

UV Photocathodes for use with BaF₂ Scintillator

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Abstract

The results of a systematic investigation of the properties of Decamethyl ferrocene, BaO, decamethyl chromocene, cyclopentadienyl iron hexamethyl benzene and CsI photocathodes, in the spectral range of BaF₂, are presented. The measurements were carried out in high vacuum. Four separate photocathode preparation techniques have also been investigated.

Keywords: UV photocathodes, BaF₂, Solid scintillator proportional counter

Introduction

In 1982 Laval *et al.*, (1982) reported the existence of a fast component in the scintillation light of BaF₂. This is centred at 220nm and 195nm and has a decay constant of 600ps. At about the same time a compound called tetrakis (dimethylamine) ethylene (TMAE) was found to have the lowest ionisation potential of any known organic compound (Nakato *et al.*, 1974). The vapor from this compound was reported to be capable of successfully detecting the ultraviolet scintillation light emitted from the xenon gas in a multiwire proportional chamber. This offered the possibility of constructing large area Detectors for example Cherenkov light, with high spatial resolution, and the ability to operate in strong magnetic fields. The coupling of BaF₂ scintillator to a multiwire proportional chamber filled with TMAE vapor was first reported by Anderson (1982). This made use of the principle that the ultraviolet scintillation light emitted from BaF₂ could ionise the TMAE vapor. The combined detector was given the name solid scintillator proportional counter (SSPC). The SSPC was first applied in an electromagnetic calorimeter to determine the energy and position of high energy electrons and

photons (Anderson 1983,1984). The detection of annihilation radiation in PET has recently been demonstrated (Anderson, 1988; Mine *et al.*, 1988)

The main physical limitations of a SSPC are on the one hand the fast ageing due to polymerisation observed with TMAE in a wire chamber (Woddy, 1988), and on the other by the small spectral overlap of the BaF₂ fast scintillation and the TMAE quantum efficiency, which allows only a small part of the BaF₂ fast emission component to be detected. The practical disadvantage of this detector is that TMAE is very reactive with air and corrosive. In addition it has a low vapor pressure at a room temperature. As a result the detector must be constructed with minimal use of organic materials and heated to 50-70°C in order to increase the vapor pressure to an adequate value.

In order to improve the SSPC it is important to find a photocathode that will detect the BaF₂ light more efficiently. This compound should be neither air-sensitive nor corrosive, and is easy to prepare as a solid photocathode. The work presented here is an investigation into such photocathode materials.

Experimental arrangement

In order to investigate the quantum efficiency of various VU photocathode materials we have developed a low current UV detector which is contained in a modified spectrophotometer (Phillips SP 800). The spectrophotometer has been converted to provide a calibrated source of UV light which is split into a reference beam and sample beam. The reference beam is monitored by a UV sensitive photodiode (Hamamatsu S1723-05) connected to a Keithly electrometer (Modle-617). The sample beam is allowed to pass through the fused quartz entrance window of the detector and to fall on the photocathode under investigation. Photoelectrons produced from the photocathode are collected on an anode wire plane situated above the photocathode, and the resulting photocurrent is recorded by a second electrometer (Keithly Modle-614). The photocurrent is measured as a function of wavelength over the interval 190 to 250nm. Once the scan has been completed the photodiode and detector results are entered in PDP-11 computer running a simple data processing routine. This corrects the data by subtracting the leakage current from the raw signal current, calculates the incident photon flux from the photodiode data and produces a table of QE vs λ .

Four separate photocathode preparation techniques have been investigated:

1. Evaporation of a solution made by dissolving the photocathode material in diethyl ether.
2. Sublimation of photocathode material under an argon atmosphere,

3. Vacuum evaporation, and

4. Vapor condensation.

The first samples were produced by dissolving the compound in diethyl ether (DEE) and applying the resulting solution to copper substrates in an argon-filled glove box. Films were also prepared by direct sublimation using a small evaporator placed in an argon-filled glove box at atmospheric pressure. The third technique involved the preparation of films in a vacuum evaporation unit working at 10^{-6} torr. The film thickness could be monitored using a calibrated vibrating quartz crystal (Itellimetric IL 002). For hygroscopic compounds, the evaporation unit was back-filled with argon before transferring the sample to the test chamber. In order to prepare condensed photocathodes, the compound is heated in a double-walled flask, and argon is then passed over the compound. The vapors carried through to the chamber are condensed on to a cooled copper substrate for a measured time. The chamber is then evacuated and the photocurrent measured as a function of incident wavelength over the range 190-280nm (See fig. 1).

Results

The first compound tested was Decamethyl ferrocene (DMFc) (Imrie *et al.*, 1990). The results obtained are shown in fig. 2. The surface obtained upon evaporating a liquied layer of DMFc dissolved in DEE produced the lowest quantum efficiency. It seems likely that this is due to the non-uniformity of the resulting surface. The argon sublimation technique was simple and resulted in quantum efficiency appreciably higher

than DMFc + DEE and not substantially inferior to that obtained by vacuum evaporation. The argon sublimation technique is particularly attractive if large area photocathodes are required. By numerically integrating the quantum efficiency curve over the BaF_2 emission spectrum the mean quantum efficiency of DMFc is estimated to be approximately 0.3%, which is similar to that obtained with ethyl ferrocene.

Results obtained from a number of films of barium oxide (BaO) and decamethyl chromocene (DMCr) were very disappointing. This was probably due to their being contaminated by oxygen or water vapor during preparation and / or transfer to the test chamber. As a result, we have concluded that these substances are too reactive for our purpose and will not be carrying out further tests on them.

The air-sensitive compound cyclopentadienyl iron hexamethyl benzene (CPIHMB) was prepared both by condensation and the argon sublimation technique. The results are shown in fig. 3. The maximum quantum efficiency achieved with both techniques was satisfactorily close to that previously obtained by condensation of CPIHMB vapor at CERN (Charpak *et al.*, 1989).

The best results obtained to date are from vacuum evaporated films of CsI, although they are substantially lower than results obtained at CERN, (see fig.4). At present we are investigating the effects of surface treatment with methane and other low ionisation-potential compounds, and already observe an increase in the quantum yield of such treated CsI photocathodes, confirming the work at CERN, although

the results are still appreciably lower in absolute terms.

Conclusion

It has been the aim of this work to investigate new air-stable photosensitive compounds which can detect BaF_2 fast emission component efficiently and which can be used at room temperature, using a simple technology to deposit them on surfaces as photocathodes.

With the products tested during the course of this investigation the maximum quantum efficiencies were obtained with CsI layers. These photocathodes are simple and easy to manipulate; they do not suffer from a brief contact with air; they are easy to prepare; they can achieve an efficiency that is comparable to or better than that of TMAE vapor if cleaner conditions than used in this work are employed. The obvious advantages of these photocathodes when used in an SSPC will be fast response, suppressed photon feedback and room temperature operation.

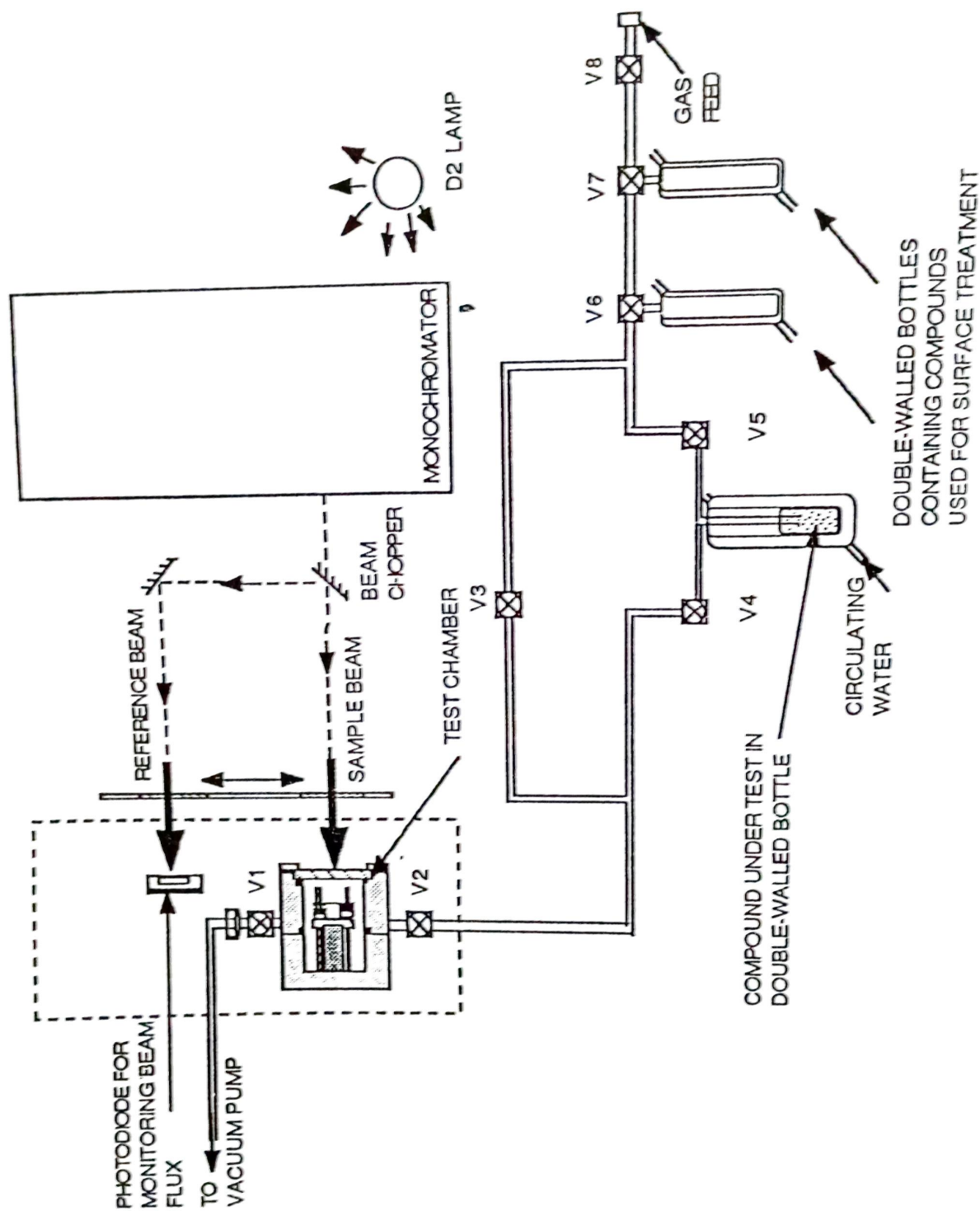
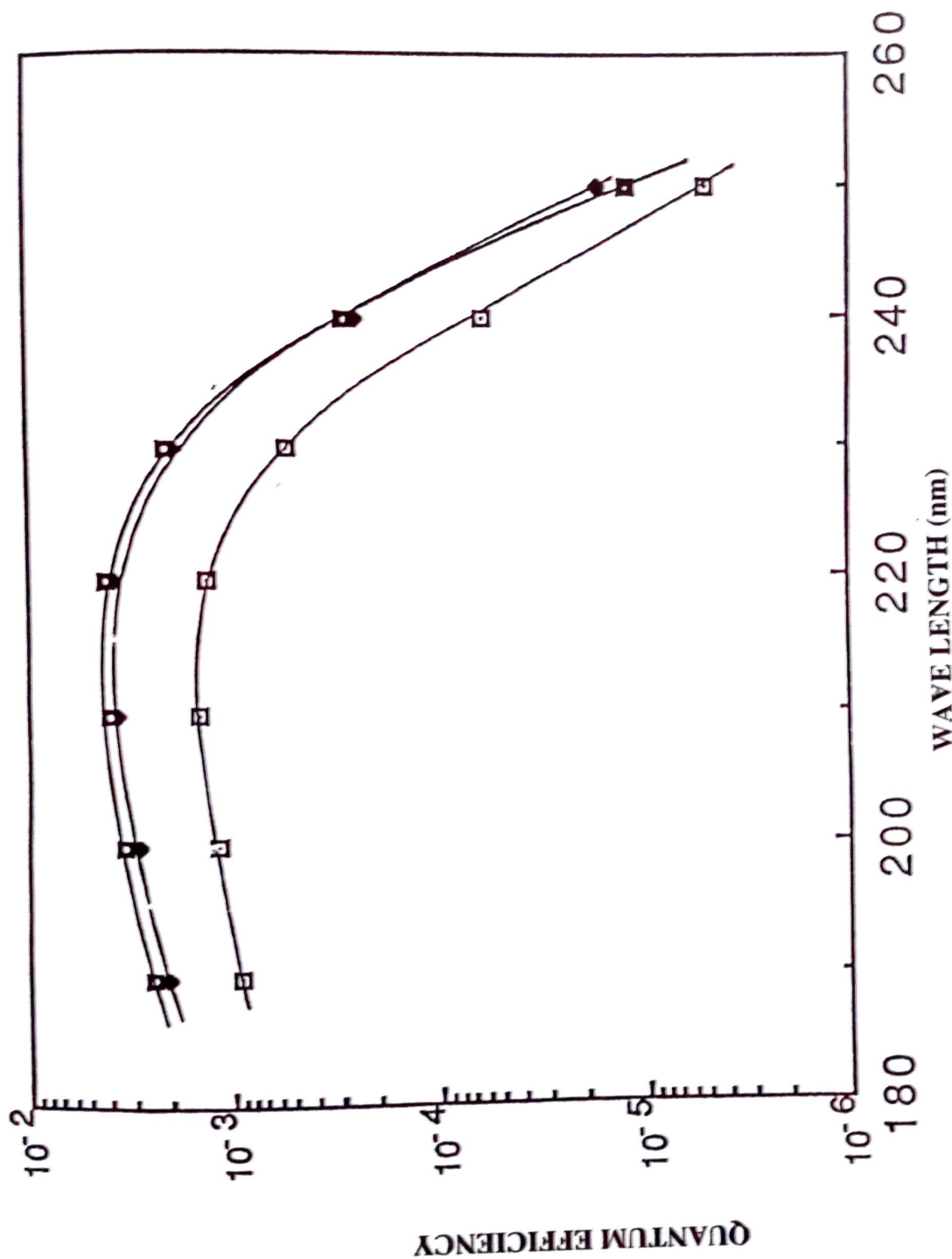


Fig 1. Schematic diagram of experimental arrangement



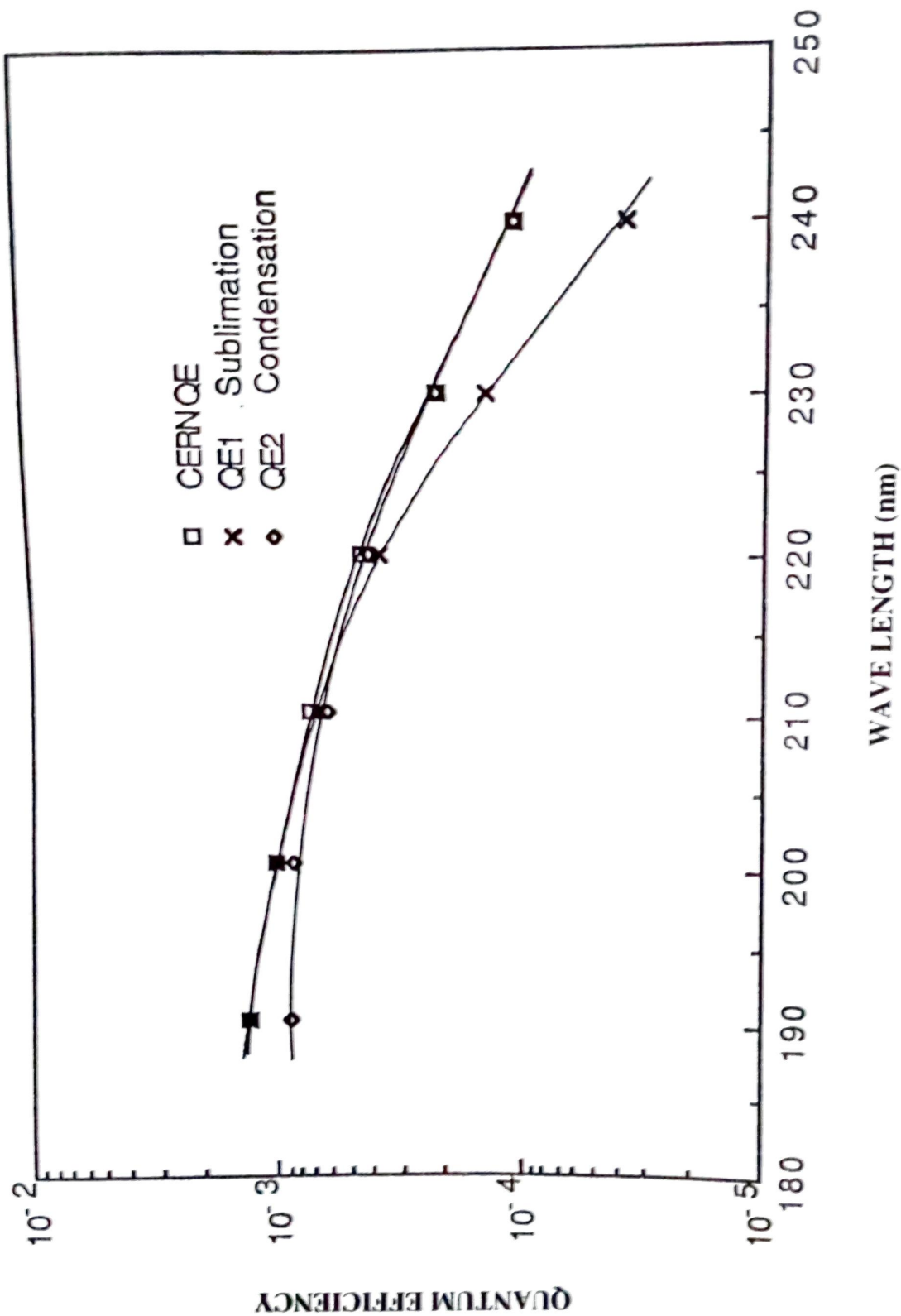


Fig 3. Quantum efficiency of CPIHMB

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