TECHNISCHE UNIVERSITÄT WIEN

VIENNA UNIVERSITY OF TECHNOLOGY

Interaction of Highly Charged Ions (HCI) with matter

or

What can you do with cold HCI?

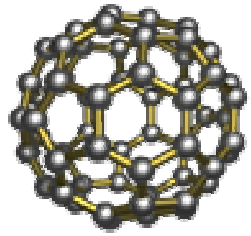
J. Burgdörfer, C. Lemell, M. Seliger

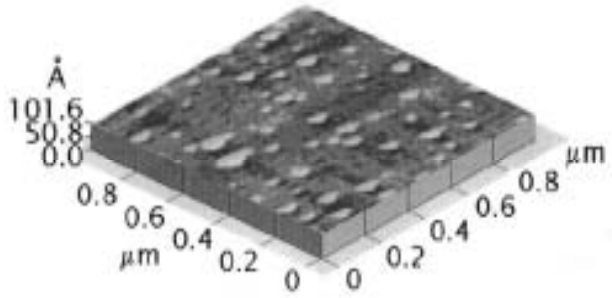
L. Wirtz, K. Tökesi, W. Palfinger

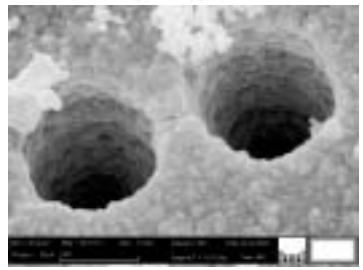
Inst. for Theoretical Physics, Vienna University of Technology

HCI – Matter Interactions at Low Velocities

- **(Condensed) Matter:**
  - Clusters
  - Surfaces
  - (Nano-) Capillaries and tubes



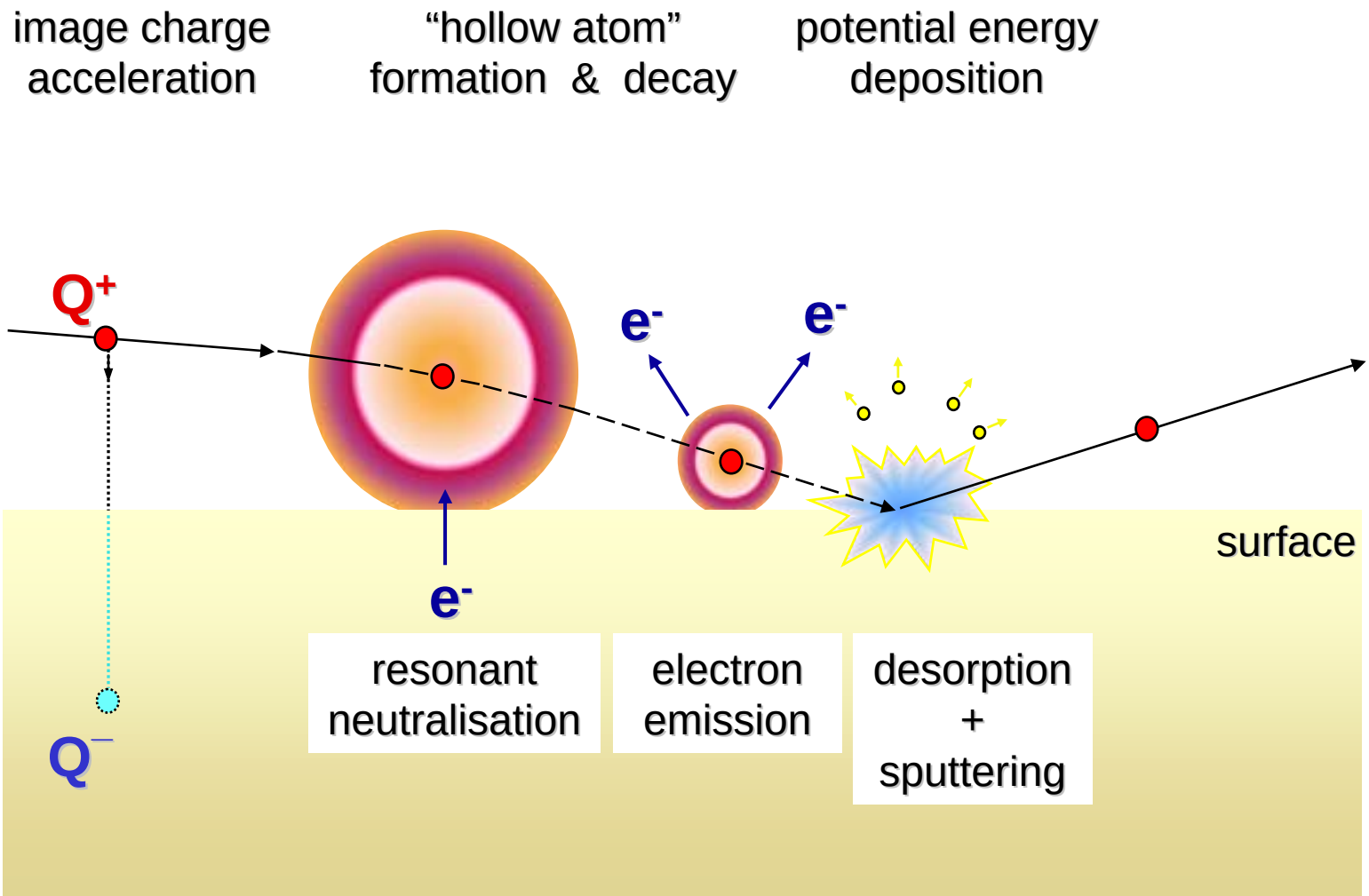




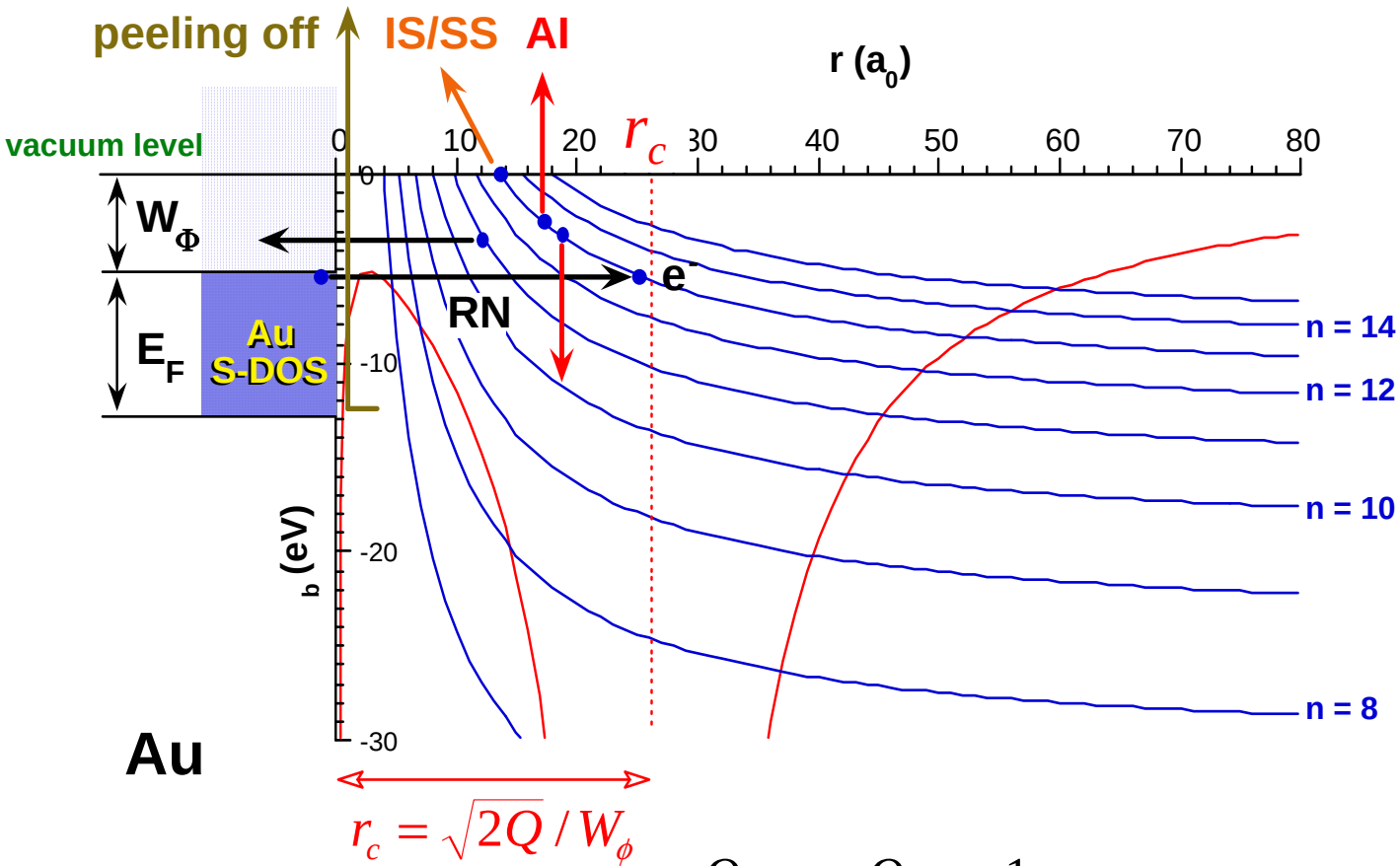
- **Low Velocities:**
  - $E_{pot} >> E_{kin}$
  - Long interaction times $\tau = \frac{\langle r \rangle}{v} \approx 100 \text{ a.u.} \approx 2.5 \text{ fs}$ **short laser pulses**
  - Strong fields $F \approx \frac{q}{\langle r \rangle^2} \geq 1$

- **Fundamental aspects:**
  - response of matter to strong (DC) fields
  - metals vs. insulators
- **Scenarios for neutralization, relaxation and dissipation**
- **Applications to material science**
  - sputtering
  - nanostructuring
- **Outlook**

HCI-surface interaction scenario



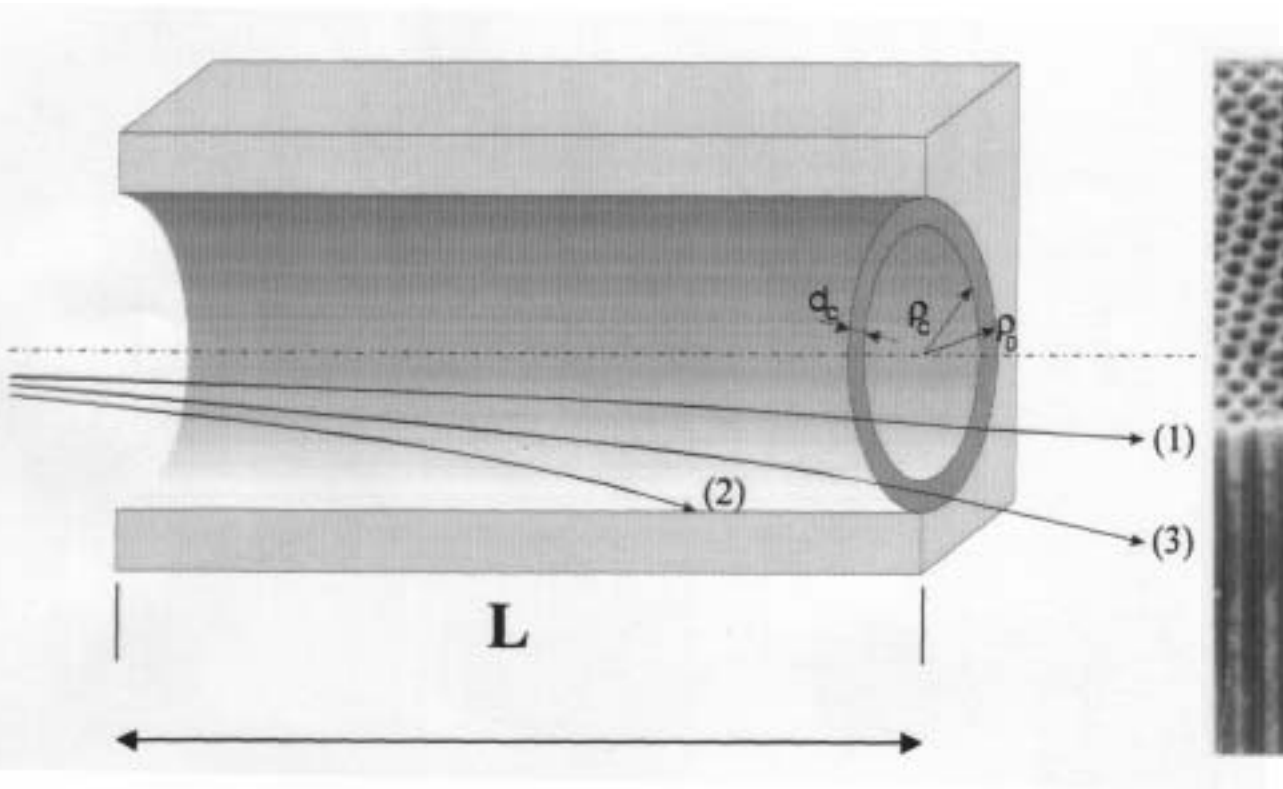
Classical Over-the-Barrier Model

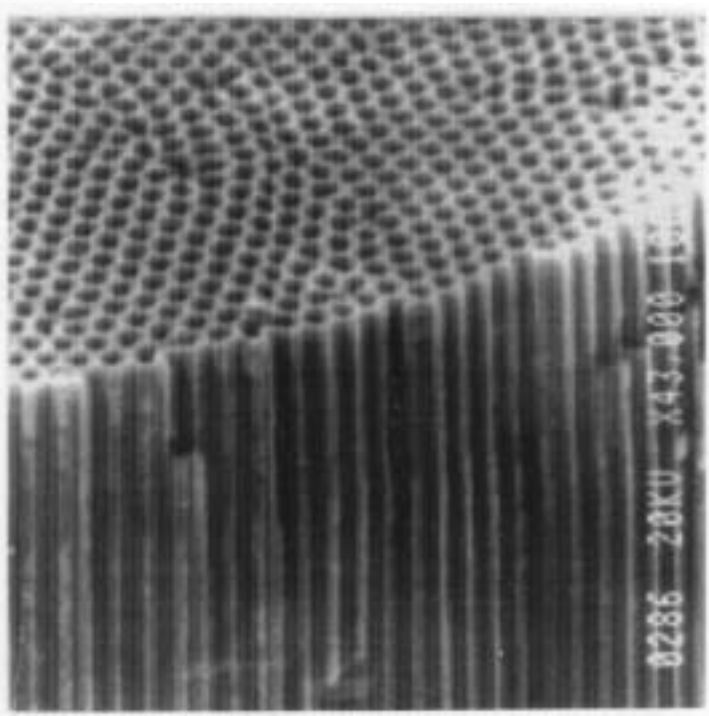


$$V(r) = -\frac{Q}{|r-R|} + \frac{Q}{|r+R|} - \frac{1}{4r}$$

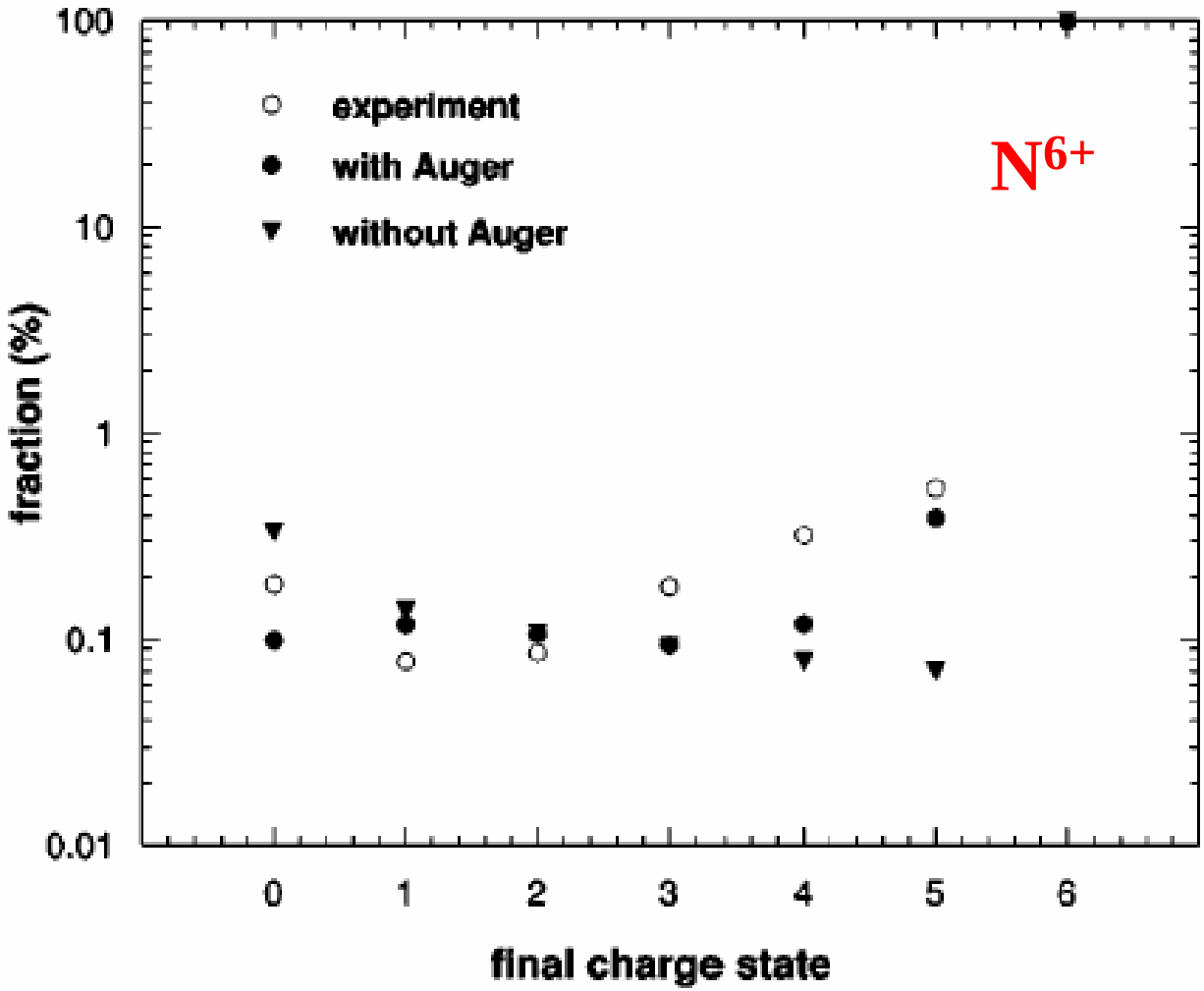
Burgdörfer et al. Phys. Rev. A 44 (1991) 5647

Tests for microcapillaries:

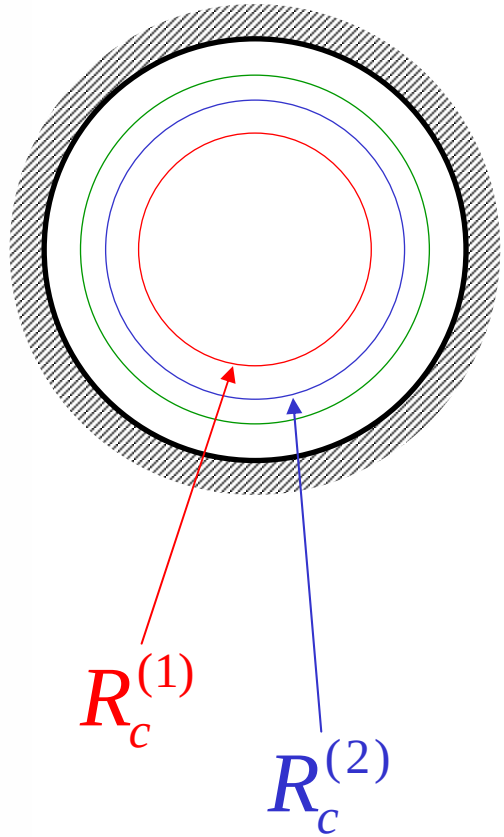




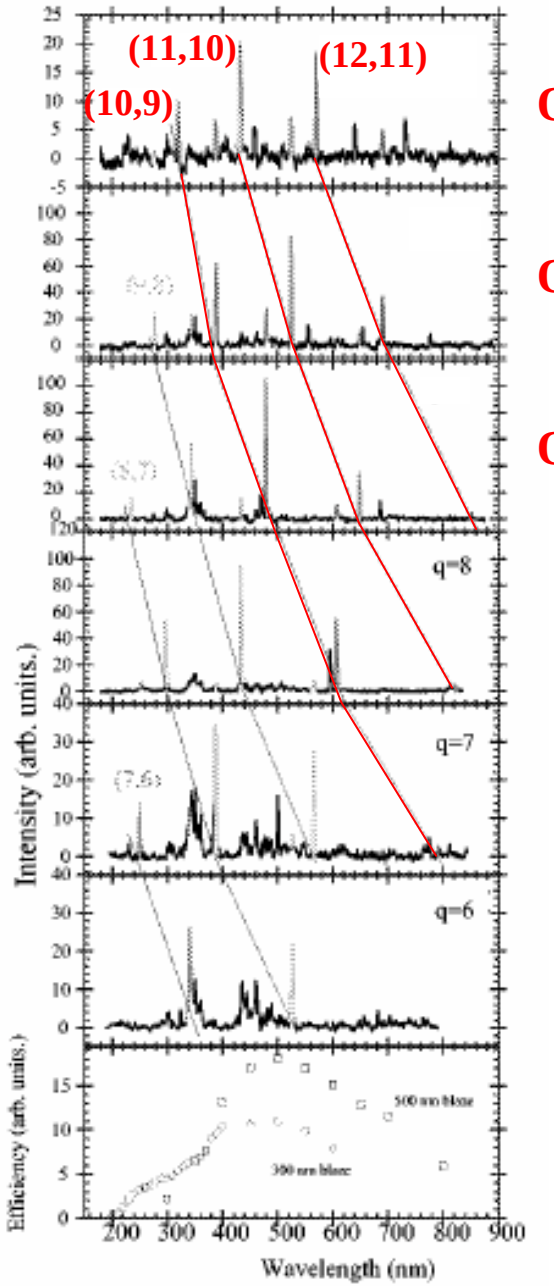
• Test of R_c



$$R_c = \sqrt{2Q}/W$$

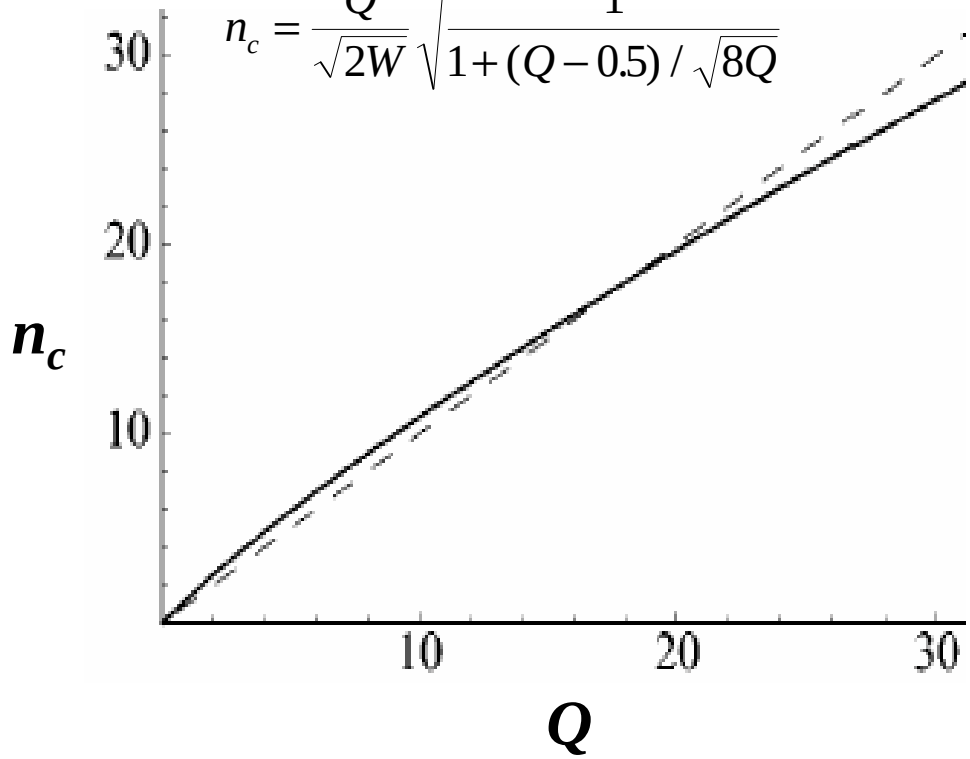


Ninomiya et al., PRL (1997)



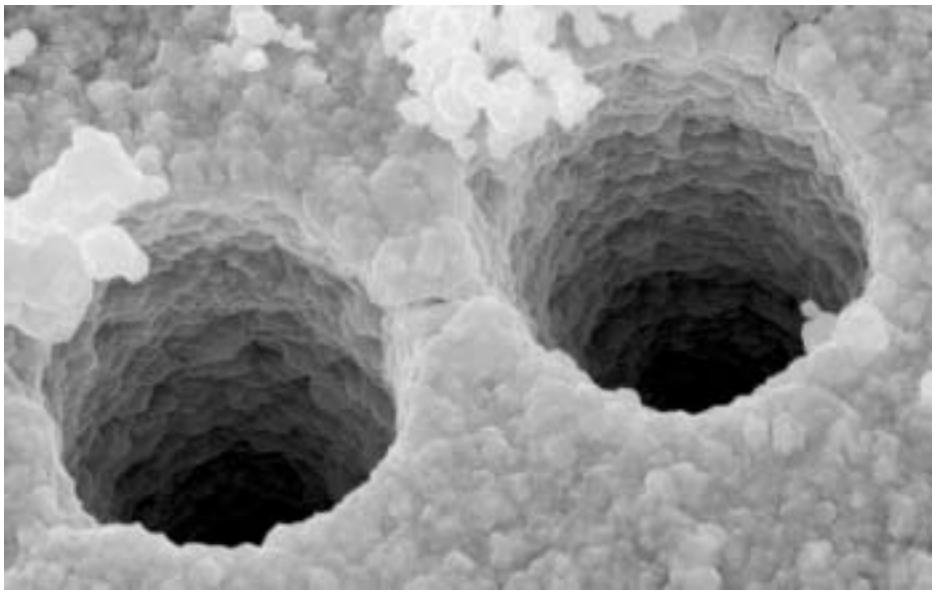
• Test of n_c

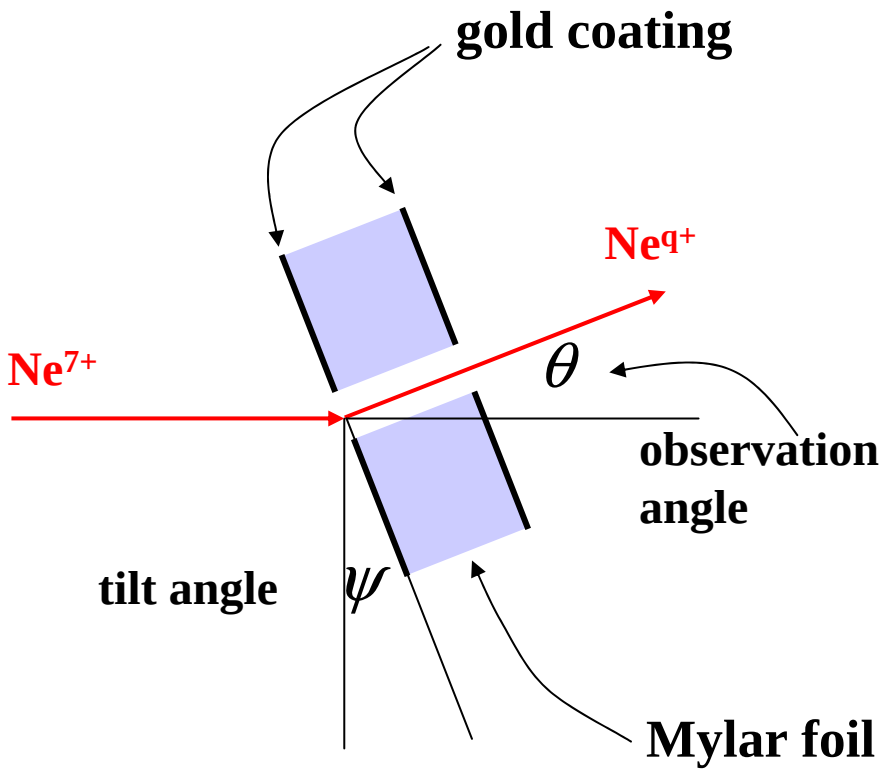
$$n_c = \frac{Q}{\sqrt{2W}} \sqrt{\frac{1}{1+(Q-0.5)/\sqrt{8Q}}}$$



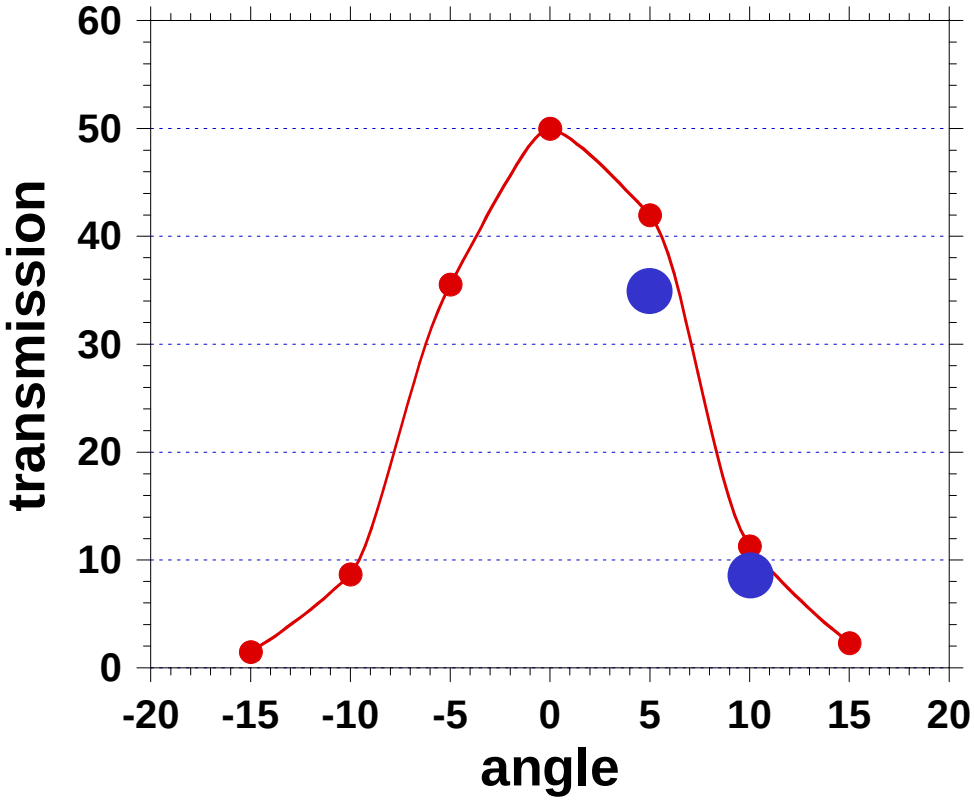
Morishita et al., submitted to PRL (2002)

Transmission through Mylar – Nanocapillaries

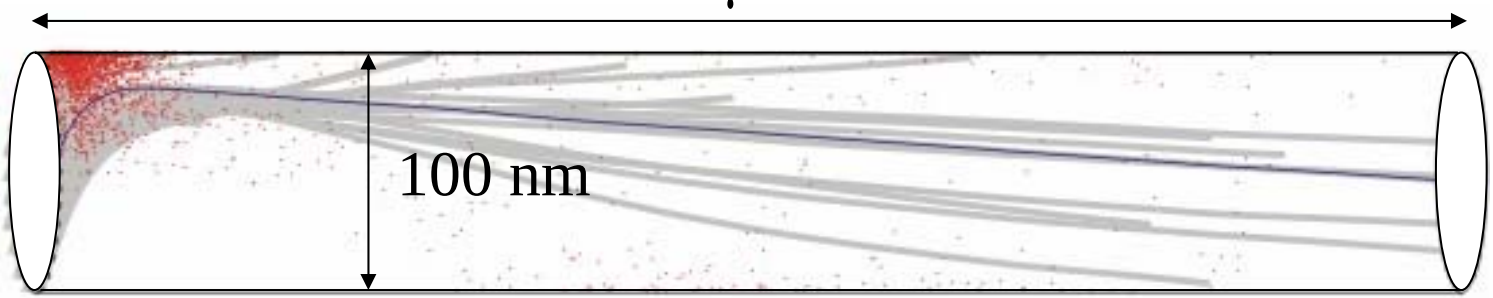




Stolterfoht et al., PRL 2002


transmission
angle
60
50
40
30
20
10
0
-20
-15
-10
-5
0
5
10
15
20

8 min


10 μm
100 nm

Applications to material science: ”soft“ sputtering

Neidhart et al. Phys. Rev. Lett. 74 (1995) 5280
Sporn et al. Phys. Rev. Lett. 79 (1997) 945

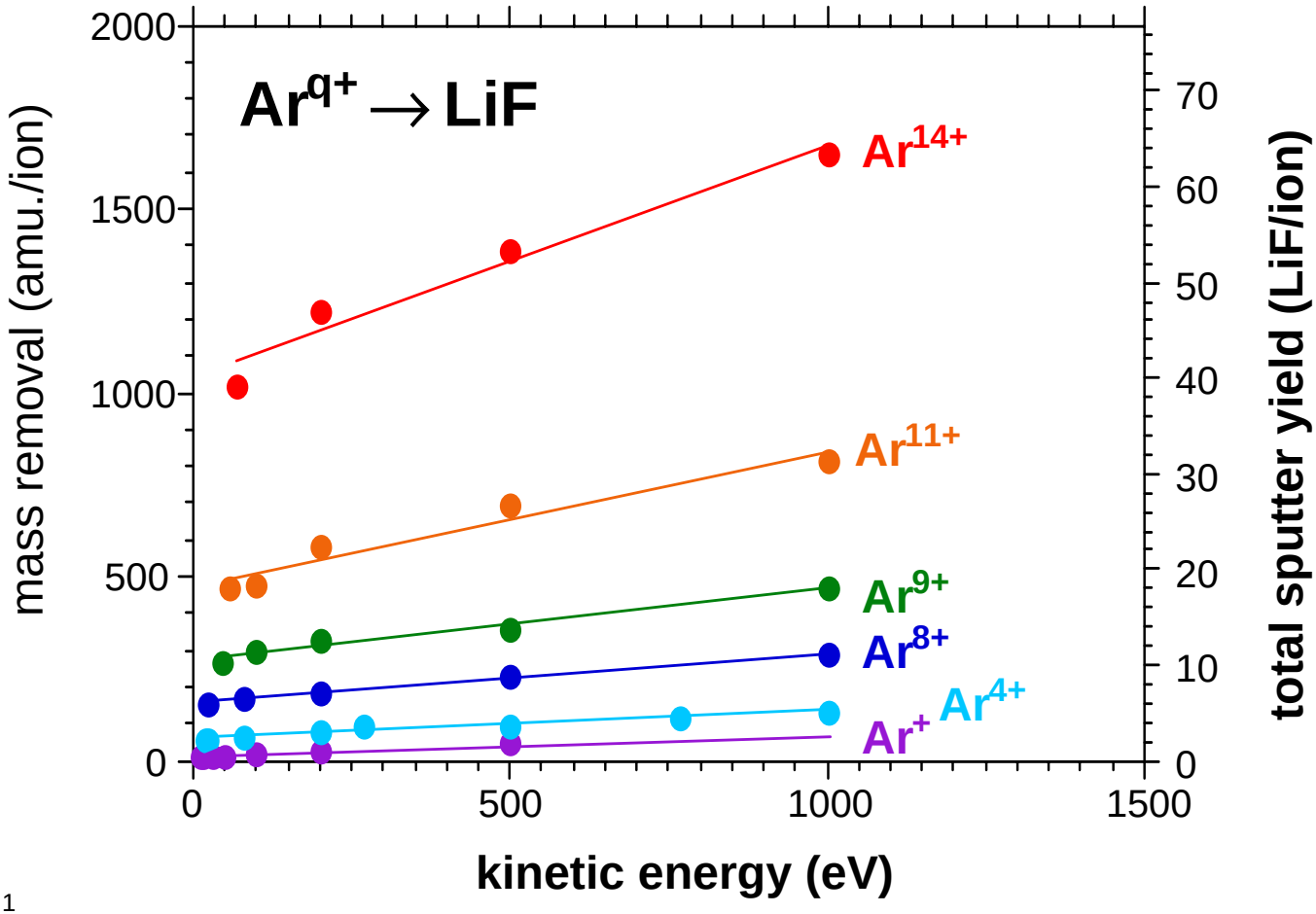


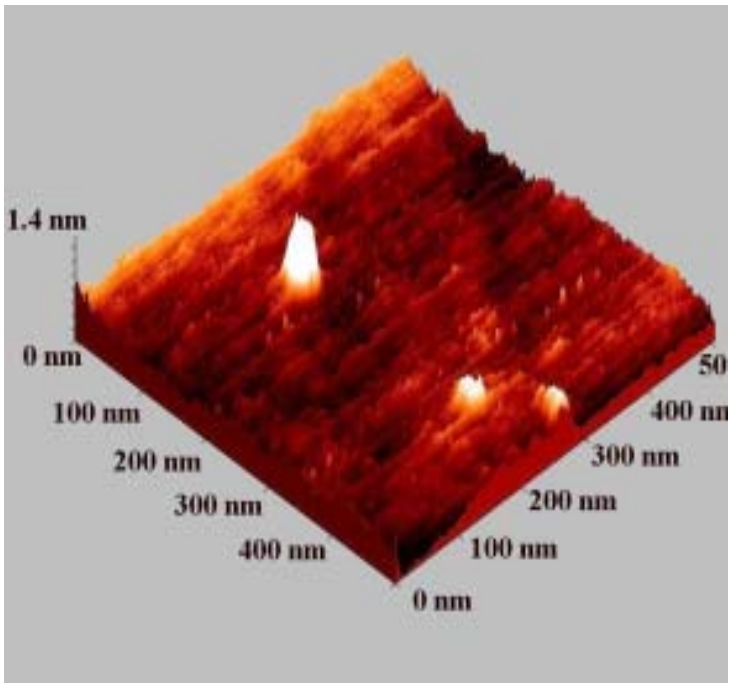
Fig. 1

Nanodefect - formation on insulators

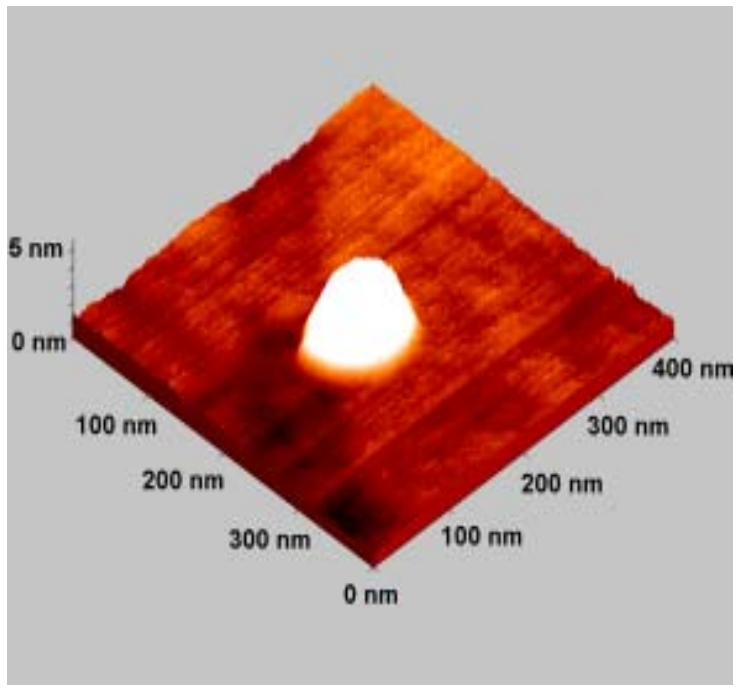
UHV - AFM, TU Wien

Gebeshuber et al. (2002)

Ar^{+} (500 eV) on Al_2O_3



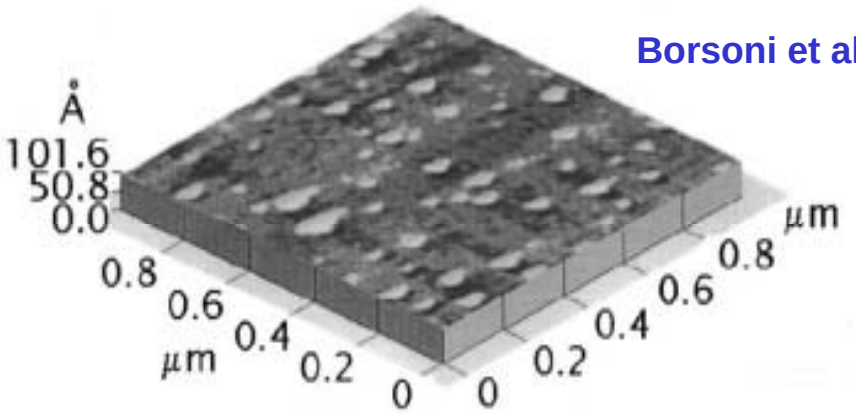
Ar^{7+} (500 eV) on Al_2O_3

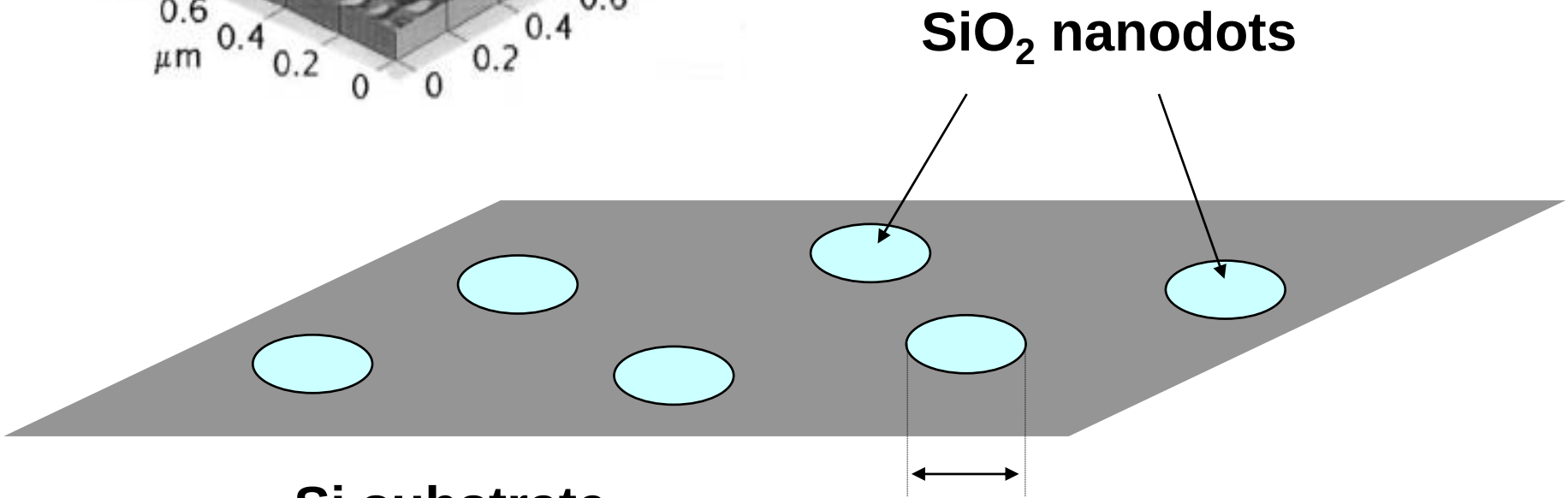


The observed defect size (both height and lateral) dimension increases with projectile charge state q

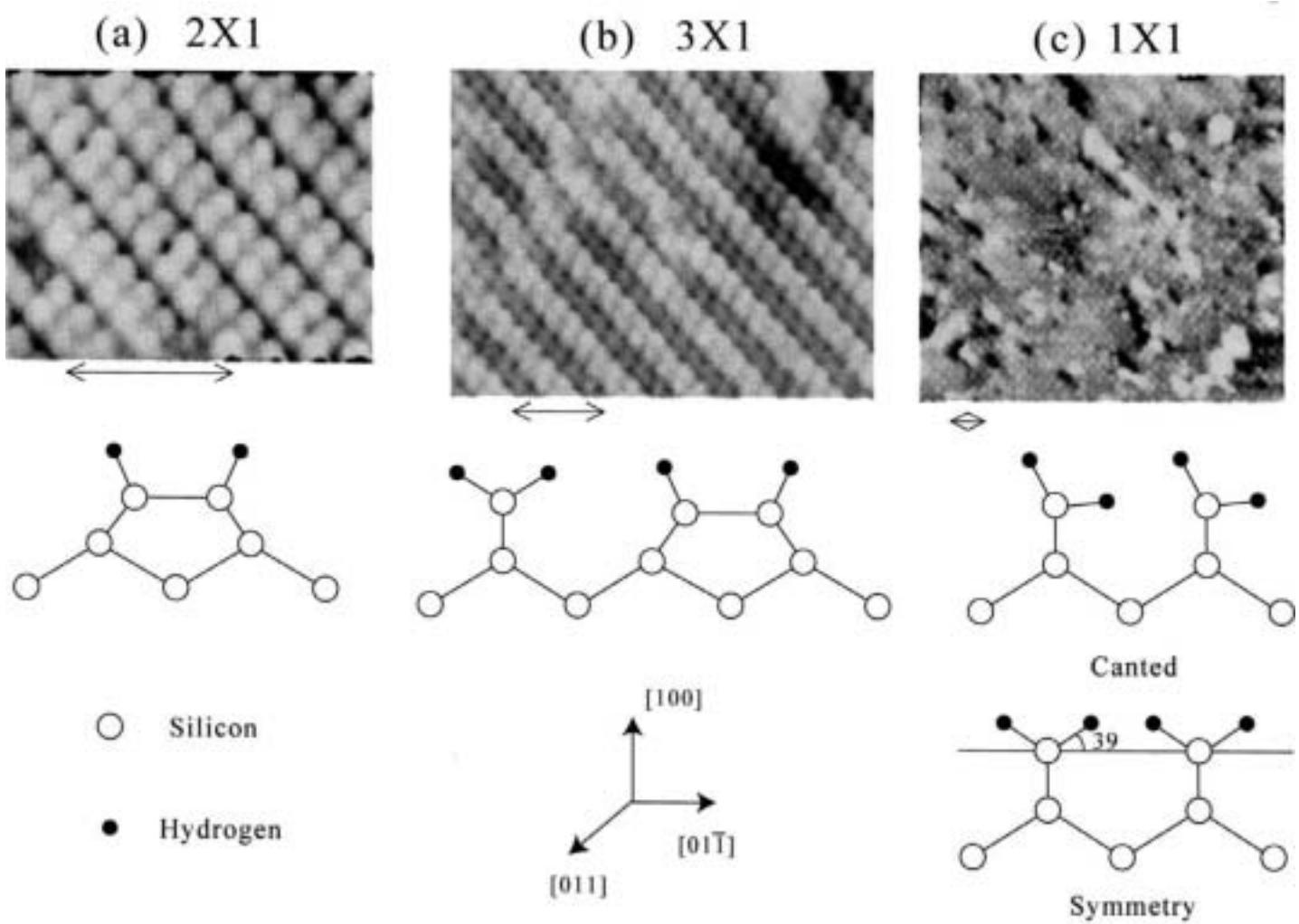
formation of ultra-shallow SiO_2 nanodots by HCl

Borsoni et al. JVST (2000)



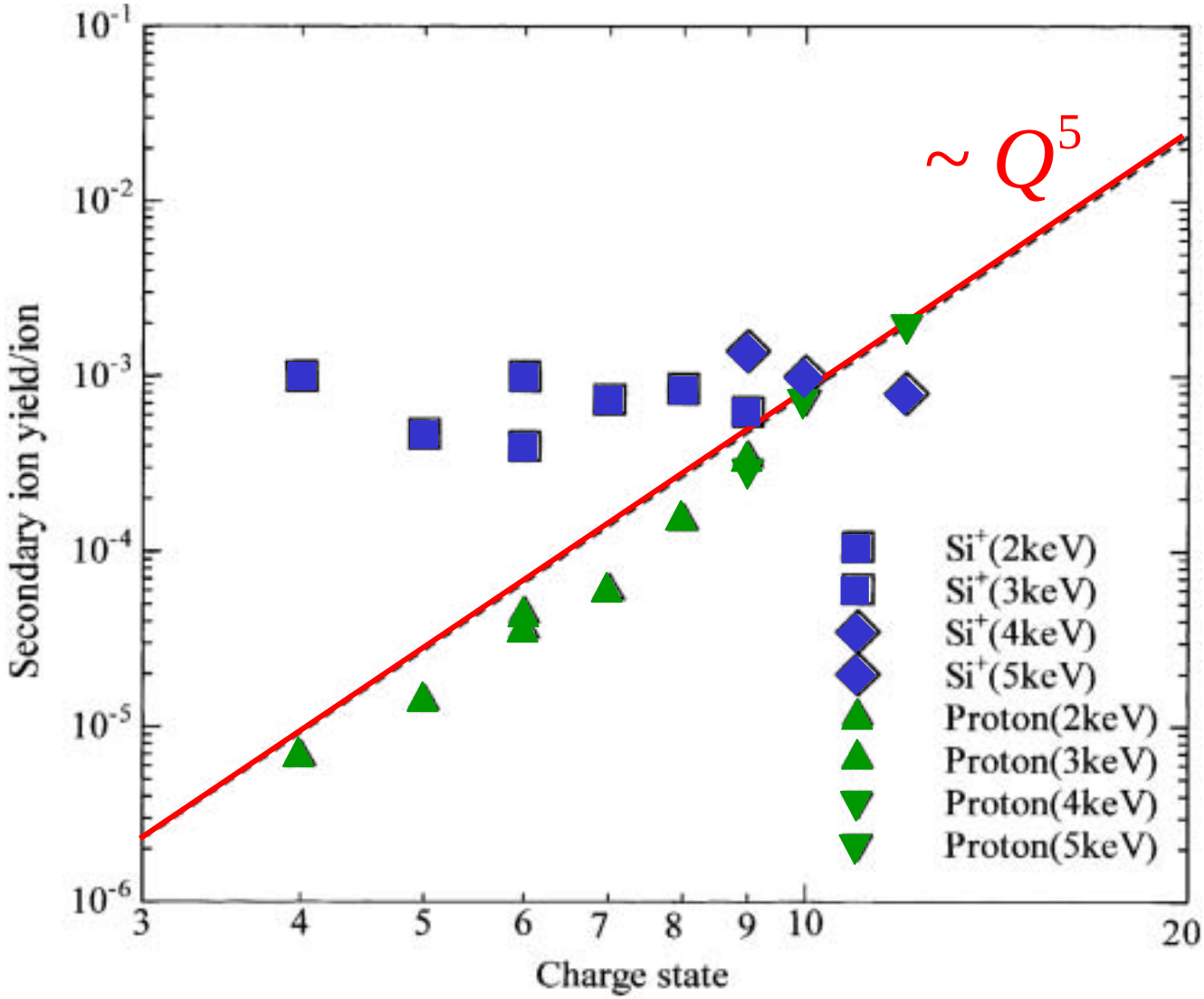


Proton-sputtering by HCI from Hydrogen-terminated silicon



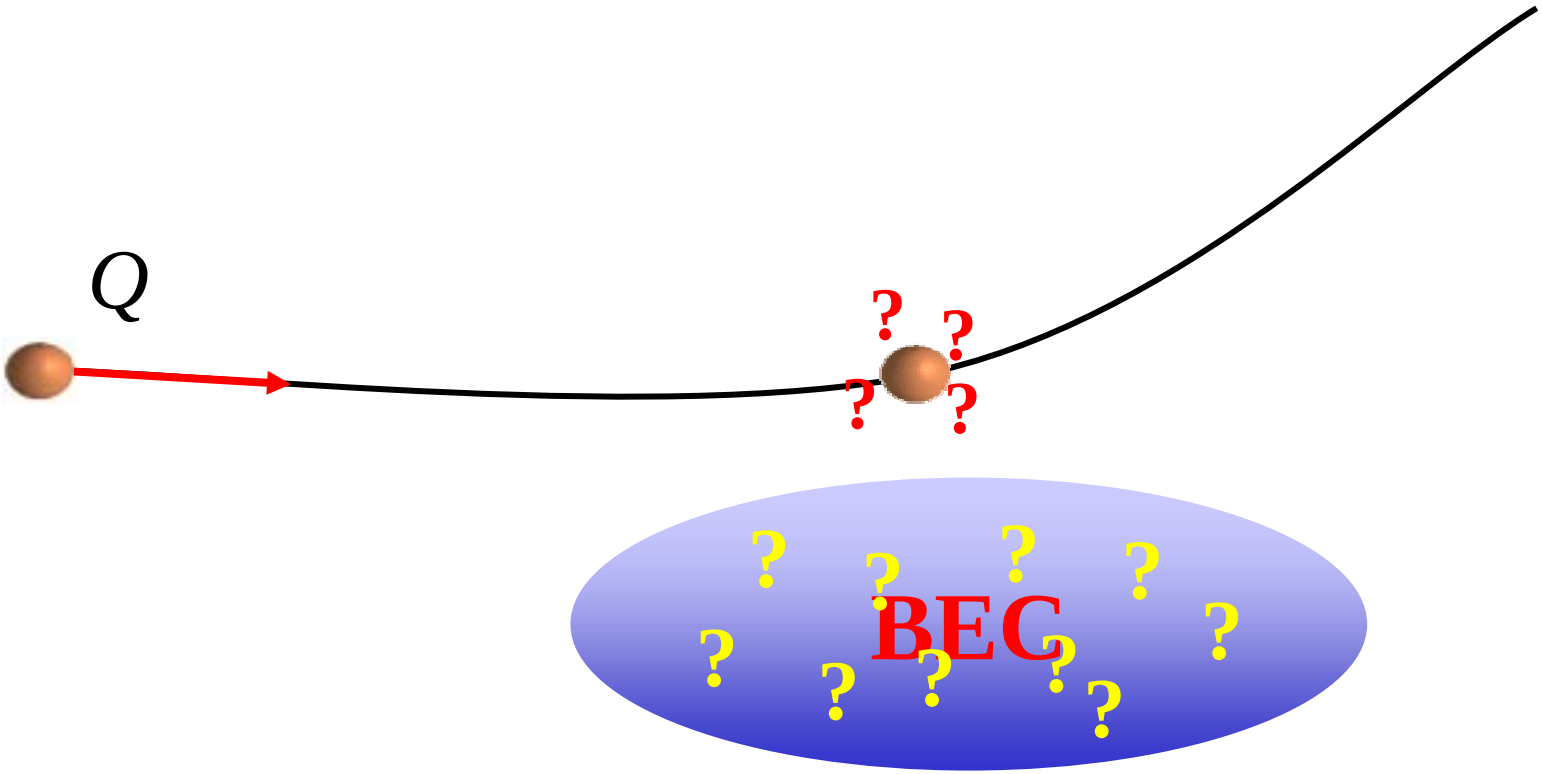
Kuroki et al., Sol. State and Mat. Sci., 2002

Strong Q dependence for H^+



Outlook: more exotic matter

Interaction of an HCI with a Bose-Einstein condensate (BEC)



Low-energy HCI important for

- **linear and non-linear response of matter to strong (DC) fields**
- **material science:**
  - **– soft sputtering**
  - **– nanostructuring**