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Abstract

The importance on quantum efficiency of a CsI photocathode of the starting material used, the deposition procedure, and electric field on the photocathode is discussed. A simple, non vacuum-deposition technique for making CsI photocathodes is also presented.

During the past two years, there has been a great deal of effort by several groups to understand the CsI and CsI-TMAE photocathodes for applications primarily in high energy physics. The quoted quantum efficiencies, QE, have varied by about a factor of three [1-5]. We feel that the differences in QE seen are due primarily to four factors: 1) the CsI used to make the photocathode, 2) the production procedure used, 3) the treatment of the photocathode after it is produced, and 4) the measurement procedure used.

We used two sources of CsI for our photocathodes: of CsI scintillator and CsI powder. In almost all measurements undoped-CsI scintillator material was used. A few measurements were made with CsI(Tl) to determine the effect of the thallium dopant. The powder was obtained from Aldrich Chemical Company, Inc. and had a claimed purity of 99.999%.

In our vacuum depositions, the photocathodes are made in a vacuum between 10^{-4} and 10^{-5} Torr. The CsI is placed in a boat and heated. The substrate is heated to 40 °C and is shielded from the boat by a shutter until the boat has reached full temperature. The shutter is then removed and the CsI is deposited at a rate of 20-50 Å/s. If new CsI is being used, a "deposition" is first made without a substrate present to boil off any contamination on the material. The substrate is then installed and a photocathode made. This cleaning of the CsI in the boat by heating has proven to be very important. We have found that photocathodes made from the first deposit of new material are always inferior to later photocathodes.

We have shown the importance of heating the CsI photocathode in either a vacuum or gas environment after it has been installed in the detector [1]. All the measurements presented here are made on photocathodes that have been heated for two days in a vacuum of approximately 10^{-4} Torr. The chamber was then filled with 20 Torr of ethane and the QE determined as described in ref.1 using TMAE gas as the reference. The electric field strength at the photocathodes during the measurements was approximately 4 kV/cm.

There is also interest in a technique, described in an earlier publication [1], by which the CsI is dissolved in a solvent and sprayed in air on a heated substrate to produce a photocathode. This "spray-on" technique offers a much simpler way to manufacture large photocathodes and offers a simple way for those without access to a vacuum-deposition system to make CsI photocathodes. The process is quite simple. First a 10% solution (by weight) of CsI is made in distilled water. This solution is then diluted to about four times its volume by the addition of ethanol. To rapidly evaporate the solvent during deposition, the substrate is heated from behind with hot air or from the front with heat lamps. The CsI solution is then sprayed on with an air brush until the desired thickness is achieved. To estimate the thickness, a thickness monitor is placed next to the substrate and is also coated.

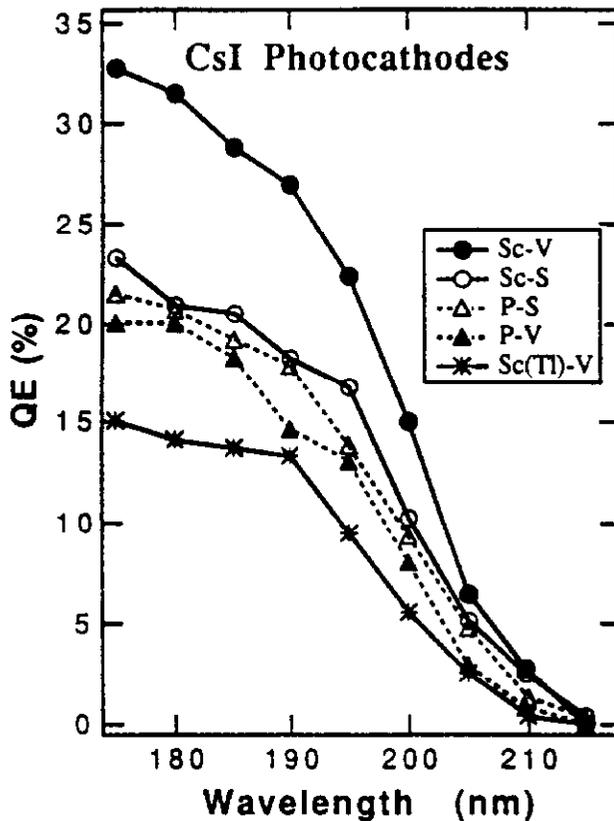


Fig. 1 The QE as a function of wavelength for five photocathodes: scintillator vacuum deposited (Sc-V), scintillator sprayed-on (Sc-S), powder sprayed-on (P-S), powder vacuum deposited (P-V), and CsI(Tl) scintillator vacuum deposited (Sc(Tl)-V).

The QE as a function of wavelength for five photocathodes is shown in fig.1. The photocathodes are made with scintillator vacuum deposited (Sc-V), scintillator sprayed-on (Sc-S), powder sprayed-on (P-S), powder vacuum deposited (P-V), and CsI(Tl) scintillator vacuum deposited (Sc(Tl)-V). One thing that is apparent is that the two photocathodes made with the powder, and the scintillator sprayed-on photocathode, have about 2/3 the QE of the photocathode made by scintillator vacuum deposited. Also, both photocathodes made with the powder CsI are somewhat inferior to even the scintillator sprayed-on photocathode. The degradation

in the QE from the thallium doping of the scintillator material is also evident.

Fig.1 shows that it is important to make photocathodes with undoped-CsI scintillator. It is known by those in the crystal scintillator business that CsI powder has a problem with collecting hydrocarbons from the air [6]. During the growing of the scintillator these impurities are removed. The initial bake out of the material removes most of the contamination that has collected on the surface of the scintillator. Powder that has not had an adequate bake out has even lower QE than shown here.

The final variable in the measured QE of a CsI photocathode is the measuring technique used. It is known that the QE of this photocathode is very sensitive to the electric field [1,2,4]. We find that the QE increases by at least 50% when going from an electric field of 1kV/cm to 4 kV/cm. Thus, measurements made in a current mode at low electric field [3] will measure a lower value than those measured by the photon counting technique [1] at a high electric field. It is also important which gas is used in making the

measurements. The QE measured in methane or ethane can be as much as 80% higher than the value measured in isobutane or vacuum, while noble gases such as argon or helium give even lower numbers [1].

This work has also shown that good CsI photocathodes can be made with a simple spray-on technique that requires a minimum of equipment. This also offers a way for very large photocathodes to be produced at a reasonable cost. Preliminary work has shown that these sprayed-on photocathodes have at least as good a resistance to aging in a wire chamber environment as the vacuum deposited [1] photocathodes.

One final note of interest concerns the QE of CsI photocathodes made from scintillator material vacuum deposited which have been left out in the room air for several days. After our standard bake-out procedure, the QE curve is very similar to the response of the three intermediate curves (Sc-S, P-S, and P-V). This indicates that there is some degradation, probably due to water, that is not recoverable with a low temperature bake out in vacuum.

Acknowledgments

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