

SUBSTRATE SURFACE PREPARATION BY LOW ENERGY ION IMPACT: SETTING THE STAGE FOR MOLECULAR PINNING OF BIOMOLECULES

Wippel F. *, El-Said A.S., Gruenberger C., Ritter R., Aumayr F. and Gebeshuber I.C.

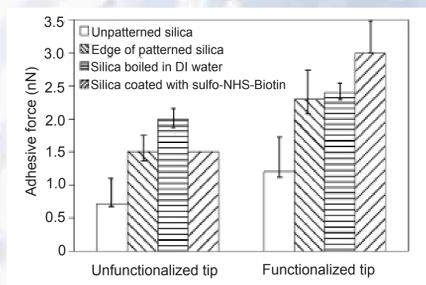
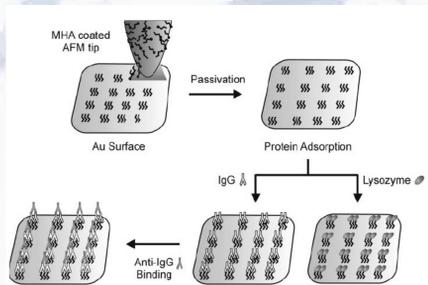
Institut für Allgemeine Physik, Vienna University of Technology, A-1040 Wien, Austria
*wippel@iap.tuwien.ac.at

INTRODUCTION

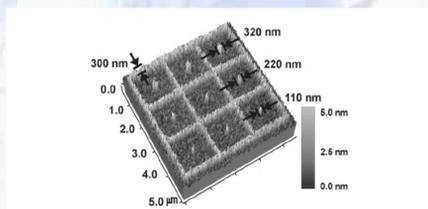
Much work has been done on immobilizing biomolecules on various substrates. Several chemical procedures have been developed for coating surfaces with all kind of large molecules [1]. But to fix large molecules (fullerenes and biomolecules such as hemoglobin and DNA fragments) to specific pre-selected spots of various substrates is still a challenge. Still the adhesion properties and mechanisms are not well understood and under research [2].

The locally well defined, firm pinning of large biomolecules on various modified substrates is the aim of this study. The substrates will be modified and prepared for immobilizing biomolecules by impact of multiply (MCIs) and single charged low energy ions.

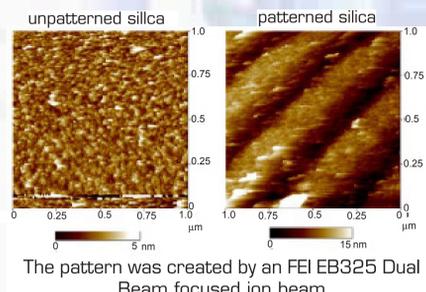
IMMOBILIZING BIOMOLECULES ON SURFACES



For forming very small structures of biomolecules dip-pen nanolithography can be used [3]. The AFM-tip is coated with a ligand of a receptor molecule. By the tip the ligand is patterned on a surface (coated with gold) in various forms. A solution containing the receptor (mostly proteins) is brought into contact with the surface. The part of the surface prepared by the AFM-tip with the ligand is coated with the protein.



Adhesion measurements were performed by B. Bhushan [2]. The figure above shows the results for the protein streptavidin on a silica surface. Four conditions were tested. The AFM-tip was functionalised by the protein streptavidin. For comparison the experiments were repeated with an unfunctionalized tip (silicon nitrate).



APPLICATION OF BIOMOLECULES PINNED ON SURFACES

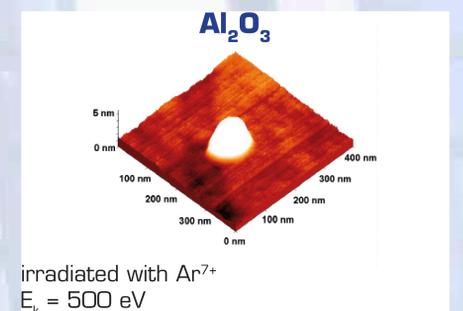
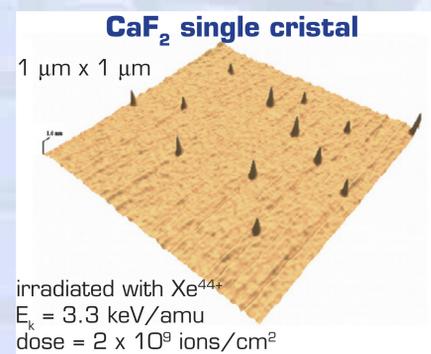
The controlled deposition of large biomolecules provides means for several applications.

Biological adhesion molecules and growth molecules shall be patterned in pre-given shapes on several surfaces. Furthermore, surfaces modified with transmitters shall facilitate the study of biomolecule-cell interactions. Patterning bioreceptors for biosensors is a continuously growing field of applied research. Molecular agents can be identified even in a complex biological milieu by the use of corresponding ligand-molecules.

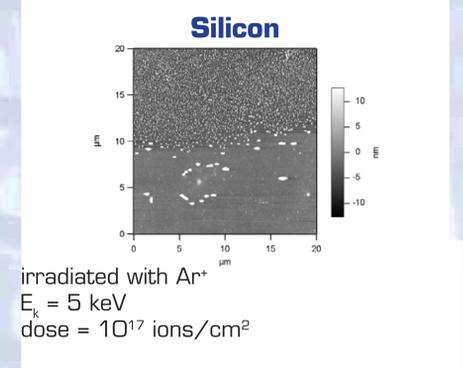
The analysis of diffraction experiments involving large molecules is still a challenge. By a simple mechanism for fixation of these molecules to surfaces might be the solution to the analysis of molecular interference experiments.

Another highly promising application lies in the field of microfluidic devices.

EFFECTS OF LOW ENERGY ION IMPACT ON SURFACES



The modifications induced by the impact of low energy ions have been under investigation for several different surfaces by our group [4,5,6]. A major finding were formations of nano-sized hillocks (diameter: 20 - 40nm; height: a few nm). These nanostructures shall be investigated regarding the usability for firm pinning of biomolecules.



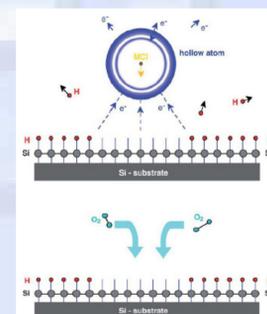
PROPOSED RESEARCH

JRA 4: PRODUCTION AND CHARACTERISATION OF GAS PHASE BIOMOLECULAR TARGETS

Task D: Substrate surface preparation by low energy ion impact

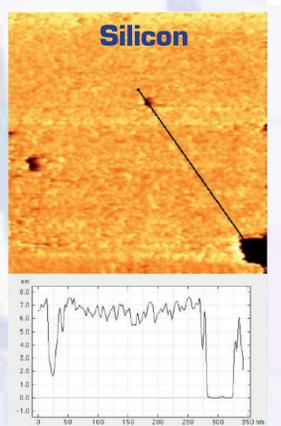
Implementation plan for the whole period	1 st year	2 nd year	3 rd year	4 th year	Month after start
Investigation of molecular pinning on various substrates (silicon, CaF ₂ , ...)					
Milestone M 4.6: Demonstration of molecular pinning on metal oxides					24
Study of molecular pinning on SiO ₂					
Milestone M 4.8: Demonstration of molecular pinning on SiO ₂					36
Study of molecular pinning on TiO ₂ and Al ₂ O ₃					
Milestone M 4.9: Demonstration of molecular pinning on TiO ₂ and Al ₂ O ₃					48
Deliverable D 4.11: Report on molecular pinning on different substrates					48

NANODOT FORMATION BY MCI IRRADIATION



Slow multiply-charged ions modify surfaces in a very gentle and controlled way (only at or slightly below the surface).

In this example the multiply-charged ions (Ar⁹⁺, Ek = 45 keV, dose = 10¹⁰ ions/cm²) were used for removing the H-termination in nanosized areas on the silicon surface [5] (left fig.). Oxygen induced into the vacuum chamber yields nanosized SiO₂ nanodots. (right fig.).



References

- [1] T.G.M Schalkhammer (2002) "Analytical Biotechnology", Methods and Tools in Biosciences and Medicin, Birkhäuser Verlag, Basel Boston Berlin
- [2] B. Bhushan *et al.* (2005) "Morphology and adhesion of biomolecules on silicon based surfaces", Acta Biomaterialia 1, 327-341
- [3] K.B. Lee *et al.* (2002) "Protein nanoarrays generated by dip-pen nanolithography", Science 25, 1702 - 1705
- [4] A.S. El-Said *et al.* (2007) "Surface nanostructures induced by slow highly charged ions on CaF₂ single crystals", Nuclear Instruments and Methods in Physics Research B 256, 346-349
- [5] I.C. Gebeshuber *et al.* (2006) "Emerging Technologies - Nanoelectronics", Proc. IEEE Conference, 324 - 327
- [6] F. Aumayr *et al.* (2003) "Slow Highly Charged Ions - A New Tool For Surface Nanostructuring?" J. Surf. Sci. Nanotech. Vol. 1, 171-174
- [7] L. Hacker Müller *et al.* (2004) "Decoherence of matter waves by thermal emission of radiation", Nature 427, 711-714