PARTICLE DETECTION BY SECONDARY ELECTRON EMISSION FROM LOW-DENSITY KCl *

R. DiNardo, BNL

INTRODUCTION

The development of advanced particle detectors for the ISABELLE facility is now under consideration. One type of detector, proposed here, utilizes the secondary electron emission from a low-density KCl layer as the particle goes through the layer. This type of detector is interesting for several reasons:

1. Since the secondary electrons are created only as a result of incident particle interaction, the mechanism is applicable for very fast detectors.

2. Because of the low density of the target (~ 0.02 g/cc), more than one detector can be placed along the particle trajectory in order to provide both space and time resolution.

3. Since the secondary emission depends on the energy loss of the particle, it is possible to determine the velocity and identity of minimum ionizing particles.

4. The secondary electron yield (usually $\gg 1$ per event) can be coupled with other detection mechanisms (phosphor, MCP, etc.).

LOW-DENSITY KCl TARGET

The low-density KCl targets used in recent high energy particle detector investigations¹⁻⁴ have been very similar to those first developed by Goetze⁵ for use in image amplifier tubes. The basic structure of the target (Fig. 1) consists of an Al_2O_3 supporting layer ($\sim 1000 \text{ \AA}$), an aluminum signal-plate layer ($\sim 500 \text{ \AA}$),

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Fig. 1. Cross section of a low-density dynode.

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MASTER⁻¹⁻

and the low-density KCl layer, which is prepared by evaporation in an argon atmosphere at a pressure of a few Torr. The resulting KCl structure is one in which ~98% of the volume occupied by the active layer is vacuum and the rest is a fibrous maze of the KCl. The average thickness of the fibers is about 100 Å.

SECONDARY ELECTRON YIELD

The secondary electron yield can vary from a few to several thousand depending on the incident particle and its velocity. Sternglass and Goetze³ calculated the secondary electron yields expected from various types of incident charged particles of different energies, on the basis of the performance of low-density KCl targets under the impact of kV electrons. They considered the mass density of the KCl layer, assumed the yield to be directly proportional to the rate of energy loss, and included corrections for the transmitted and back-scattered energy. They obtained a useful curve of secondary electrons emitted per incident particle for different rates of energy loss (Fig. 2). They also did experimental tests with α particles and got results in good agreement with their theoretical expectation. Recent results by Faivre et al.⁴ show secondary yields of about 5 per incident particle for high energy protons and electrons for a 300- μ m layer.

SPATIAL RESOLUTION OF SECONDARY ELECTRON EMISSION

Goetze studied the spatial resolution of the secondary electron emission from 40- μ m-thick KCl layers by imaging onto a phosphor and found it to be better than 40 μ m. As the thickness of the low-density KCl layer is increased, the scattering of secondary electrons within the KCl layer should also increase.

Fig. 2. Calculated number of secondaries emitted from typical high-grain dynodes for charged particles with different rates of energy loss, dE/dx .

RESPONSE TIME OF SECONDARY ELECTRON EMISSION

Using pulsed incident currents, Sternglass and Goetze⁸ showed the response time for secondary electron emission from 10- to 20- μ m-thick KCl layers to be <0.5 ns. Recently Ageron et al.⁵ measured time resolutions to better than 0.25 ns.

LINEARITY OF SECONDARY ELECTRON EMISSION

The secondary electron yield for incident kV electrons has been found to be constant over a range of electron current densities of 2×10^{-12} to 2×10^{-7} A/cm². Garwin and Edgecumbe¹ carried out yield measurements on low-density KCl layers (~ 25 μ m) with electrons from the Stanford linear accelerator. For an incident electron beam of 965 MeV, they found the secondary yield to decrease strongly for beam intensities $\geq 10^9$ electrons/pulse or 10^{-9} A (1.25-cm² spot size). The effect is thought to be due to bombardment-induced conductivity in the KCl, which limits the magnitude of the internal field possible.

POTENTIAL OF KCl SURFACE AND COLLECTOR

A review of different secondary electron emission investigations reveals not only a difference in beam mode (particle, pulse, or constant current) but also a difference in the method of field-assisting the emission.

As a result of secondary electrons escaping the KCl surface, the surface achieves a positive charge density. Under constant current conditions, the exit surface finally assumes a potential equal to that of the collector. The electric field across the low-density layer is then the collector voltage divided by the layer thickness. The investigations by Goetze et al.⁹ show that, when the KCl surface charges up to the collector potential, the relation between the secondary electron yield and the collector voltage is independent of the target-to-collector distance. This result makes it clear that differences in potential of the KCl surface will result in variations in the secondary electron yield over the KCl surface.

Most of the high energy particle investigations²⁻⁴ have used particle or pulsed beams and very large collector voltages. No indication has been given whether the KCl surface had reached steady-state charge stabilization.

ENERGY OF INCIDENT PARTICLE

Garwin and Edgecumbe¹ measured the dependence of the secondary electron yield on incident energy for 100- to 1000-MeV electrons and a 25- μ m KCl layer. They found the yield to increase logarithmically with increasing energy, in agreement with the results expected from the relativistic rise in the ionization losses. For thicker KCl layers (~ 500 μ m) the density effect must be considered.

THICKNESS OF KCl LAYER

Both the secondary electron yield and particle detection efficiency have been measured as a function of low-density KCl layer thickness with 400-MeV protons. Faivre et al.⁴ found the secondary electron yield to increase from 2.2 to 4.87, and the particle detection efficiency to increase from 75 to 94%, as the KCl thickness was increased from 100 to 400 μm . The layout of the experiment is shown in Fig. 3.

TARGET LIFETIME

The operational lifetime of the KCl target is of much concern in practical utilization as a particle detector. Goetze et al.⁹ subjected a low-density KCl layer to a 7-kV electron beam of 10^{-5} A/cm² for 1000 hr. The gain stayed at its stabilized value throughout that time within the experimental uncertainty in the secondary electron yield, $\pm 4\%$. The total incident charge delivered to the KCl layer was 1.6×10^{-2} C/cm². Using high energy electrons, Garwin and Edgecumbe¹ noted $<10\%$ degradation of gain for total charge of 0.5 C/cm², so that particle densities of about 10^{18} particles/cm² are tolerable. It seems that such a detector will easily have sufficient radiation resistance for use at ISABELLE.

Fig. 3. Experimental layout for measuring secondary electron yield and particle detection efficiency.

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