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&
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ENERGY AND ANGULAR DISTRIBUTION OF ELECTRONS TRANSMITTED THROUGH A SINGLE GLASS MICROCAPILLARY

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Abstract. We present an experimental study on transmission of low-energy electrons at the incident energy of 200 eV through a single glass microscopic capillary (inner diameter: 0.15 mm, length: 12.4 mm). The energy and angular distributions of electrons passing through the cylindrical shaped capillary were measured for different tilt angles of the capillary in reference to the incident electron beam direction. The angular distributions suggest possible existence of guiding effect. However, the measured energy spectra show that electrons also suffer inelastic processes inside the capillary,

1. INTRODUCTION

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 bio-nanotechnologies and possibility to investigate fundamental processes of electron-surface interactions. The investigation of the transmission of electrons through highly insulating nanocapillaries has been triggered by an intensive research on guiding of highly charged ions (HCI) by insulating capillaries. The first pioneering experiment on guiding of HCI by insulating PET nanocapillaries were reported by Stolterfoht and coauthors in 2002 [1], followed by a large amount of papers presenting both experimental and theoretical results, as well as interesting applications of this effect (see e.g. [2]).

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The first results on electron guiding by array of insulating nanocapillaries made in Al_2O_3 and PET were reported in 2007 by Milosavljević et al. [3] and Das et al. [4], respectively. In recent years, a number of experimental and theoretical results on electron guiding have been reported for different types of insulating micro and nanocapillaries [5]. Furthermore, the processes of electron transmission through insulating capillaries appeared to be more complex than in the case of HCI guiding, where the guiding is dominantly due to the Coulomb deflection. In the case of electrons the close electron-surface interaction and secondary electron emission, as well as Coulomb deflection, must be taken into account [6]. Actually, different reported results suggest that some of these processes can be more or less pronounced, which might also depend for example on the type of insulating capillaries, the incident electron current, and energy.

In the present contribution we present preliminary results on transmission of low-energy electrons of 200 eV through a single glass capillary of high aspect ratio. We investigate both angular distribution of electrons transmitted with the incident energy and energy distribution of electron escaping the capillary.

2. EXPERIMENTAL

2.1 Preparation of microcapillaries

The glass capillary sample was prepared at the ATOMKI laboratory in Debrecen, Hungary. The high aspect ratio single glass capillary was obtained by heating a straight glass tube made of Borosilicate glass and stretching it by applying constant force at the two ends. The final capillary sample with a desired diameter was cut by a diamond cutter and polished in order to obtain smooth surface. Previous measurements in the ATOMKI laboratory for similar samples have shown a smoothness of about 3 nm, and x-ray photoelectron spectroscopy (XPS) shows the cleanliness.

The front side of the capillary tube and its holder was coated with a layer of graphite to prevent excess charges upon electron bombardment of the capillary holder. The sample was fixed into an aluminium disk holder and a UHV compatible glue was used to fix the tubes. In the present case, the glass 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.

2.2 Experimental setup

The measurements of transmission of electrons through the single glass microcapillary were performed in the Laboratory for atomic collision processes at the Institute of Physics Belgrade, Serbia. The modified crossed-beams experimental setup has been essentially described previously [3,6]. Briefly, the setup includes an electron gun and a double cylindrical mirror energy analyzer. This system 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 electron gun produces a well collimated electron beam, with a diameter and an angular divergence estimated to be approximately 1 mm and 1^{o} at 200 eV of the incident energy, and with an energy spread of about 0.5 eV. The used incident electron beam current sent to the entrance of the microcapillary was typically about 10 nA but further measurements are needed for an estimation of the electron flux entering the capillary. The base pressure in the experimental chamber was about 5×10^{-7} mbar.

The glass capillary sample fixed on its holder was mounted on a target holder made of Al, allowing a change of the orientation of the capillary axis with respect to the electron beam direction (see Figure 1). 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 outgoing 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 (full width at half-maximum – FWHM).

Figure 1. Photo of the experimental setup. The capillary sample, mounted on a rotatable holder, is shown in the middle of figure; the entrance of the energy analyzer is on the left and electron gun on the right side.

3. RESULTS

Figure 1 shows the results of our preliminary measurements. Figure 1a shows the angular distributions of electrons transmitted through the single glass capillary at the incident energy of 200 eV, at three different tilt angles of the incident electron beam with respect to the capillary direction. The measurements were performed by fixing the angle between the capillary and the incident beam (measured by a resistor) and then by recording the signal intensity (count rates) of transmitted electron current as a function of the observation angle – the angle between the capillary direction and the axis of the entrance electron lens of the analyzer. The zero tilt angle has been approximately defined in the present case according to the maximum transmitted signal. The results show transmission of electrons even at large tilt angles, where direct transmission should be geometrically prevented, thus suggesting en existence of the guiding effect.

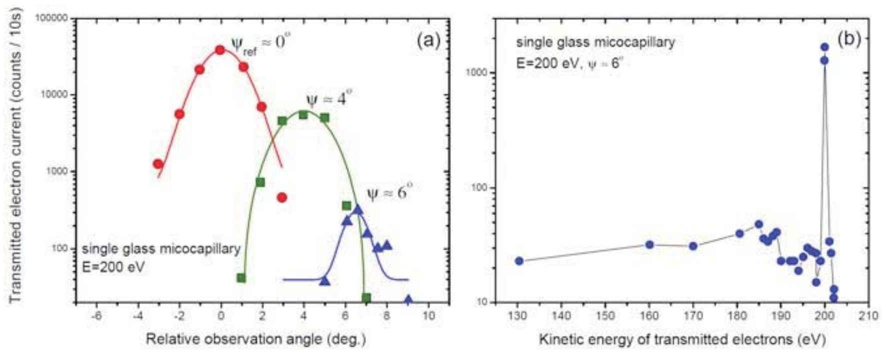

Figure 2. (a) Angular distribution of electrons transmitted through the capillary at the incident energy, for different tilt angles (ψ). (b) Kinetic energy distribution of electrons escaping the capillary at the tilt angle of 6^o.

Figure 2b. shows the measured kinetic energy distribution of electrons escaping the capillaries at large tilt angle. Except the dominant peak at about 200 eV corresponding to elastic transmission, there is a significant fraction of electrons that suffer inelastic collisions.

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