Charge state and energy loss of heavy ion beam interacting with porous and solid matter.

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Materials with fine porous nano-structure are very promising as targets for ICF driven by laser or heavy ion beams [1] providing high uniformity of the energy deposition. Silica gel is one of them. Its structure is formed by chains of colloidal SiO_2– beads of 3 - 5 nm in diameter. The chains build the 3-D open cell structure, with pores of 30 - 50 nm [2]. The nm uniform silica-gel structure provides a continuously expanded interaction volume. In order to investigate the possible influence of the porous nano-structure on the ion stopping process, the energy loss and the charge state distribution of the 11.4 MeV/u Ca ion beam interacting with Al foils and silica-gel targets with approximately the same linear densities ρx were measured and analysed.

For energy loss measurements a time-of-flight (TOF) method was used. A stop detector consisting of a micro-sphere plate with a rise time of 150 ps was placed at the end of the 473 cm long time-of-flight path after the target.

At RFQ LINAC phase correlation between the beam microstructure and the accelerating rf voltage structure (~ 36 MHz sine wave) is well defined at any point of the beam line including the target and stop detector positions. The stop detector signal and the UNILAC rf signal were recorded simultaneously using a two-channel digital oscilloscope (sample rate 2.5 GS/s). The phase correlation between the ion beam micro bunches and rf-signal peaks measured without a target served as a time reference point. When the target is placed in the way of the ion beam, a phase shift of the beam microstructure relative to the rf signal occurs due to the ion energy loss in stopping medium. Together with an accurately measured target-detector distance this shift gives rise to the difference between the initial ion velocity and the velocity after the beam passed through the target. This procedure allows measuring of the ion energy loss in the target. As a result, 11.4 MeV/u calcium beam energy losses in aerogel and aluminium targets have been determined. The experimental results are summarized in the Table I.

Target/ Density g/cm^3	Linear density, mg/cm^2	Energy loss, MeV/u	
		experiment	SRIM2003
Al/ 2.7	6.9	1.572	1.558
Al	12	2.882	2.812
Al	13.81	3.141	3.283
Al	16.98	4.17	4.15
Silica-gel/0.023	7.015	1.692	1.77
Silica-gel/0.019	12.0	3.061	3.16
Silica-gel/0.048	13.6	3.384	3.635

Experimental data on the stopping power for fast ions are traditionally compared with the values predicted SRIM code. We also present such a comparison in Table I. One can see that our experimental results on the Ca ion energy loss in Al targets are in good agreement with SRIM2003 values.

For the analysis of the charge state distribution after interaction with the investigated target, the beam burst is deflected in the B=1–1.8 T magnetic field of a dipole magnet. The ions are split according to their charge-to-mass ratio Q/m and energy. The ion impacts were detected by a plastic scintillator of 1mm thickness, viewed by a camera which produces intensified images on a charge coupled device (CCD). The background picture of the foreign lighting and CCD noise was registered and subtracted for each image. The images were then projected along the direction of the dispersion. Since the beam energy after the target is known from the TOF measurements, the charge state distribution of the ion beam can be determined. Figure 1 shows the charge state distribution of the Ca ion beam with initial energy of 11.4 MeV/u after penetration of the 50-μm-thick Al foil and the silica gel target of approximately the same linear density. The measured ion beam energies after the aluminium target are 8.3 MeV/u, and after the piece of gel 8.06 MeV/u.

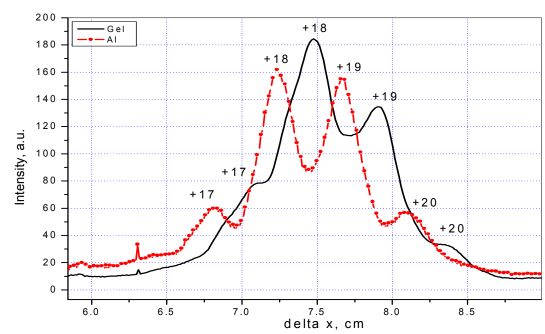

Fig.1 Ca ion charge state distribution

The curves are shifted along the x axis due to the difference in the final energy of the ion beam. The averaged Ca ion charge measured after the Al target is Z_{av}=18.5; the averaged ion charge measured after the gel target is Z_{av}=18.2 with the experimental accuracy of 1–2%. These results allow suggesting that at our experimental conditions the pore of 30–50 nm size does not seriously influence the ion stopping processes.

References:

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