ION-SURFACE SCATTERING EXPERIMENTS AT ORNL MIRF USING DECELERATED BEAMS

F. W. Meyer and V. A. Morozov

While there has been much experimental work[1-5] investigating multicharged projectile scattering from metal and insulator surfaces under grazing or near-grazing incidence conditions and total scattering angles below 90°, there have been to our knowledge no experiments carrying out such studies for larger total scattering angles. We have recently assembled and already used for some initial measurements a new apparatus for ion-surface scattering studies employing decelerated ion beams that permits time of flight (TOF) energy loss and charge state distribution measurements of projectiles backscattered from solid targets into 120° following impact at normal to grazing incidence and with energies down to a few eV/charge. Beam deceleration is accomplished by a six-element zoom lens whose 2-mm-diameter exit aperture is located 2.5 cm upstream of the target at the center of the chamber. Initial diagnostics of the decelerated beams were performed by monitoring beam current transmitted through a narrow slit in the target plane as it was scanned through the decelerated beam. Typical spot sizes on target of beams decelerated to final energies below 10 eV/charge are 2-4 mm. The energy spread of the decelerated beams could be measured by use of the electron spectrometer positioned at zero degrees to sample the decelerated ion beam, and monitoring the ion beam impinging on the front microchannel plate as function of the spectrometer pass energy. This feature is essential to accurate determination of the final decelerated beam energy due to the strong influence of the ECR source plasma potential at the lowest energies, and the energy shifts taking place within the beam chopper, neither of which are straightforward to calculate *a priori*. Decelerated beam intensities in the μA range are routinely obtained for energies as low as 10 eV/charge.

In its present configuration, the apparatus is equipped with a linear TOF system 75 cm long and oriented 120° with respect to the incident beam, featuring a floatable drift tube for charge state analysis, and a movable 180° spherical sector spectrometer for analysis of electron emission and characterization of the decelerated beam (when in the zero degree position) that is mounted on an x-y-z manipulator with rotation. The target is attached to a sample mount (heatable to 600°C) on a second x-y-z manipulator also with rotational degree of freedom. The chamber is further equipped with an ion sputter gun for sample cleaning and a residual gas analyzer head. To permit TOF analysis, a beam chopping system was installed about 2 m upstream of the 90° deflector and is capable of producing ion pulses as short as 20 ns in width.

To date, we have performed measurements of energy loss and charge state distributions for multicharged C, O, Ar, and Pb projectiles incident on Au(110) with energies in the 100-500 eV/q range. The measurements were performed for incidence angles spanning the range 0 to 80° (relative to the surface normal), and for a range of incident charge states that samples both filled and (partially) vacant

projectile inner shells. For the C and O projectiles, both positively and negatively charged scattered projectiles were analyzed by simple reversal of the polarity of the applied drift tube voltage. In order to exploit one of the unique capabilities of the TOF technique, i.e., energy analysis for both neutral and charged scattered projectiles, one of the areas of concentration has been study of the dependence of the projectile energy loss on the final scattered charge state. Initial results for incident Ar and O projectiles are shown in the figures below.

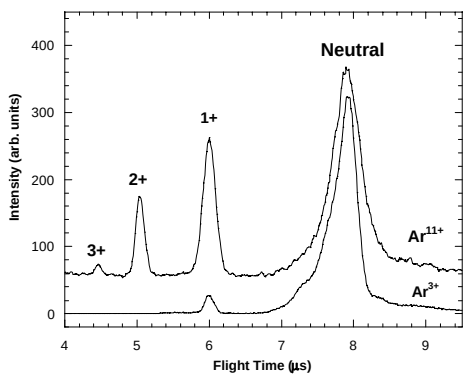

Fig. 1. Scattered projectile TOF spectra for 4.6 keV Ar^{q+} ions incident on Au(110) at normal incidence.

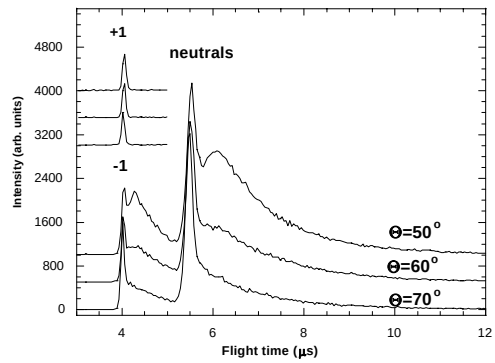

Fig. 2. TOF spectra of scattered +1, neutral, and -1 charged projectiles for 2.5 keV O^{6+} + ions incident on Au(110) over a range of angles.

As has also been noted by Huang et al.[5] for incident Ar projectiles, the energy loss peak positions of the scattered projectiles correspond very closely to the values expected for binary collisions between the incident projectiles and isolated Au target atoms. However, there appear to be systematic differences between the energy loss profiles of the neutral and positively charged scattered projectiles. For example, in the case of incident Ar projectiles, the neutral scattered projectile peak displays an energy straggling tail towards longer flight times (lower energies), as well as a broadening on the high energy (short flight time) side of the binary collision peak that has been attributed to double scattering events leading to the same final deflection of 120°. Neither of these features are evident in the energy loss peaks associated with the positively charged scattered Ar projectiles which are each fitted by simple Gaussians. The difference in energy loss profiles between neutrals and positively charged scattered projectiles is much more prominent in the case of the O incident projectiles, where the neutrals display a secondary energy loss peak on the longer flight time side of the binary collision peak, whose prominence is strongly incident angle dependent, while the 1+ component again is described by a simple Gaussian. Efforts are underway to identify the collision sequence leading to the second energy loss peak, using MARLOWE,[6] and to

understand the strong variation of the primary binary collision peak width observed with incidence angle.

The absence of features in the energy loss spectrum associated with double collisions or energy straggling in the case of projectiles scattered as positive ions, suggests that projectile survival as a positive ion is unlikely unless the backscattering occurs from a target atom located at the sample surface in a single binary collision. The fact that the dominant observed positive scattered charge state is 1+, as also observed by Huang et al.,[5] is interpreted as evidence for very efficient multicharged projectile neutralization even for the case of large scattering angle, single collisions with target atoms lying in the topmost (surface) layer.

The differences noted between the neutral and positively charged scattered projectiles are not evident in the negatively charged scattered projectiles. In the case of both C and O incident projectiles, the negative charge fraction energy loss peak shapes closely mirror those of the scattered neutrals. The implication of this similarity is that negative ion formation takes place only after complete neutralization of the projectile has occurred, consistent with earlier indications regarding negative ion formation noted[1,4] for grazing interactions of multicharged O projectiles with Au(110) and Al(110).

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