IONIC VELOCITY AS A MEASURE OF AN INTERPLAY OF THE NEUTRALIZATION ENERGY AND THE DEPOSITED KINETIC ENERGY IN THE SURFACE NANOSTRUCTURE CREATION

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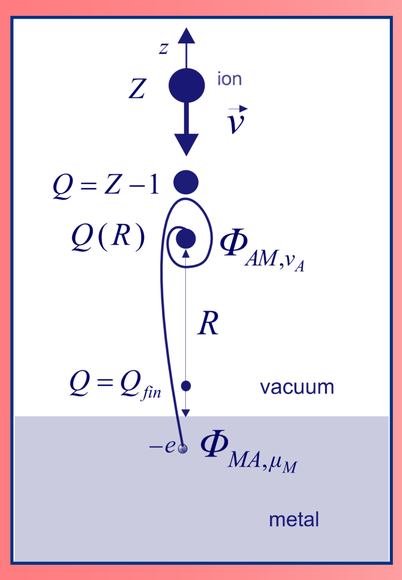
We consider the role of the ionic velocity in the nanostructure creation during the interaction of highly charged Xe^{Z+} ions with solid surface. The quasi-resonant two-state vector model and the micro staircase model are used for the analysis of the neutralization process accompanied by the surface modification. For very low ionic velocity, the neutralization energy gives the main contribution in the surface nanostructuring, while for large ionic velocity the nanofeatures are created due to the kinetic energy loss (nuclear and electronic stopping power). The existence of the critical velocity, which separates these two regions, is discussed.

INTRODUCTION

Highly charged ions (HCI) → Surface → Nanostructures creation

Two-state vector model (TVM) + micro staircase model for the cascade neutralization

CRITICAL VELOCITY



HCI approaching to the metal surface (metal-vacuum, MV-system)

arbitrary velocity

Cascade neutralization

$$Q = Z \rightarrow Z-1 \rightarrow \ldots \rightarrow Q_{\text{fin}}$$

surface modification

$$\Psi_1(\vec{r},t) \text{ and } \Psi_2(\vec{r},t) \rightarrow I_{\mu_M,\nu_A}(R)$$

Two-state wave functions — **Mixed flux**

$$T_{\mu_M,\nu_A}(t) = \left| \int_R^\infty I_{\mu_M,\nu_A}(R)\, dR \right|^2 / v^2 \rightarrow P_{\nu_A}(R) = \int \sum_{n_{1M},m_M} T_{\mu_M,\nu_A}(t)\, d\gamma_M$$

Transition probability density — **Population probability**

neutralization cascade → Q_{fin} → $W^{(Z,\mathrm{MV})}$

Neutralization energy in the MV-system

$$W^{(Z,\mathrm{MV})} = W_{Z,\mathrm{pot}} - W_{Q_{\mathrm{fin}}^{\mathrm{MV}},\mathrm{pot}}$$

$W_{q,\mathrm{pot}}$ **Ionic potential energy**

Nanostructure formation

Low ionic velocity → **neutralization energy = potential energy**

Moderate ionic velocity → **neutralization energy and deposited kinetic energy**

Definition of the critical velocity v_c

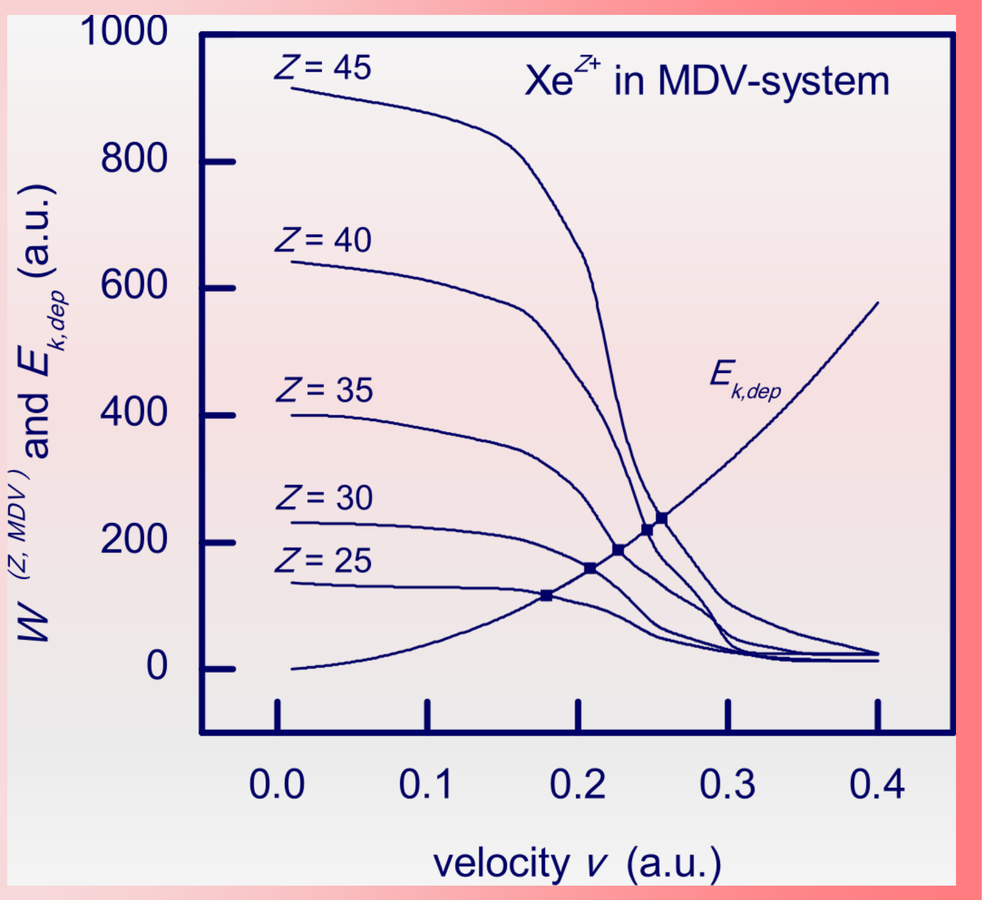
$$W^{(Z,\mathrm{MV})}(v_c) = E_{\mathrm{k,dep}}(v_c)$$

RESULTS

Nanocraters formation by the impact of HCI on metal surface covered with a thin dielectric film (metal-dielectric-vacuum system, MDV-system)

$$W^{(Z,\mathrm{MDV})} = W^{(Z_{\mathrm{eff}},\mathrm{MV})}$$

Z_{eff} **effective ionic charge in the dielectric**



$W^{(Z,\mathrm{MDV})}$ **+ deposited kinetic energy**

Required energy for the crater formation

Z	25	30	35	40	45
Z_{eff}	18.7	23	27.5	31.4	35
v_c (a.u.)	0.18	0.21	0.23	0.25	0.26

The critical velocities are the ones for which the neutralization energy and the deposited kinetic energy equally contribute to the nanostructure creation

The critical velocities can be used to predict the particular form of the surface nanostructures for a given *v*

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