Energy deposition of highly charged ions transmitted through single layer MoS_2

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Synopsis Highly charged ions (HCIs) are an efficient tool for the perforation of suspended 2D materials. Only a fraction of their potential energy is transferred to the atomically thin target during the very short interaction time and is available for pore formation. Charge exchange spectra were measured for highly charged xenon ions transmitted through suspended, single layer MoS_2 in order to determine the deposited potential energy available for pore formation. Additionally, charge exchange dependent ion stopping responsible for kinetic sputtering was measured simultaneously.

2D materials have come into the spotlight because their intriguing features make them promising candidates for future electronic and optoelectronic applications. In order to utilize 2D materials in specific applications surface-sensitive modification techniques have to be applied. Highly charged ions have been demonstrated as a promising tool for nanostructuring of 2D materials [1, 2]. They store potential energy in the keV range, which is deposited in close vicinity to a surface upon neutralization. The impact leads to strong electronic excitations, which may subsequently result in nanostructure formation. Even in freestanding 2D layers pore formation [1, 2] induced by HCI impact was observed despite their ultra-small thickness limiting the fraction of deposited energy. For the present study, charge exchange of highly charged xenon ions passing freestanding monolayers of MoS_2 was measured in coincidence with the time-of-flight (TOF) of the projectiles. Angle and charge state resolved spectra were recorded. A bimodal exit charge state distribution is observed as shown in Fig. 1. The distribution at high outgoing charge states is characterized by small scattering angles. This points to collisions occurring in a narrow range of larger impact parameters with the target atoms. The distribution at low charge states accompanied by larger scattering angles originates from close collisions with the target atoms. A model description for the two distinctly separated charge state distributions is discussed based on a spatially confined Interatomic Coulombic Decay process. Our experimental data is put into context of recently observed pore formation on freestanding MoS_2 by HCIs [2].

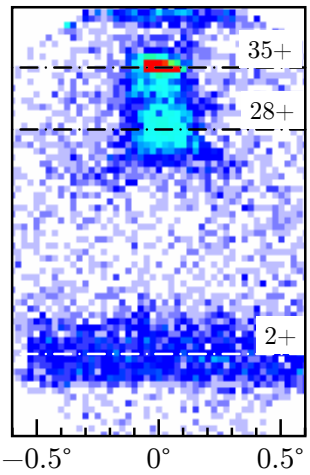

Figure 1. Charge state and scattering angle resolved spectrum for incident xenon ions of charge state 35+ and kinetic energy of 100 keV transmitted through single layer MoS_2.

References

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