x10^{-4}$

Vapor sample showed very poor homogeneity, yield even disappeared in some areas. Also vapor sample demonstrated poor adhesion, photoemission film got away by slight rubbing by finger, PLD samples show very good adhesion, film endure high pressure friction by rubber material. Achieved quantum yield results are lower, than known in literature [4]. We attribute this to the fact that the time spent in the air was too long so the coating had absorbed too much moisture. Annealing in the measurement vacuum chamber we did not performed in this work.

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