A Transmission Beam Current Monitor Based on Residual Gas Ionization

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The ERD setup at the Q3D spectrograph of the Munich Tandem Accelerator allows precise, depth resolved measurements of impurity contents in solid state samples (e.g. semiconductor materials) [1]. To learn more about not only contents, but also lattice sites of impurities, future channeling experiments are planned. The measured quantity herein is the number of scattered ions of a certain species per incident ion in dependence on its incident angle, which is reduced for lattice atoms near main lattice directions [2]. Therefore, it is necessary to monitor the incident beam current on the sample in real time. A reliable beam current measurement on bulk samples cannot be performed in the Q3D scattering chamber due to secondary electron emission. Therefore other ways have to be investigated to provide a versatile, accurate real-time beam current monitor.

A possible solution is the employment of beam-induced residual gas ionization for current measurement [3,4]. Herein the secondary ions generated in a defined volume by interaction of the beam with the residual gas are accelerated towards a microchannelplate stack (fig.1).

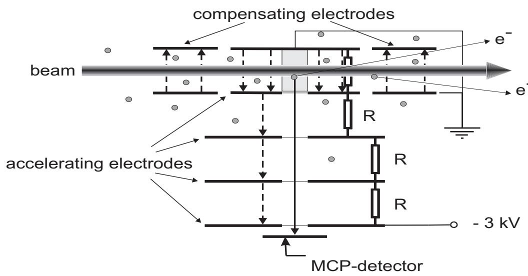

Fig. 1: Electrode configuration of transmission beam current monitor

The countrate of detected ions is given by

$$\frac{dN}{dt} = C \cdot n \cdot \Delta x \cdot I \cdot \sigma$$

where n is the density of the residual gas, σ the crossection for residual gas ionization, C the collection and detection efficiency, Δx the interaction length and I the beam current. This leads (with C=1) cto an expected countrate of 10^5 Hz for 1 nA (el.) of 170 MeV ^{127}I at 1×10^{-7} mbar, with n=5.4×10^9 cm^{-3}, Δx=1 cm and σ=5×10^{-14} cm^2 (estimated from the stopping power of Iodine in nitrogen). Since σ varies with gas composition it is necessary to calibrate the measurement by a faraday cup. Only a small long term drift can be tolerated in order to minimize the need for recalibration. Since residual gas pressure affects the detection efficiency of the MCP detector due to surface contamination, pressure has to be kept low and stable in order to maintain a constant efficency.

After installing the monitor in front of the Q3D scattering chamber and pumping the system down to 1×10^{-6} mbar, test measurements were carried out during a regular ERD-beamtime at the tandem accelerator. The rate of scattered ions from the ERD sample (fixed angle) was taken as a calibration for beam current. The beam current was around 1 pnA of ^{127}I at 170 MeV. The actual current was calculated from the number of scattered particles from defined samples at known geometry. The countrates in both ERD experiment and beam monitor are normalized by their average value and plotted against time in fig.2a. Despite of large fluctuations the ratio, also plotted in fig.2a, is approximately 1 with a small linear increase. This may be due to pressure increase or electron polishing of the channel plate surface during high countrate operation, leading to better secondary ion yield. This increase can be corrected in future, however. The fluctuations around the linear trend are below 2% FWHM in all runs and provide a reliable current calibration for channeling measurements. In fig.2b the countrate is plotted against the ion current for several runs. The different symbols correspond to different ERD runs and show an efficiency spread due to pressure fluctuations. Within a single run the spread is very small. From the linear fit though all data points the total detection efficiency for 170 MeV ^{127}I at 10^{-6} mbar can be determined to 1.36×10^{-5} counts/beam particle with an efficiency constant C of about 0.1.

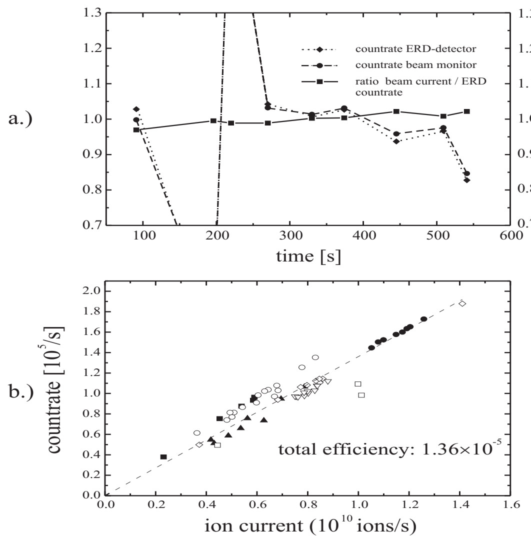

Fig. 2: (a) Countrates in beam monitor and ERD-detector (dotted/dashed) and their ratio (solid). (b) Countrate in beam monitor vs. ion fluence determinied by ERD. Different symbols correspond to different ERD-samples.

As a summary, the beam monitor meets the specifications and will be used as a calibration tool for channeling applications. In the near future, a transportable housing equipped with a turbomolecular pump and a gate valve will be added. This allows the monitor to be retracted and moved to every standard 4" CF cross piece in the beamline without flooding the system.

References

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