Conductivity mechanism probed by ion transmission through nanocapillaries during the discharging process

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Synopsis We studied the decrease of the guided transmission due to discharging of nanocapillary walls in polyethylene-terephthalate (PET) foil. After developing the stable guided transmission, the ion beam was switched off and the transmission was tested time to time by short pulses. The transmission monotonically decreased but its time dependence significantly deviated from a simple exponential decay. Our results suggest a non-linear connection between the guiding field and the depleting current of the deposited charge.

Guiding properties of nanocapillaries in insulating materials has gained increasing interest in the last decade [1-4]. The root cause for this process is the self-organizing electrostatic charging up. The incident ions collide with the inner walls of the capillary, deposit their charge and form a repulsive electrostatic field. The subsequently incoming ions are deflected in this field and transmitted through the capillary.

In a regular case the transmission of incident ions monotonously increases until a stable transmission is reached. By switching off the incident beam, the guiding field slowly decays due to the discharge of the capillary walls. The subsequent decrease of the transmission was measured in two early works [1,5]. Later it was recognized [6,7] that it can be a probe for studying the motion of charges at insulator surfaces.

In the present work, we measured the transmission of 3-keV $^{22}Ne^{7+}$ ions through nanocapillaries (~200 nm diameter, $3x10^8/cm^2$ density) formed in a 12µm thick PET foil. After charging up the sample, we switched off the incident beam, and studied the decay of the transmission. From time to time, the transmission rate was tested by three consecutive short pulses. It is noted that the test pulses may recharge the capillary. Since the transmission was practically the same for all the three test pulses, we concluded that this was not the case.

The transmission rate was a monotonically decreasing function of time (see fig. 1.). At the beginning the transmission dropped quickly but later the decay slowed down significantly. In a linear-logarithmic plot the decay function clearly deviates from a straight line, demonstrating that the decay is not exponential, which would be expected in a linear system with field independent conductivities.

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We assume that without incident beam, the time development of the transmission is determined only by the discharge current. As a first attempt, for the field dependence of the conductivity we apply the already considered nonlinear Frenkel-Poole model [3,8], which results in a good agreement with the experimental data.

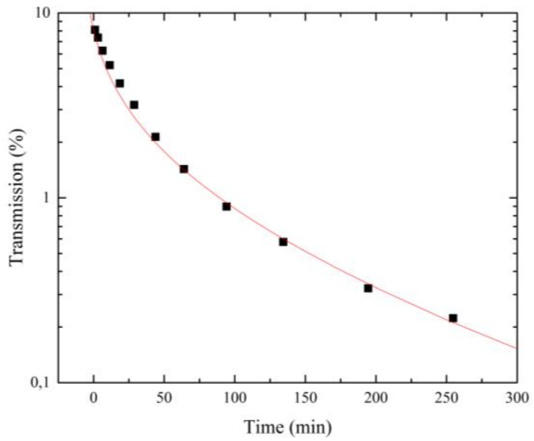

Figure 1. Experimentally measured decay of the transmission at Ψ=5.7° tilt angle as a function of time (squares). The curve is a fitting of the data by the nonlinear conductivity model.

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