USE OF NEG PUMPS TO ENSURE LONG TERM PERFORMANCES OF HIGH QUANTUM EFFICIENCY PHOTOCATHODES

Daniele Sertore#, Paolo Michelato, Laura Monaco (INFN/LASA, Segrate (MI))
Paolo Manini, Fabrizio Siviero (SAES Getters S.p.A., Lainate (MI)).

Abstract

Laser triggered photocathodes are key components of the electron sources of 4th generation light machines. However, they are very sensitive to the vacuum level and its composition. Photocathodes are usually prepared in UHV chamber and then transferred, keeping the extreme vacuum condition, to the operation sites. Since transportation/storage may last from several days to weeks, retaining UHV conditions is a fundamental task to the photocathode usage. In this paper the results obtained using a novel pumping approach are given. This approach is based on coupling a 20 l·s^{-1} ion getter pump with a Capacitorr® D100 Non Evaporable Getter (NEG) pump. Pressure of $2\cdot10^{-11}$ mbar was achieved with the NEG pump after 2 days bake-out, as compared to $8\cdot10^{-10}$ mbar achieved with the ion pump alone, after 7 days bake-out. Such pressure values were retained even in absence of power, due to the ability of the NEG to remove gases by chemical reaction. Long term monitoring of cathodes QEs was also carried out at different photon wavelengths over more than 6 months, showing no degradation of the photo-emissive film properties.

INTRODUCTION

High Quantum Efficiency (QE) photocathodes are nowadays routinely used as laser triggered emitters in the advanced high brightness electron sources.

Besides the different materials available, semiconductor photocathodes are the preferred choice in application where high charge per bunch and/or long pulse train and/or high duty cycle is required. These emitters satisfy the main requests for their application in RF guns such as high QE, good QE spatial uniformity, long operative lifetime, and stable operation along the bunch train. The main drawback is their sensitivity to gas pollution and hence the request of Ultra High Vacuum (UHV) conditions from their deposition to their use in the gun. UHV has to be kept also during transportation that represents one of the critical operations in our case, since the cathodes are deposited in Milano and then transferred to the accelerator sites (DESY-HH, DESY PITZ).

In this paper, we present the results of a new pumping system for the transport box able to guarantee UHV condition for a long period even in absence of power.

CATHODE LIFE CYCLE

At INFN Milano, we prepare Cs_2Te photocathodes using a standard and reproducible procedure [1]. The cathodes are deposited on a Mo substrate, mechanical polished to mirror like finishing, in an UHV chamber. This deposition process guarantees the production of cathode with final QE usually above 10 % and spatial uniformity better than 90 %. The photocathodes, after production, are stored in a UHV box that allows transporting the cathodes to the requesting laboratory.

Presently, the transport system is pumped by a 60 l·s^{-1} ion getter pump that needs to be powered all the time to keep the UHV condition in the system and prevent gases such as CO or CO_2 to degrade the film quality [2]. For this reason, we developed a portable power supply to keep the ion getter pump working also during the transportation between laboratories. During more than hundred transportations in more than a decade [3], we had only few power failures that degraded the characteristics of the cathodes [4].

THE NEW PUMPING CONFIGURATION

Recently we begin a collaboration with LBNL for delivering cathodes for the APEX experiment. For this activity, the cathodes will be shipped by airplane and, given the restriction on airplane transportation, we have to develop a vacuum solution that doesn't require any electrical power and it is, possibly, lighter and of smaller volume to reduce transportation costs.

Possible pumps that satisfy our requirements are Titanium Sublimation Pumps (TSP) and Non Evaporable Getter (NEG) Pumps. TSP pumps usually require large sublimation areas to get high pumping speed while NEG pumps provide high pumping speed and larger capacity in a compact size. For this reason, we choose a NEG pump, Capacitorr® D-100 from SAES [5] for its compactness and high pumping speed (see Fig. 1 for pumping characteristics for H_2 and CO).

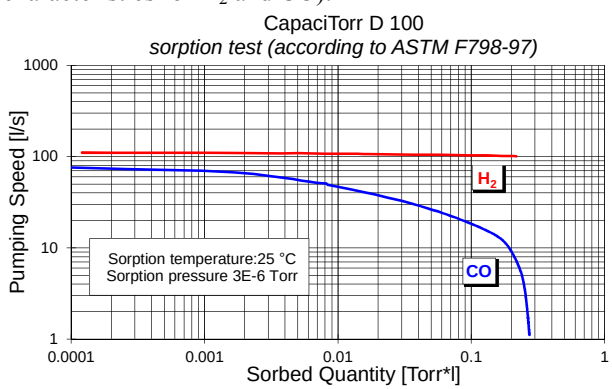

Fig. 1. Pumping speed of the Capacitorr® D-100 pump for CO and Hydrogen.

A getter is a substance that removes molecules from the gas phase by a chemical reaction on its active surface.

#daniele.sertore@mi.infn.it

NEG are produced by alloying reactive metals in vacuum. Despite TSP pumps, NEG do not require evaporation but a thermal activation process. Once activated, the NEG removes carbon oxides, O_2, N_2, and water at room temperature by surface adsorption, while H_2 forms a solid solution in the bulk. In UHV-XUHV range a high pumping speed can be maintained for years without power consumption, thanks to the high capacity in a very compact size. Moreover the pump has no vibration, and no interference with electric and/or magnetic fields.

New pumping Layout

In order to accommodate the NEG pump, we have redesigned the layout of pumping components in the transport box. Moreover, we have installed a 20 l s^{-1} ion getter pump to remove gases like methane that are present in the system but not pumped by the NEG pump. The final layout is reported in Fig. 2.

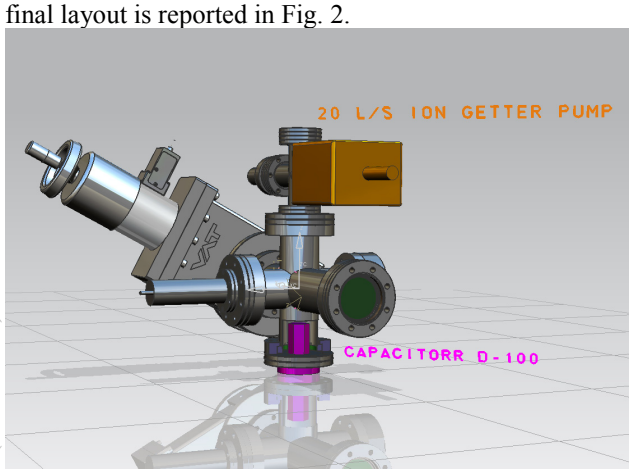

Fig. 2. Layout of the transport box with the D-100 NEG pump (bottom) and 20 l s^{-1} ion getter pump (top) installed.

EXPERIMENTAL RESULTS

We have performed different tests on the new pumping system to compare the results with the vacuum level (low 10^{-10} mbar range) achieved in the actual transport system pumped by a 60 l s^{-1} ion getter pump.

Test with 20 l s^{-1} Ion Getter Pump

To establish a baseline condition, we have at first installed only the 20 l s^{-1} ion getter pump on the system and then baked the system to test the ultimate pressure achievable in this configuration.

The bake out consists in heating the system up to 200 °C, and then increases only the temperature of the ion pump to 250 °C. When the decrease rate of the pressure is below 5 10^{-8} mbar/day, the ion pump is cooled to 200 °C, it is switched on and then we proceed cooling done the whole system to room temperature. The turbo pumping system (TMP) used during the bake out process is closed as soon as the ion pump alone is able to maintain in UHV the system. The bake out process lasts about 6 days. Fig. 3 shows the typical bake out process. The final vacuum level reached with only the ion pump is in the high 10^{-10} mbar range.

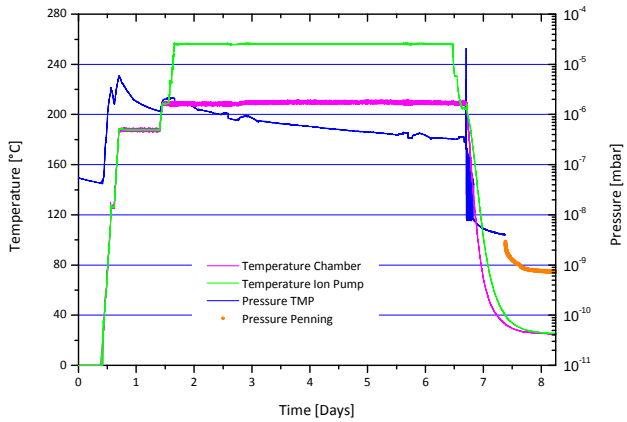

Fig. 3. Vacuum system bake out process with only a 20 l s^{-1} ion getter pump installed. In the pictures temperatures and pressures are reported.

Test with ion pump and D-100

After the first test, we vented the system with nitrogen and installed the D-100 NEG pump in addition to the ion getter pump. We proceeded then with the standard bake out follow by the NEG activation as shown in Fig. 4.

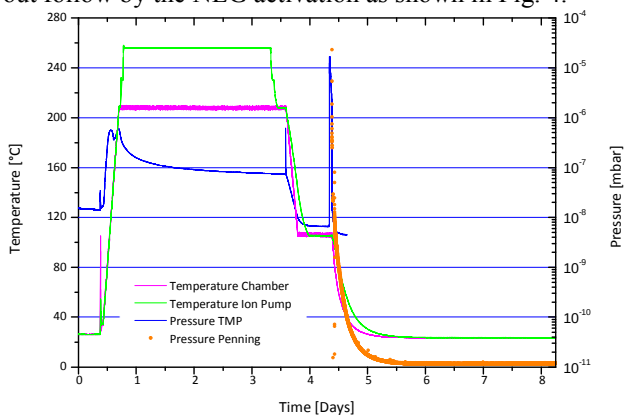

Fig. 4. Bake out of the system with both 20 l s^{-1} ion getter pump and D-100 NEG pump installed. The NEG pump activation corresponds to the large pressure increase at 120 °C. The final pressure is in the low 10^{-11} mbar range.

A vacuum level in the low 10^{-11} mbar was reached with a bake out duration of only 4 days. The different behavior of the roughing vacuum (fast drop at the bake out beginning) is attributed to a contribution from the NEG pump, even if it is not still activated. The NEG pump is activated during the cool down phase when the system reaches 120 °C. The activation lasts one hour and is controlled by a dedicated SAES device. During this operation, the ion pump is switched off and the TMP pump provides the necessary pumping speed for removing the gases (hydrogen mainly) produced by the NEG activation.

Fast bake out process

To further shorten the bake out, we have done a test using an activated NEG pump also during the bake out process. In this configuration, we perform two NEG activations: the first when the whole system reaches

200 °C and the second, during the cool down phase, at 120 °C. The former activation prepares the D-100 to assist the pumping during the bake out process while the latter regenerates the NEG surface before its final usage for the long term pumping. With this procedure, we have shortened the bake out time to only two days, reaching a vacuum level comparable to the one achieved in the second test.

Long term stability

As reported in the introduction, one of the key point in using a NEG pump is the need to save the cathode characteristics also in case of a power failure. For this reason, we performed a long test run leaving the NEG pumping with the ion pump switched off. As shown in Fig. 5, the vacuum level remained in the low 10^{-11} mbar range for more than a month.

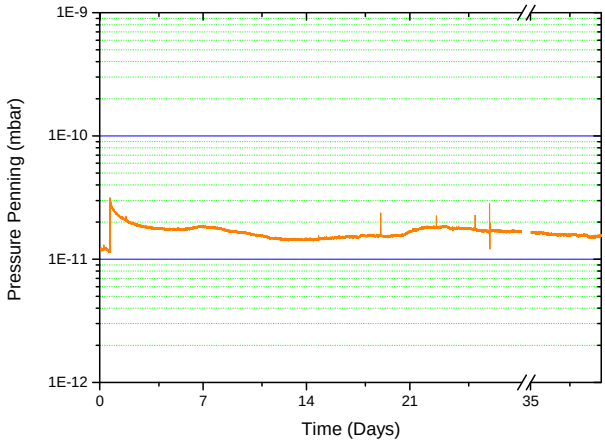

Fig. 5. Long term test of the D-100 pump, with ion getter pump switched off. A stable vacuum level in the 10^{-11} mbar range was achieved for more than a month.

PHOTOCATHODE QE

The final test on the performance of the new pumping system is the cathode QE behavior. A stable QE value is the indication that the system is performing as expected and no pollution from gases is acting on the cathodes.

The QE maps shown in Fig. 6 reports the spatial distribution of the QE after more than five months of cathode storage in the transport system with long periods of D-100 pumping only as in Fig. 5. No significant change in the distribution is visible as well as no degradation of the QE that implies no pollution from the residual gases present in the storage system.

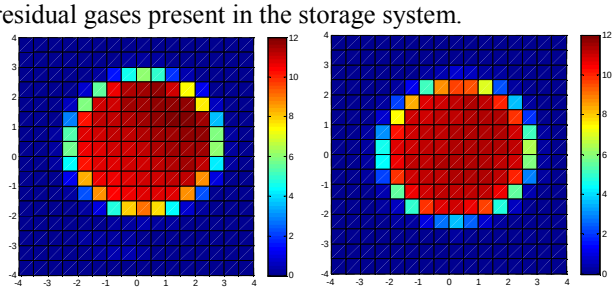

Fig. 6. QE maps at the 254 nm: after the deposition (right) and 5 months later (left).

Fig. 7 shows spectral responses (QE at different photon energies) of the same cathode for the same time (18-Nov-10 cathode dep.). The shape of these curves is related to the energy band of the cathode materials. We have observed, also in this case, no variation in the QE at higher photon energies. We may point out a small variation of the response at low photon energies, even if this difference is well within the acceptable variation. In a previous experiment [6], an exposition to 26 monolayers of O_2 produced a change in the spectral response at low energy of two orders of magnitude while in our case the modification in the curve is barely visible.

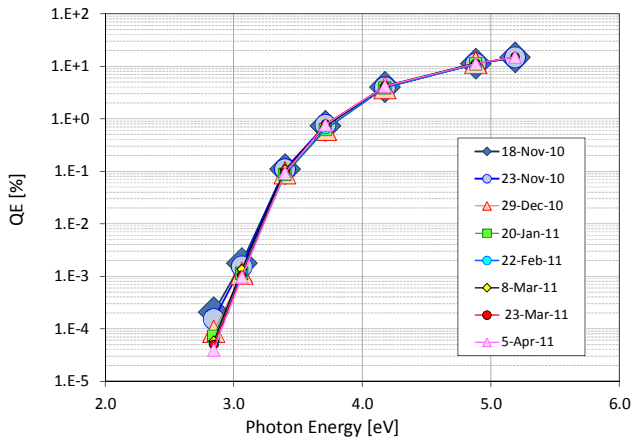

Fig. 7. QE at different photon energies vs time starting from cathode deposition. Only at lower photon energies a small modification in the curve is visible.

CONCLUSIONS

A new layout for the transport system of photocathodes has been tested. A small ion getter pump and a NEG pump replace a heavy ion getter pump, guaranteeing pumping speed also in case of power failure. The vacuum level reached is in the low 10^{-11} mbar range (one order of magnitude better than the previous configuration) and no noticeable photoemission properties variation has been observed. The availability of a compact solution like the SAES NEXTorr®[7] pump which combines an even smaller ion pump (5 l/s for N_2) with a NEG pump may provide a further step towards more compact and reliable photocathode transport systems.

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