Institut für Allgemeine Physik - Vienna University of Technology

Charging and discharging of nano-capillaries during ion-guiding of multiply charged projectiles

M. Fürsatz[1], W. Meissl[1], S. Pleschko[1], I.C. Gebeshuber[1], N. Stolterfoht[2], HP. Winter[1], and F. Aumayr[1]

[1]Institut für Allgemeine Physik, Vienna University of Technology, Wiedner Hauptstraße 8-10, 1040 Vienna, Austria

[2]Hahn Meitner Institut Berlin, Glienicker Str. 100, D-14109 Berlin, Germany

http://www.iap.tuwien.ac.at/www/atomic/

e-mail: aumayr@iap.tuwien.ac.at

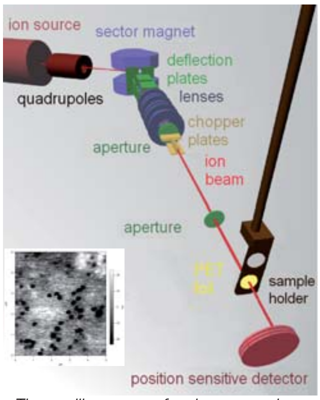
ABSTRACT

Efficient guiding of slow (typ. keV) highly charged ions (Ne^{7+}) through insulating nano-capillaries has been observed even if the capillaries were tilted by up to 20° with respect to the incoming ion beam direction [1]. Surprisingly, the majority of the projectile ions was found to survive the transition through the insulating capillary in their initial charge state. Measured 1-dim. scattering distributions of the transmitted particles indicated propagation of the projectile ions along the capillary axis. As reason for this "guiding effect" a charging-up of the inner walls of the capillaries in a self-organized way due to impact of preceding projectile ions has been proposed [1-4].

Theoretical modelling of the experimental observations has so far proven to be a challenging task [1-4]. Difficulties arise especially due to the different characteristic times observed in the experiment for capillary-wall charging and discharging [3, 4].

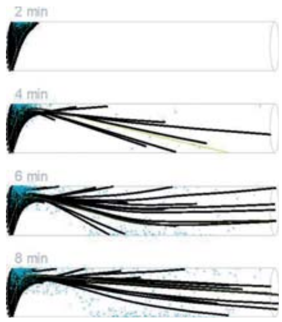
To gain more insight into this interesting phenomenon we have measured the 2-dim. scattering distribution of transmitted projectiles during the charging-up process.

EXPERIMENTAL SETUP



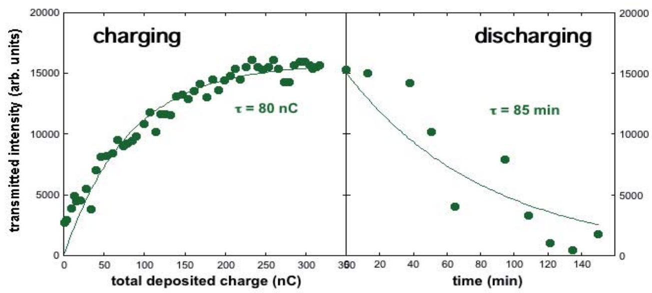
The capillary target for these experiments consisted of a 10 µm thick PET (polyethylene terephthalate) foil from HMI-Berlin. It was characterized with AFM at TU Wien (mean capillary diameter: 180 nm ± 25%, capillaries per unit area: $4x10^8$ cm^{-2}).

CHARGING SIMULATION



Simulation of charging effects in insulating capillaries taken from ref. [3].

TRANSMITTED INTENSITY DURING CHARGING-UP AND DISCHARGING



Evolution of the transmitted intensity as a function of total deposited charge during the charging-up phase (left) and as a function of time during the discharging phase (right). Data for 12 keV Ar^{8+} projectiles and 4° tilt angle.

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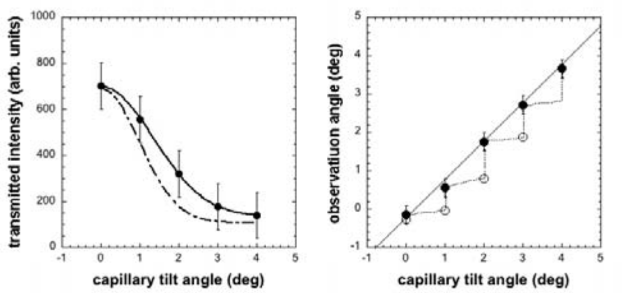
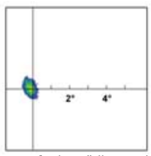
HCI GUIDING THROUGH NANO-CAPILLARIES

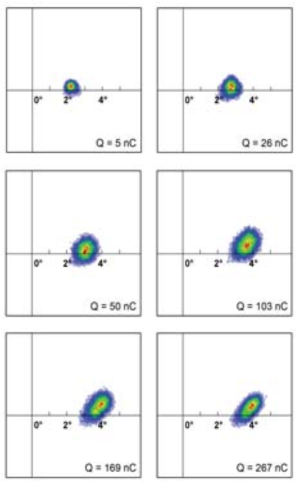


Intensity of the transmitted projectiles (left) and observed peak angle of „guided" projectiles (right) after transmission of the PET capillary target as a function of capillary tilt angle for 12 keV Ar^{8+} projectiles. The dash-dotted curve in the left part shows the results of modeling calculations [11] using the theoretical framework described in [3, 4]. Interestingly our data for the „uncharged" capillaries (open symbols) indicate a certain time/charge dependence of the guiding effect, which we wanted to investigate in more detail.

EVOLUTION OF 2-D SCATTERING DISTRIBUTION DURING CHARGING-UP

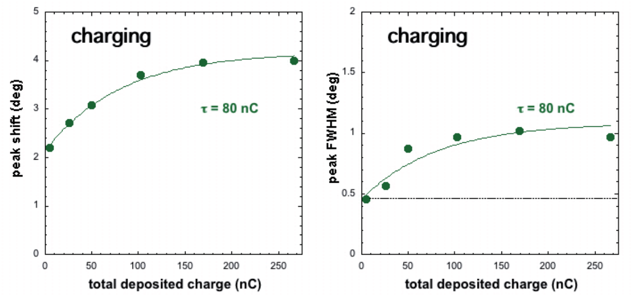


above: Image of the "direct beam". 0° corresponds to the position of the incident ion beam (i.e. when removing the nano-capillary target).



right: Evolution of the measured 2-dim. scattering distribution for 12 keV Ar^{8+} ions transmitted through PET capillaries (tilt angle 4° with respect to the incident ion beam direction) during the charging-up phase.

below: Peak position (left) and width (FWHM, right) of the guided projectiles as a function of total deposited charge during the charging-up phase. Data for 12 keV Ar^{8+} projectiles and 4° tilt angle.



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