Nuclear Instruments and Methods in Physics Research B 354 (2015) 328–331

Contents lists available at ScienceDirect

Nuclear Instruments and Methods in Physics Research B

journal homepage: www.elsevier.com/locate/nimb

Interaction of proton microbeam with the inner surface of a polytetrafluoroethylene macrocapillary

I. Rajta *, G.U.L. Nagy, R.J. Bereczky, K. Tőkési

Institute for Nuclear Research, Hungarian Academy of Sciences (MTA Atomki), P.O. Box 51, H-4001 Debrecen, Hungary

ARTICLE INFO

Article history:
Received 22 September 2014
Received in revised form 10 December 2014
Accepted 16 December 2014
Available online 23 January 2015

Keywords:
Proton micro beam
Mesoscopic capillary
Charged particle guiding

ABSTRACT

The transmission of 1 MeV proton microbeam through a single, cylindrically shaped, micrometre-sized polytetrafluoroethylene capillary was studied. The capillary axis was tilted with respect to the axis of the incident ion beam. The tilting, the aspect ratio of the capillary and the small beam divergence disabled the geometrical transmission of the beam through the target. The time dependence of the intensity, the charge-state and the deflection of the transmitted beam were investigated. We found that pure guided transmission of a MeV/amu energy ion beam is possible through an insulator capillary.

1. Introduction

Charged particles are able to pass through insulator capillaries keeping their initial energy and charge state even if the capillary axis is tilted with respect to the incident beam axis larger than the geometrical limitation. The phenomenon is called guiding effect and it has been intensively studied since its discovery [1–12]. According to our recent knowledge guiding effect is based on the creation of self-organised charge patches on the inner surface of the target capillaries, producing a guiding electric field. The guiding sets in when these charge patches reach a dynamical equilibrium, i.e. the arriving and leaving particles result in a constant amount of charge: arriving ions come from the incident beam, while the accumulated charge decreases by transport into the bulk or on the surface towards the capillary exit. The first experimental and theoretical works used insulating foils (PET, Al_2O_3, etc.) with randomly distributed nanocapillaries as targets combined with highly charged, slow heavy ions (HCIs) projectile ions. These conditions showed up certain difficulties, such as the imperfect parallelism of the capillaries [13] or the collective effect of the neighbouring capillaries. Later, to avoid these difficulties, the single, micrometre sized and cylindrical shaped capillaries came into focus [14–21]. The advantage of using these types of targets is the many possible technical applications of them, such as to provide ion beams steering or focusing without external power supplies.

In the present work the transmission of 1 MeV proton microbeam through a single, cylindrically shaped, micrometre-sized polytetrafluoroethylene (PTFE) capillary was studied. The capillary axis was tilted with respect to the axis of the ion beam such that the geometrical transmission of the beam through the target was impossible. We present the charge-state, the deflection and the time dependence of the intensity of the transmitted beam.

2. Experimental setup

In our experiments we used a single, cylindrically shaped and micrometre-sized capillary made of PTFE. Fig. 1 shows a picture of the macrocapillary target of $L = 44.5$ mm long and $d = 800$ µm diameter. As projectiles we used single charged H^+ ions. The beam was focused down to $2 \times 2\ \mu m^2$ and the energy of the proton microbeam was 1 MeV. The beam focus was on the centre of the capillary entrance, the current was a few pA.

The tilt angle of the capillary axis was 1° relative to the beam axis. Since the aspect ratio of our capillary targets is ~56 and the divergence of the proton microbeam is less than 0.3° the target was geometrically non-transparent for the beam.

To perform the capillary experiments with proton microbeam, the Oxford-type nuclear microprobe installed on the 0° beam line of the 5 MV Van de Graaff accelerator of MTA Atomki, Hungary, was modified [18]. To measure the intensity of the incoming current, a beam chopper [22] placed in front of the target was used. The particles backscattered from the chopper are detected with a particle detector by periodically interrupting the beam by a rotating vane. This allowed us to control the incident beam current according to the particle count rate. The transmitted current was monitored by a Faraday-cup at the outlet of the capillary. The signal from the beam chopper and the Faraday-cup was recorded in every second by a PC data acquisition system.

* Corresponding author.

http://dx.doi.org/10.1016/j.nimb.2014.12.042
0168-583X/© 2015 Published by Elsevier B.V.

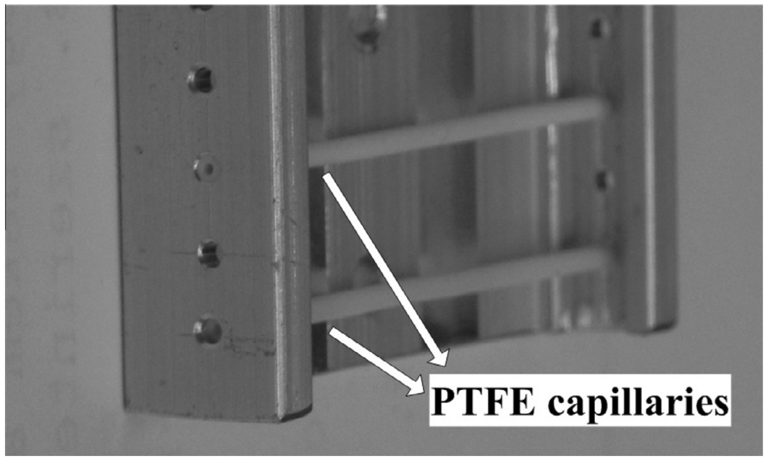

Fig. 1. Picture of our cylindrical shaped PTFE macrocapillary targets.

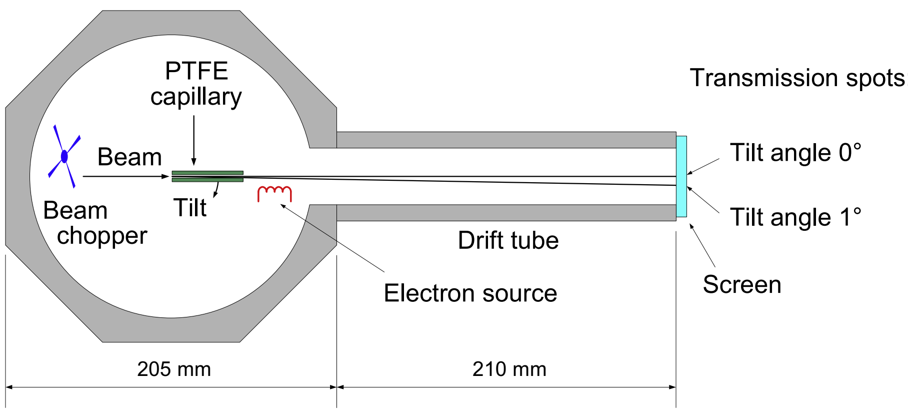

Fig. 2. The schematic diagram of the experimental setup for measuring the deflection of the transmitted beam (top view).

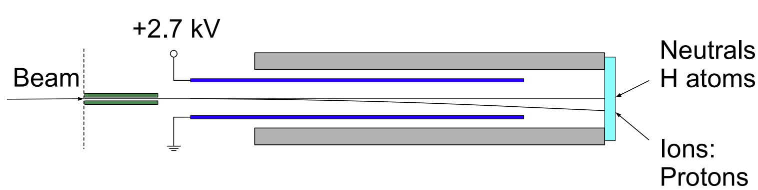

Fig. 3. The schematic diagram of the experimental setup for measuring the charge state of the transmitted beam (side view).

For the deflection measurements another setup was used. In order to visualise the transmitted beam a fluorescent screen, which has orange colour when the beam reaches it, was placed at the end of the chamber. Since we carried out our investigations at small angles (typically around 1°), a 210 mm long drift tube was placed between the target and the screen to magnify the deflection. The screen was mounted onto a transparent substrate, thus we could observe the actual position of the beam from behind. Fig. 2 shows the schematic view of the experimental setup for measuring the deflection of the transmitted beam.

Inside the drift tube an electrostatic parallel-plate deflector was mounted (Fig. 3), to provide charge state determination of the particles transmitted through the capillary, since they can either keep their initial charge state and remain protons or lose their charge and become neutral H atoms. 2.7 kV DC high voltage was applied between the two copper plate-electrodes. The distance of the plates is 20 mm. The formed electric field (given by the potential difference and the distance of the electrodes), the length of the deflector plates and the drift space remaining between the screen

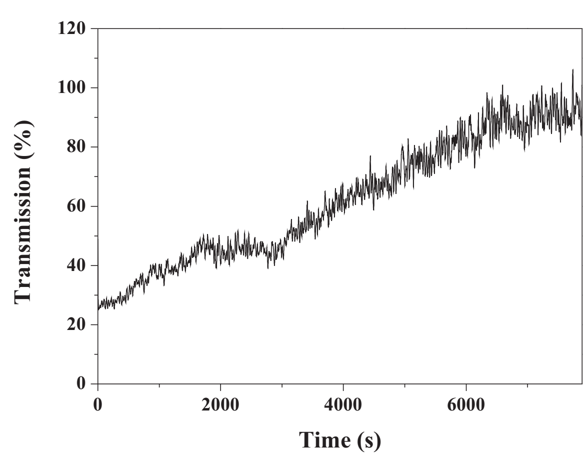

Fig. 4. Time trend of the transmission of the 1 MeV proton beam. When the beam was let in the capillary, the transmission started to increase gradually. At 90% it reached a plateau.