# Study of nanostructures formed by the interaction of low-energy HCI xenon with Ti and Au nanolayers using AFM and STM techniques

**A. Foks1,\*, I. Stabrawa1, D. Banaś1, A. Kubala-Kukuś1, Ł. Jabłoński1, P. Jagodziński1,   
D. Sobota1, K. Szary1, M. Pajek1, E. Mendyk2, K. Skrzypiec2 and M. Borysiewicz3**

1Institute of Physics, Jan Kochanowski University, 25-406 Kielce, Poland  
2Faculty of Chemistry, M. Curie-Skłodowska University, 20-031 Lublin, Poland  
3Institute of Electron Technology, 02-668 Warsaw, Poland

\*corresponding author: arkadiuszfoks95@gmail.com

The method of surface modification by the impact of low-energy highly charged ions (HCI) can be used to change the topology of the surface, and thus has potential to develop materials with new and unique properties. [1]. This method can be used e.g., for creation of various surface nanostructures (pits, craters, hillocks) [2], for nanopatterning [3], and perforating of single-layer materials [4]).

In this work, modifications of Ti and Au nanolayers caused by highly charged xenon ions were studied. The nanolayers were prepared at the Institute of Electron Technology (Warsaw, Poland) using VST TFDS- 462U deposition system. As a substrate Topsil (Warsaw, Poland) Si (110) polished prime wafers type N were used. The nanolayers were irradiated with Xeq+ (q = 15 – 40) ions in the energy range hundreds of keV (nuclear stopping power regime) at a fluence of about 1010 ions/cm2 using low energy HCI accelerator with the EBIS ion source installed at the Institute of Physics, Jan Kochanowski University (Kielce, Poland) [5, 6]. Well pronounced modifications of the nanolayers surface, due to impact of the HCI ions, in the form of hillock and craters have been observed.

The topographic modifications of the samples surface induced by Xeq+ ions were investigated using atomic force microscopy (Faculty of Chemistry, UMCS, Lublin, Poland) and scanning tunneling microscope (Institute of Physics, Jan Kochanowski University, Kielce, Poland).

The AFM measurements of the studied samples were performed using Multimode 8 AFM equipped with NanoScope software (Bruker-Veeco, USA). The AFM was operated in SCANASYST-HR fast scanning mode using SCANASYST-AIR-HR probe (Silicon Tip on Nitride Lever) with the cantilever of force constant k = 0.4 N/m. The measurements were performed in air. The lateral and vertical resolutions were 4 nm and 0.1 nm for the 1 μm x 1 μm, and 2 nm and 0.1 nm for the 500 nm x 500 nm images. Data acquisition by STM method was performed using SPM Aarhus 150 operating with Nanonis control system (SPECS). The tip was polycrystalline tungsten wire etched by the argon ion sputtering. Measuring equipment is located in the ultra-high vacuum chamber (10-10 mbar) and operating in the room temperature.

The obtained images were analyzed with the WSxM software. The collected data made it possible to correlate the mean nanostructures size (diameters, depths, heights, volumes) with different ion parameters.

**References**[1] J. V. Barth *et al.* 2005 *Nature* 437 671  
[2] F. Aumayr *et al.* 2011 *J. Phys.: Condens. Matter* 23 393001  
[3] J. Gierak 2014 *Nanofabrication* 1 35  
[4] R. Kozubek *et al.* 2019 *J. Phys. Chem. Lett.* 10(5) 904  
[5] D. Banaś *et al.* 2015 *Nucl. Instr. Meth. B* 354 125   
[6] I. Stabrawa *et al.* 2017 *Nucl. Instr. Meth. B* 408 235