Dynamics of the projectile ion velocity during the stopping process in solids

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The investigation of heavy ion stopping dynamics using associated *K-shell* projectile and target radiation was in the focus of the reported experiments. Ar projectile ions with the initial energie of 11.4 MeV/u were stopped in quartz and low density aerogels. K-shell projectile and target radiation was investigated spatially resolved perpendicular to the ion beam trajectory using spherically bend mica crystal spectrometer [1,2]. In contrast to the target radiation, the radiation of relativistic ions moving with velocities of 1/10 of light speed undergo relativistic Doppler effect. Fig.1 shows the Doppler line shift attenuation due to the ion energy loss along the ion track in solid target. In the picture, λ_0 – the wavelength of a radiative transition in the ion at rest, λ_{D1} and λ_{D2} – shifted due to the Doppler effect wavelength of the same radiative transition of the moving ion at the beginning and the end of the observed trajectory.

The variation of the Doppler shift of the projectile radiation measured along the ion beam track was used to determine the ion velocity dynamics [3]. K-shell resonance radiative transitions in Ar^{+17} (Lyα) and Ar^{+16} (Heα) were used. Si - Kα (target material) served as a reference line.

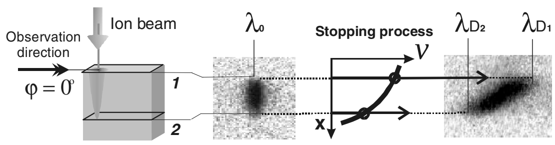

Fig. 1 Variation of the Doppler line shift along the ion beam track in the stopping process.

The choice of SiO_2 aerogel with low avarage densities of 0.04-0.15 g/cm^3 as a target material [4] allowed to stretch the ion stopping range by more than 10-50 times in comparison with solid quartz. For the first time, dynamics of the ion stopping process in solid was resolved. The dependence of the ion velocity on the trajectory coordinate was measured over 70-90% of the ion beam track with a spatial resolution of 50-70 µm. The experimental results normalized on V_{input} - the initial ion velocity are compared with the results of the projectile velocity dynamics calculated using SRIM program are presented in Fig.2

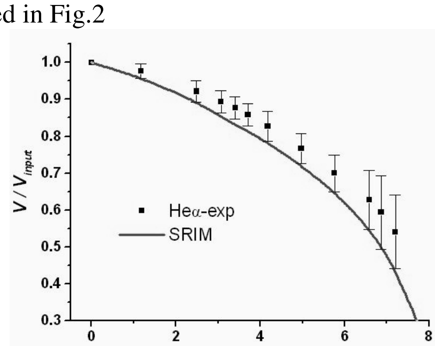

Fig.2 Measured dependence of the Ar ion velocity on the penetration depth in 0.04g/cm^3 aerogel target .

We investigated the possible influence on the stopping process of the aerogel porous nano-sracture. The energy loss and charge state distribution of 11.4 MeV/u Ar ion beam interacting with 50 um Al foil and 3mm aerogel target of the same linear density were measured. For energy loss measurements time-of-flight method was used. The ion charge state distribution was analyzed by mean of the calibrated magnet with the entrance slit.

The energy loss of 11.45 MeV/u Ar beam in 3 mm of 0.04 g/cm^3 aerogel target has been measured to be of 3.40±0.07 MeV/u, in Al foil of 50±1 µm thickness - of 3.16±0.07 MeV/u. This results are in a good agreement with SRIM-calculated value of 3.20±0.07 MeV/u.

Fig.3 demonstrates measured Ar projectile charge state distributions after interaction with Al and aerogel targets.

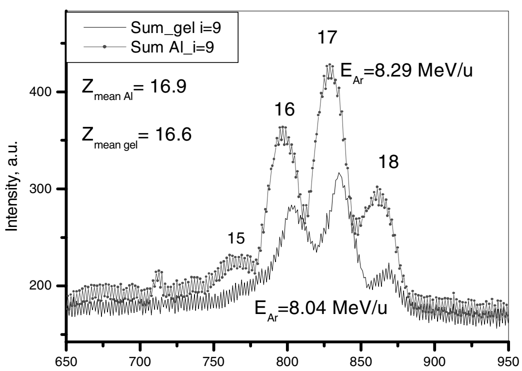

Fig. 3 Ar charge state distribution after aerogel target with a linear density of 0.012g/cm^2 and Al target of 0.013g/sm^2.

Measured average charge states of Ar ions are: Z=16.9 after Al and Z=16.6 after aerogel target.

These results prove that at our experimental conditions the SiO_2 aerogel pores of 30-50nm sizes does not seriously influence the ion stopping processes.

Finally, the combination of the outstanding properties of spherically bent crystal spectrometers and the target material used in the experiments has allowed to visualize and to measure the projectile ion stopping dynamics in solid matter.

References:

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