CHARGE STATE DISTRIBUTION OF HIGHLY CHARGED IONS PASSING THROUGH MICROCAPILLARIES

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The formation mechanism and the properties of hollow atoms have been intensively studied by many groups[1,2]. To study the intrinsic nature of hollow atoms in the first generation-hollow atom above the surface(HAA)-is difficult in typical ion-surface experiments, because the time interval between the HAA formation and its arrival at the surface is shorter than its intrinsic lifetime. A new and powerful method known as Beam Capillary Spectroscopy (BCS) has been recently developed [3,4] allowing their direct observation in vacuum by using a thin microcapillary as a target.
We have measured the charge state distribution $f(q_f)$ of the ion transmitted through a Ni microcapillary target as a function of the final charge state q_f in order to study the formation mechanism and the properties of HAA. 22 keV O^{q+} and N^{q+} ions (q =5,6,7) from a 14.5 GHz ECR ion source at RIKEN were used as incident projectiles. The charge state of the ion transmitted through the target was analyzed by a new charge state analyzer built in Atomic Physics Lab. It consists of two sets of deflectors combined with a ceratron. The deflectors are arranged in a "cascade" type configuration, the beam being deflected on vertical direction in his passing from one deflector towards another, until it reaches the ceratron. The first deflector consists of planar electrodes inclined at 15° with respect to the beam direction. The second one is a 128° cylindrical sector type. One of the electrodes for each deflector is grounded. As high voltages up to 20kV can be applied on both deflectors, the analyzer can in principle separate rather high charge states (13+ from 14+) for incident energies in the range of few hundreds keV. The ceratron is located very close to the exit of the second deflector. The negative voltage is applied to a mesh, which is located in front of the ceratron, to prevent possible stray electrons entering the ceratron. A movable Faraday cup located between deflectors is used for adjusting the beam. The Ni microcapillary target (area: 4mm^2, length : 3.8 μm) is set in front of the analyzer. The pressure of the target region is approx. 2x10^{-8} torr. The beam is collimated by a 5 mm aperture, which is located at 1m from the target, and a 2x2 mm aperture cerated by a four jaw slits system.
Results are shown in Fig. 1. One can see in Fig. 1 the following features: (1) One electron capture fraction($q_f = q$-1) is the predominant in the charge changed fractions, independent of the projectile and initial charge state. (2) Almost neutralized projectiles (q=1) are produced in large quantities and comparable to that for one electron capture. (3) The other charge states fractions ($1< q_f < q$-1) are lower than those for q_f=1 and q_f=q-1. (4) For the same initial charge state q, almost similar behavior was found in the final charge state distributions.

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The total fraction CF of the all transmitted ions who captured electrons from microcapillary walls can be estimated by CF $\subset 2d_c / r$ with $d_c \subset (2q)$ ½ $/ W$, where d_c is the critical distance for one electron capture, r is the nominal radius of the microcapillary and W is the binding energies of the target valence electrons. The CF formula is given under the conditions of the beam entering parallel with the capillary axis and the capillaries being of perfect cylindrical shape. The present target used in the measurements has capillaries with radii varying between 50nm on the backside and 90 nm on the front side of the target. In this situation a nominal radius of 70nm (~ 1300 a.u.) has been chosen. For this value the expected CF is ~ 3% for q=7 and decrease to 2.5% for q=5. As can be seen in Fig. 1, we have measured a larger total fraction CF, probably due to different conditions of the beam and the capillary from the ideal conditions as mentioned above.

Our present results are in qualitatively agreement with the theoretical one[5)]. Also the present measurements for N^{6+} ion beam can be qualitatively compared with a previous measurement with N^{6+}(28 keV) incident projectile on a Ni microcapillary target [6)] with a different nominal radius(250nm) and length(1.5 μm). We found an overall agreement for final charge states distribution pattern in both cases.

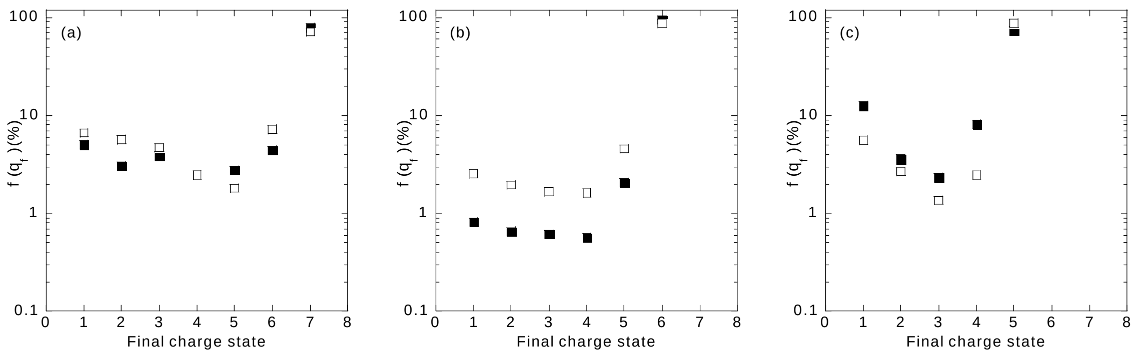

Fig. 1. Charge state distributions $f(q_f)$ of 22 keV O^{q+} (filled symbols) and N^{q+} (open symbols) ions transmitted through the Ni microcapillary target. (a): q=7; (b): q=6; (c): q=5

In conclusion, the transmitted charge state distribution related to hollow ion formation has been studied for two projectiles: O and N ions, with the same total energy 22keV, for projectile charge states from 5+ to 7+. The transmitted charge state fractions depend on the initial projectile charge state in a larger extent than on the nature of the projectile.

We are planning to measure K x rays emitted from ions passed through the microcapillary in coincidence with the final charge states as a next step to study of the HAA formation.

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