

Transmission of ~ 10 keV Electron Beams through Thin Ceramic Foils

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The excitation of dense gas targets with particle beams requires the use of entrance foils through which the projectiles can enter the gas. Very thin (~ 300 nm) ceramic membranes made from layers of 77 ± 5 nm SiO_2 and 223 ± 5 nm Si_3N_4 are routinely used by our group to send low energy electron beams ($E \approx 12$ keV) into gas targets [1,2]. Light emission induced by beam power deposition in the gas is studied and used for practical applications such as photoionization in the ion-sources of mass spectrometers [3]. For the fundamental studies as well as for the practical applications it is important to characterize the interaction of the projectiles with both the entrance foil and the target gas. The shape of the electron beam excited volume had been studied by observing the light emitting volume and performing Monte Carlo simulations using the program CASINO [4,5]. Here we describe a measurement which characterizes the energy loss of the projectiles in the entrance foil [6].

Electron beams of variable particle energy were produced by an electron gun and sent through the ceramic membrane. A retardation field method was used to analyze the energy distribution of the electrons. These distributions were compared with model calculations performed with the program packages CASINO and Geant4 [7]. The experimental setup is schematically shown in Fig. 1. A retarding voltage was applied between an entrance electrode on ground potential (G in Fig. 1) with a 2 mm diameter entrance aperture covered by a grid and a second electrode (R in Fig. 1) with a 5 mm aperture, also covered with a grid. The beam current was measured on the third electrode (D) versus the retarding voltage. The energy distributions were derived by differentiating the beam current versus retarding voltage data.

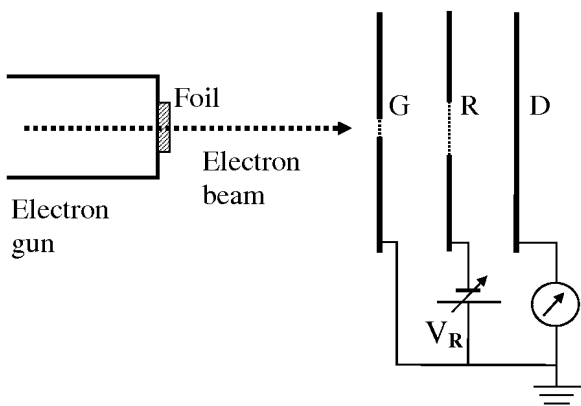


Fig. 1: Schematic drawing of the setup. An electron beam is sent through a 2×2 mm² silicon oxide/silicon nitride foil. The energy distribution is measured via the retardation voltage V_R which is applied to the electrode **R**. It is placed between a grounded entrance electrode **G** and an electrode **D** used for collecting the electrons and measuring the beam current.

First the retarding field technique has been tested without the entrance foil. The results have shown good agreement with known near mono-energetic electron energy dis-

tributions of the beam generated by the electron gun. The transmission through the foil was measured for three energies of the incident electrons: 12.12, 10.12, and 8.09 keV. A measurement under an angle of 30° with respect to the beam axis was also performed for comparison with angular resolved model data which are provided by the Geant4 package.

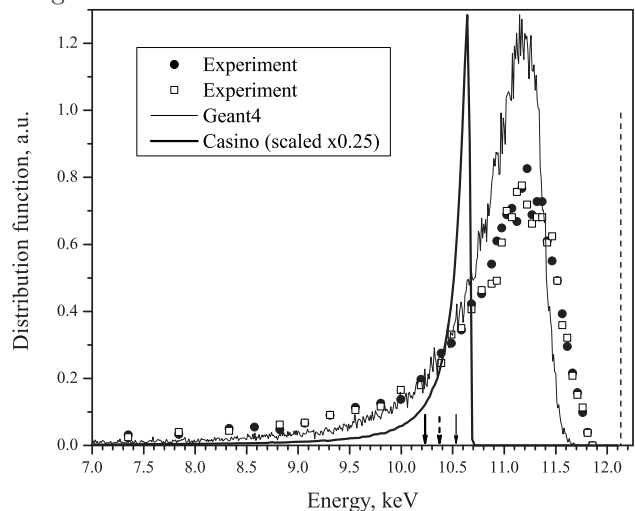


Fig. 2: Measured and modeled electron energy distribution functions for an incident electron energy of 12.12 keV (dashed vertical line). The two experiments correspond to beam currents which differ by roughly one order of magnitude. The arrows indicate the average transmitted energies for the experiment (dashed), Geant4 (thin line), and CASINO (thick line), respectively.

The results of the measurement under 0° and for an electron energy of 12.12 keV are shown in Fig. 2. This is the situation which is most relevant for our practical applications. The main result is that the energy distribution of the electrons exiting the foil is adequately represented by Geant4 simulations. The distribution provided by the CASINO package is too narrow and the peak is shifted to significantly lower energies than observed experimentally. The average energy which is transmitted through the foil is, however, well reproduced by both Monte Carlo programs, CASINO and Geant4 (arrows in Fig. 2). For applications of this study it was particularly important to quantify both the experimental error and the errors which must be expected when applying the model programs. It was found that the maximum uncertainty of the transmitted energy is 6% for electron energies of 10 to 12 keV. This value results from a linear sum of a 3% error of the experimental data and the $\sim 1.5\%$ errors of the foil parameters and the maximum observed difference between the measured and calculated average transmitted energy. A detailed discussion of the data and their accuracy can be found in [6].

References

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