Characterization of 200 eV electrons transmission through a single glass microcapillary at large tilt angles

A.R. Milosavljević,[a1] R.J. Bereczky,[b] M. Kovačević[a], K. Tökési,[b] and B.P. Marinković[a]

[a] Institute of Physics Belgrade, University of Belgrade, Pregrevica 118, 11080 Belgrade, Serbia

[b] Institute of Nuclear Research of the Hungarian Academy of Sciences, H-4001 Debrecen, Hungary, EU

Synopsis Transmission of low-energy electrons of 200 eV through a single glass capillary was investigated. The results show transmission of electrons at large tilt angles, where direct transmission should be geometrically prevented, thus indicating the existence of the guiding effect. Nevertheless, the transmitted current intensity was found to vary in time, while beside the dominant elastic peak, a significant contribution of inelastically scattered electrons was also obtained.

The transmission of electrons through insulating (micro) nanocapillaries with high aspect ratio has been attracting large interest in recent years. This research is motivated both by potential application of low-energy electron manipulation at (micro) nanometer scale in highly developing bionanotechnology. In this work we investigate the transmission of low-energy electrons of 200 eV through a single glass capillary of high aspect ratio. In the present contribution, angular distribution of electrons transmitted with the incident energy, kinetic energy distribution of electron escaping the capillary and time dependence of transmission intensity were investigated.

The glass capillary sample was prepared at the ATOMKI laboratory in Debrecen, Hungary. The sample was fixed into an aluminium disk holder and a UHV compatible glue was used to fix the tubes. The capillary has the inner diameter of d=0.15 mm and the length of l=12.4 mm, therefore, the aspect ratio (l/d) is 82.6. The measurements were performed in the Laboratory for atomic collision processes at the Institute of Physics Belgrade, Serbia (see [1] for more details). In our measurements the electron gun produces a well collimated electron beam, with a diameter and an angular divergence estimated to be approximately 1 mm and 1° at 200 eV of the incident energy, and with an energy spread of about 0.5 eV.

Figure 1(a) shows the angular distributions of electrons transmitted through the single glass capillary in the straightforward direction and at relatively large tilt angle of about 6°. The electrons are transmitted even at the large tilt angle, where direct transmission should be geometrically prevented, thus suggesting the existence of the guiding effect. The measured kinetic energy distribution of electrons escaping the capillary at 6° (figure 1(b)) also indicates a significant fraction of electrons that suffer inelastic collisions, beside the dominant elastic peak. Finally, figure 1(c) shows the time dependence of transmitted current intensity at the tile angle of 6°, starting from the discharged capillary. The unstable behavior of transmission could be the consequence of a quite large incident current of the order of 10 nA. A similar effect has been recently reported for highly charged ions guiding [2].

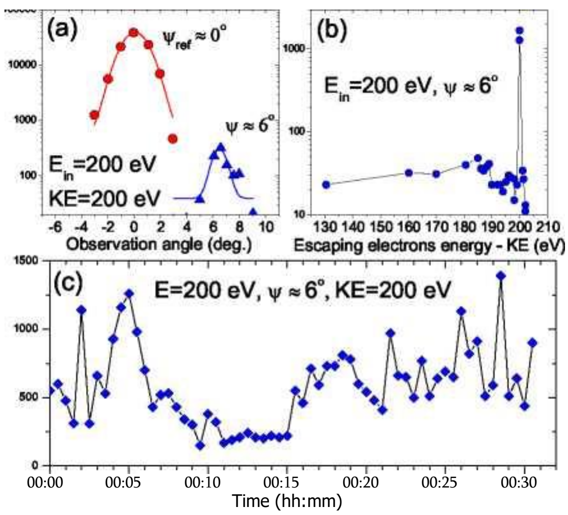


Figure 1. (a) The angular distribution of electrons transmitted through the capillary for different tilt angles (Φ). (b) The kinetic energy distribution of electrons escaping the capillary at the tilt angle of 6°. (c) The time dependence of transmitted current intensity at the tile angle of 6°.

Acknowledgements

The work was supported by the Ministry of Education and Science of Republic of Serbia (Project No. 171020) and by the Hungarian Scientific Research Fund OTKA No. NN 103279.

References

[1] A. R. Milosavljevic *et al* 2012 *Proc. 26th SPIG, Zrenjanin, Serbia* p79

[2] T. Ikeda *et al* 2012 *J. Phys. Conf. Series* 399 012007

[1]E-mail: vraz@ipb.ac.rs

Transmission of 200 eV electrons through a single glass microcapillary at large tilt angles

Institute of Physics Belgrade

A.R. Milosavljević [a], R.J. Bereczky [b], M. Kovacević [a], K. Tőkési [b], and B.P. Marinković [a]

[a] *Institute of Physics Belgrade, University of Belgrade, Pregrevica 118, 11080 Belgrade, Serbia*
[b] *Institute for Nuclear Research, Hungarian Academy of Sciences, H-4001 Debrecen, Hungary, EU*

Institute for Nuclear Research

Background

Guiding of charged particles through various types of insulating capillaries has attracted considerable attention in recent years [1].

The very recent observation of a seemingly similar guiding effect for electrons through insulating capillaries came as another surprise [2,3].

However, in contrary to guiding of HCI by insulating capillaries due to formation of charged patches and Coulomb deflection, the transmission of electrons through insulating capillaries appeared to be more complex. A general opinion is that both the Coulomb deflection (as in the HCI case) and an electron-wall interaction contribute to the process.

The aim

In this work we investigate the transmission of low-energy electrons of 200 eV through a single glass capillary of high aspect ratio. In the present contribution, angular distribution of electrons transmitted with the incident energy, kinetic energy distribution of electron escaping the capillary and time dependence of transmission intensity were studied.

The sample

The glass capillary was prepared at the Institute for Nuclear Research, Hungarian Academy of Sciences (Atomki) laboratory in Debrecen, Hungary.

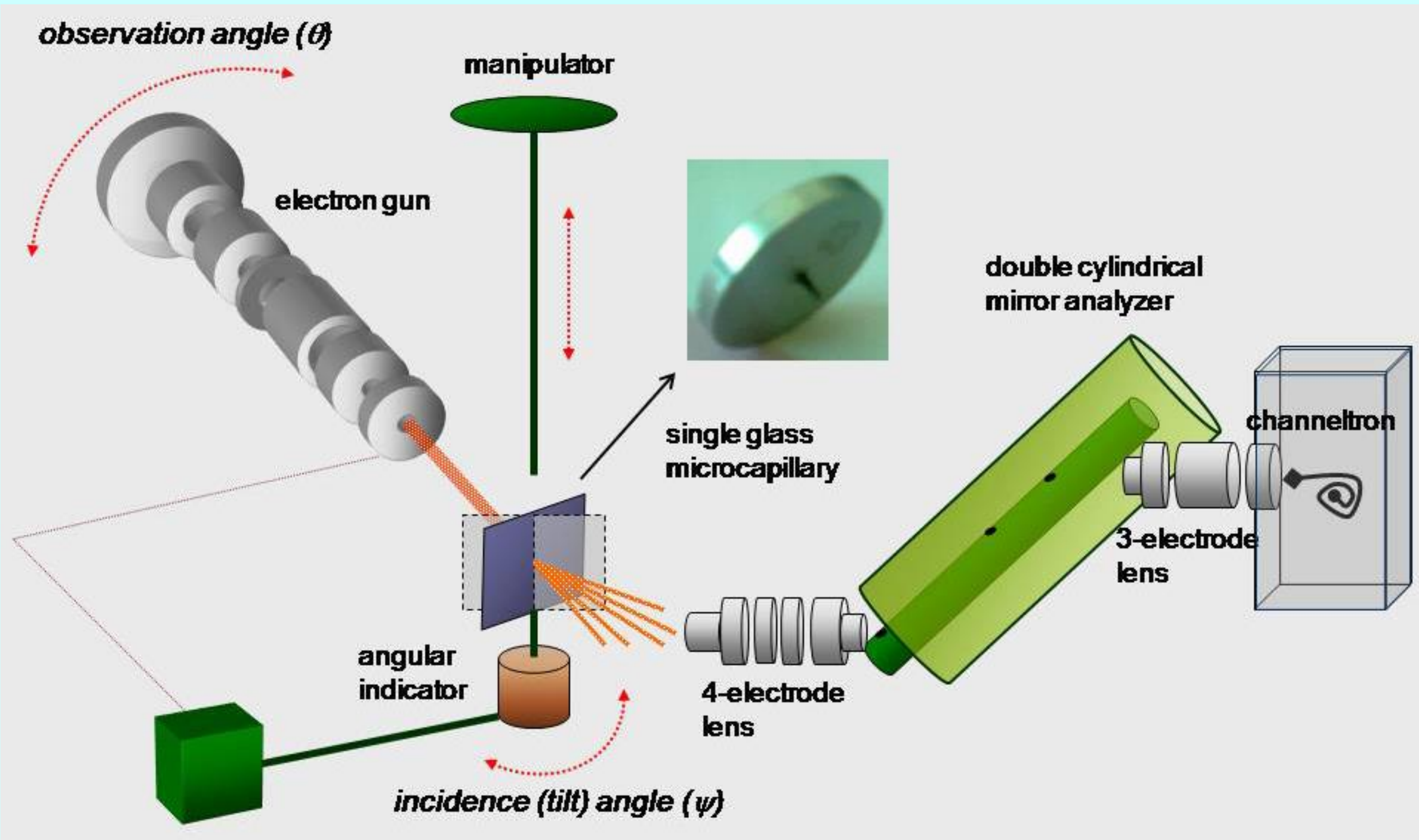
Single glass capillary

- **cylindrical-shape**
- **produced from borosilicate (glass**
- **inner diameter: 150 μm, length: 12.40 mm, aspect ratio: 82.6**
- **the full external surface of the capillary was covered with graphite**

The experiment

The measurements were performed in the Laboratory for atomic collision processes at the Institute of Physics Belgrade, Serbia [4].

The experimental setup



Schematic drawing of the experimental setup

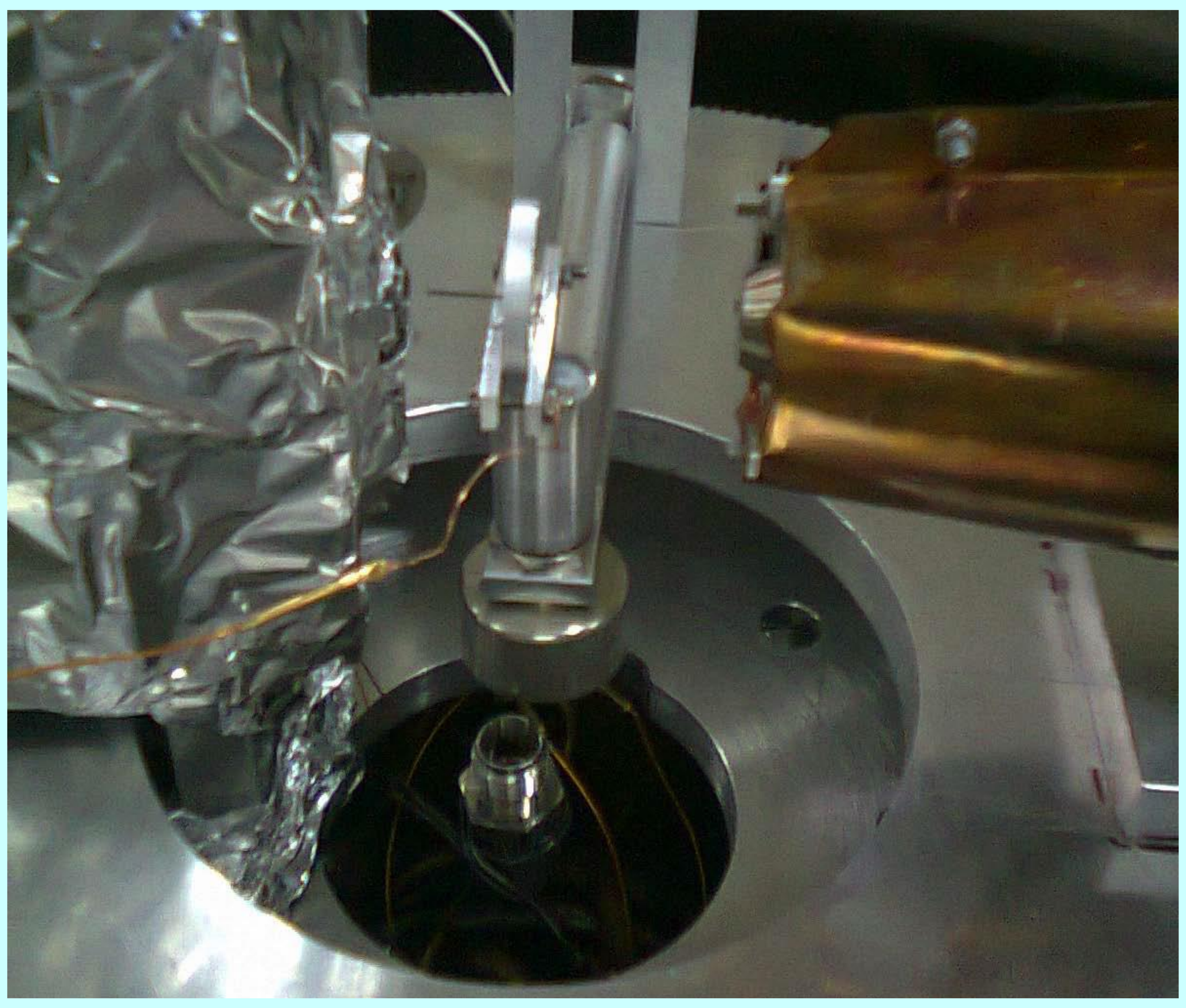
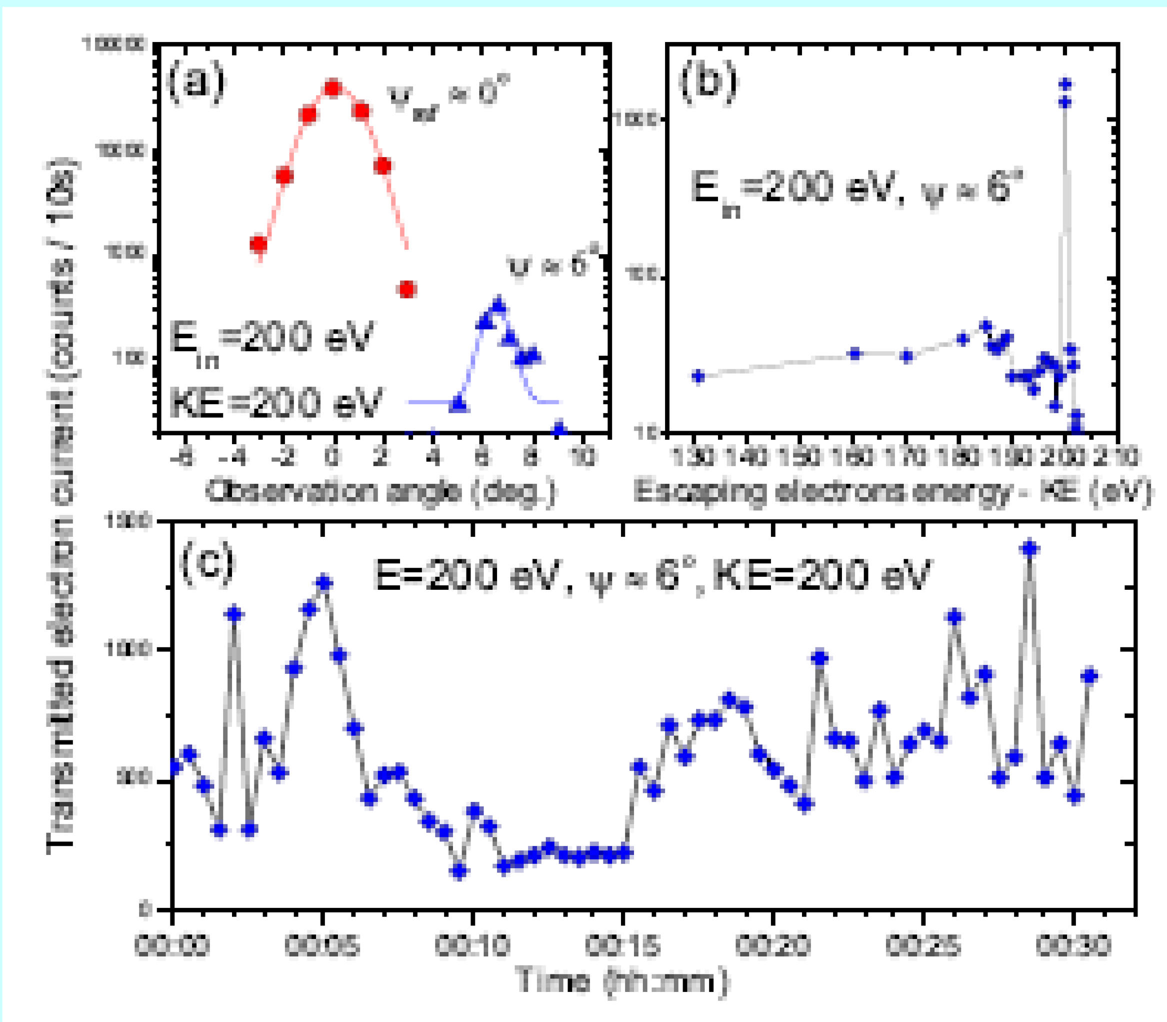


Photo of the experimental chamber with the capillary sample

- **The system includes an electron gun and a double cylindrical mirror energy analyzer and allows measurements of transmitted current at incident electron energies from about 100 eV to 350 eV, variation of both tilt and observation angles and an energy analysis of transmitted electrons.**
- **The used incident electron beam current sent to the entrance of the microcapillary was typically about 10 nA and the size of the beam ~ 1mm.**
- **The pressure in the experimental chamber was about 5×10^{-7} mbar.**
- **The transmitted electrons, after being selected by energy are detected by a single channel electron multiplier working in a single-counting mode.**
- **The energy spectra of out going electrons were measured in the constant pass-energy mode of the energy analyzer by adjusting the retarding potential of the entrance electrode, with the overall resolution of about 1.0 - 1.5 eV.**

Results



(a) The angular distribution of electrons transmitted through the capillary for different tilt angles Ψ.

(b) The kinetic energy distribution of electrons escaping the capillary at the tilt angle of 6°.

(c) The time dependence of transmitted current intensity at the tile angle of 6 °.

Conclusions

- **The electrons are transmitted even at the large tilt angle, where direct transmission should be geometrically prevented, thus suggesting the existence of the guiding effect.**
- **The measured kinetic energy distribution of electrons escaping the capillary at 6° also indicates a significant fraction of electrons that suffer inelastic collisions, beside the dominant elastic peak.**
- **The unstable behavior of transmission could be the consequence of a quite large incident current of the order of 10 nA.**

Acknowledgements

The work was supported by the Ministry of Education and Science of Republic of Serbia (Project No. 171020) and by the Hungarian Scientific Research Fund OTKA , No. NN 103279 and by the Bilateral Cooperation Program between the Hungarian and Serbian Academies.

References

[1] E. Gruber et al. Phys Rev. A 86 062901, 2012.
[2] B.S. Dassanayake et. al. Phy. Rev. A 81 020701 (R) , 2010.
[3] A.R. Milosavljevic et .al. Phys ReV A 75 030901(R) 2007.
[4] A. R. Milosavljevic et .al .2012 Proc. 26th SPIG, Zrenjanin, Serbia p79.

Email: bereczky.reka@atomki.mta.hu