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A pre-sample charge measurement system for quantitative NMP-analysis

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ABSTRACT

In many IBA applications the main aim is to obtain quantitative figures characterizing the sample. Normally charge, i.e. number of probe particles, is used for normalization and is measured either by collecting the charge deposited in the sample or by collecting the particle in a post-sample Faraday cup or in combination. Both these techniques have drawbacks and results can be difficult to compare for samples with different matrix composition.

In this work, we present an upgraded design and test results from the Lund NMP pre-sample charge measurement system. The system presented is based on a pre-sample beam deflection controlled by the beam scanning system for the nuclear microprobe. It can be operated in different modes, but during normal operation the beam is blanked once per pixel and the corresponding charge is collected during the beam-off period. The system does not only measure an average of the beam current during data collection, but actually a pixel-by-pixel normalization is possible. Data of the system performance are presented and in addition illustrations of how quantitative measurements both for PIXE and elastic scattering can be made more reliable.

1. Introduction

For many IBA applications the main aim is to obtain quantitative information characterizing a sample, e.g. PIXE and RBS. Normally charge, i.e. number of probe particles are measured either by collecting the charge deposited in the sample or by collecting the particle in a post-sample Faraday cup and used as reference. Both these collection techniques have drawbacks and results could be difficult to compare with standard samples with different matrix composition. The Faraday cup measurements is limited in conditions where part of the incoming beam is scattered e.g. in semi-thick samples, thus to small charge is measured. For focused ion beam analysis the problem could be even worse with changing matrix composition over the analyzed area. One attempt to reduce the matrix effects is the "Q factor method" suggested by Grime [1] for microPIXE analysis, where backscattering information is used to compensate for variations in secondary electron emission by detailed modelling. An alternative way, using pre-sample measurement, has been suggested by Bouanani et al. [2] who developed a "slit – fine mesh grid" system where a fraction of the incoming beam is collected on the grid and used for normalization. Alternative techniques include pre-sample beam monitoring by e.g. a rotating chopper or scattering of part of the beam into a particle detector using a thin foil. Such techniques are indirect and must be calibrated regularly. The method presented in this paper can be classified as an electric high voltage chopper where both chopping frequency and intercepting time can be software controlled.

One of the advantages with focused ion beam analysis is the control the experimentalist has over the beam. The normal microprobe set-up has a number of beam defining slits with geometrically small openings and the last focusing takes place after the last pair of slits. This means that the beam passing these slits is well defined in position and the same as on the sample. Hence, measuring the beam at this position will give the charge on the sample.

Beam blanking has previously been used, mainly far upstream, with intention to reduce pile-up or minimize beam-induced damage in the sample by removing the beam during pulse processing [3]. Alternative use has been for low dose applications like single cell irradiation [4], implantation [5] or ion beam lithography [6], where beam control and irradiation dose are important. In this work, we present an upgraded version of the charge measurement system at the Lund nuclear microprobe, now adapted for pixel-by-pixel normalization. It is based on a pre-sample beam deflection previously developed for ion beam lithography [6,7] and is controlled by the beam scanning system for the nuclear microprobe.

2. Experimental set-up

The beam blanker system is installed at the sub-micron beamline at the Lund nuclear microprobe facility [8–10] and controlled by a CAMAC based data acquisition and control system [11]. Fig. 1

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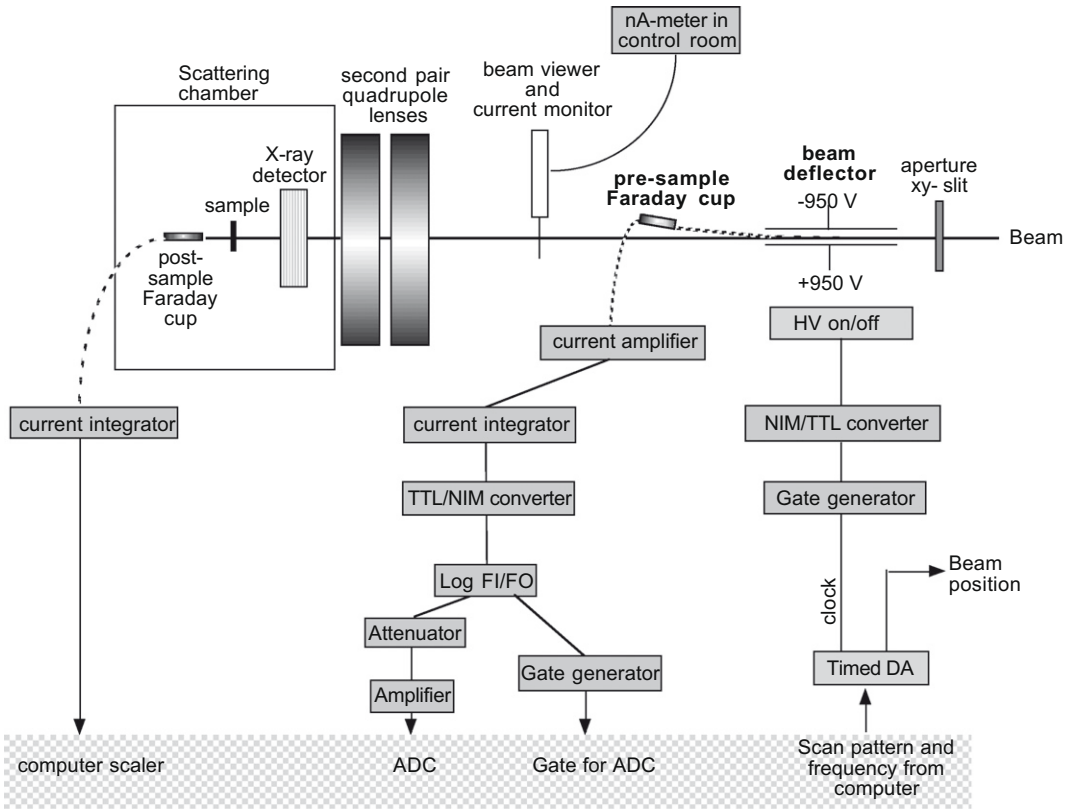

Fig. 1. The layout of the experimental set-up. On top the position of the different elements in the beam-line is shown and below a drawing of the pulse handling part of the blanking system is shown.

shows the mechanical layout of the last part of the beam-line with the blanking system and a corresponding layout of the electronic control and read out. The beam enters from the right, passes the last aperture (*xy*-slits) and passes between two 250 mm long deflector plates (blanker). In case of no electrical field the beam will continue through the focusing magnet onto the sample and in case of voltage on (blanking) it will be directed into the pre-chamber Faraday cup. The voltage is generated by a supply, PVM-4210 [12], from Direct Energy Inc., and can be varied up to ±950 V, i.e. a maximum potential difference of 1900 V and has to be set for each individual particle–energy combination. The specification of the pulse rise time is 15 ns, the throughput delay approximately 100 ns and the pulse recurrent frequency 20 kHz. The Faraday cup is read out by a current amplifier coupled to a standard current integrator from Ortec [13]. Here the range has to be adapted and optimized for the current of each individual application so that the range (10 kHz) of the current integrator is used optimally.

Calibration can be done using the current information from the beam viewer/stopper, just after the pre-sample Faraday cup. The TTL signal from the current integrator is shaped before conversion by the ADC and then treated in the same way as an ordinary detector signal, and hence stored with position information. Since these "charge events" mainly take place during beam-off it does not disturb the ordinary data stream.

3. Experimental test and discussion

3.1. Pre-chamber measurements

The first tests of the system were performed before the chamber using the current from the beam viewer as a reference. In Fig. 2a the count rate from the pre-sample Faraday cup is plotted versus measured current at the beam stop. It shows a linear dependence over the range from about 100 pA and upwards and the deviations

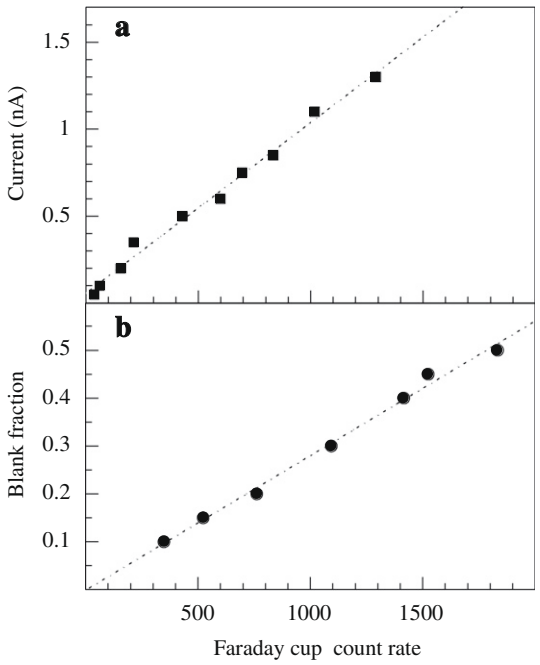

Fig. 2. The results from the pre-chamber measurement show the expected linear dependence. Faraday cup count rate versus current (a) and versus blanking fraction (b). The small scattering around the lines is contributed to experimental errors in reading the current and setting the blanking fraction gate width.