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Interaction of multiply charged ions with single layer graphene Part I: charge exchange and energy loss

V. Smejkal*, E. Gruber* [1], M. Kralik*, R. A. Wilhelm†, R. Heller†, S. Facsko†, and F. Aumayr* [2]

* Institute of Applied Physics, TU Wien, Wiedner Hauptstr. 8-10/E134, 1040 Vienna, Austria
† Helmholtz-Zentrum Dresden-Rossendorf, Inst. of Ion Beam Physics & Materials Research, 01328 Dresden, Germany

Synopsis The exit charge state distribution and the energy loss of slow multiply charged ions transmitted through single layers of graphene and 1 nm thick carbon nanomembranes is analyzed.

Due to its unique electronic properties, single layer graphene (SLG) has attracted enormous attention since its discovery [1] as an excellent candidate for future nanoelectronics. SLG can be considered as the ultimately thin membrane made of sp^2-hybridized carbon atoms. Disorder as induced e.g. by collisions with energetic electrons or ions affects the electronic structure and opens the possibility to modify and tailor the properties of this true 2D material. Collision studies between ions and free-standing SLG are also of fundamental interest, because they bridge the gap between atomic collisions in gaseous and those in solid targets.

For the transmission of slow highly charged ions through slightly thicker 1 nm carbon nanomembranes (CNMs) we have recently observed two distinct exit charge state distributions accompanied by a strong charge state dependent energy loss [2] as well as the creation of nano-sized pores for Xe^{q+} projectiles in charge states $q \geq 25$ mainly by deposition of their potential energy [3].

To learn more about the microscopic interaction mechanism we have extended our studies to the case of slow multiply charged Ar^{q+} ions transmitted through SLG (and CNMs in comparison). In a new experimental setup in Vienna, slow Ar^{q+} ions ($q \leq 9$) are extracted from an ECR-ion source [4], mass analyzed and collimated before traversing a free standing SLG or CNM target mounted on a TEM grid. The ions exiting the target foil are analyzed in a spherical electrostatic energy analyzer (COMSTOCK AC-903B) equipped with a channelplate detector. A typical spectrum (intensity vs. analyzer voltage) recorded for 144 eV/amu Ar^{4+} ions through a CNM is shown in figure 1.

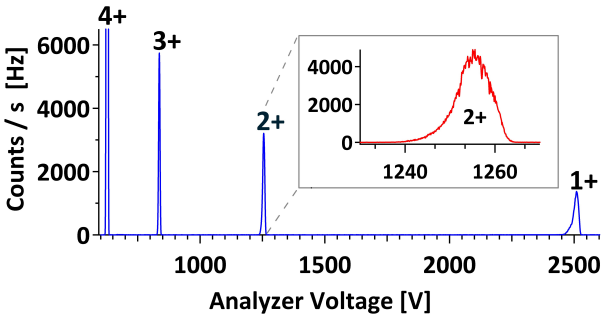


Figure 1. Charge state and energy spectrum (e.g. see insert for ions exiting as Ar^{2+}) of 5.76 keV Ar^{4+} projectile ions after transmission through a 1 nm thick carbon nanomembrane.

Such spectra give information on both the exit charge state distribution (i.e. charge exchange between multiply charged ions and SLG) as well as the mean value of the energy loss and the energy loss distribution (see the insert of fig. 1) as a function of the charge state and kinetic energy of the primary projectile. E.g., figure 1 clearly shows that charge equilibrium of the projectile has by far not been reached within the 1 nm thick foil and therefore non-equilibrium effects can be studied. Further information on the interaction is derived from the comparison between results for SLG and CNMs.

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[1] E-mail: egruber@iap.tuwien.ac.at
[2] E-mail: aumayr@iap.tuwien.ac.at

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