Why Surface Science and Nanostructure Physics?

example 1: MOSFET and the high k-dielectrics

Intel's new 45 nm processors

HfO₂ deposited by atomic layer epitaxy (ALE)

Fig.1
Example 2: the Car Exhaust Catalytic Converter

H.J. Freund,

Fig. 2
Example 3: Nanotubes

- View into a carbon nanotube
- Harvesting and spinning of nanotubes
- Vision of the space elevator realized through nanotubes

M. Zhang et al., Science 306, 1358 (2004) Fig.3
Lecture Plan „Physics of Surfaces and Nanostructures WS0910

1. Structure of Surfaces
   - basic concepts of surface crystallography
   - measuring surface structure
   - reconstruction, examples
   - domain walls and the Frenkel-Kontorova model
   - surface defects and their measurement

2. Electronic Structure of Surfaces
   - work function and its measurement
   - jellium model
   - surface states
   - quantization effects in confined geometries
   - measuring surface electronic structure

3. Adsorption, Desorption, and Catalysis
   - physisorption and chemisorption
   - measuring surface composition and binding
   - rates of surface chemical reactions and the transition state
   - charge transfer and binding mechanisms
   - concepts of heterogeneous catalysis (volcanoplot etc.)
   - nanocatalysis
4. Thermodynamic Aspects of Surfaces
- the surface excess
- surface stress, surface free energy and surface tension
- chemical potential and Laplace pressure
- phase transitions and phase equilibrium
- applications of capillary concepts

5. Epitaxy and Thin Films
- nucleation
- kinetic processes and homoepitaxy
- epitaxy and elastic energy in thin films, quantum dots
- organic thin films
- applications (hard coatings, semiconductor thin films)

6. Surface and Thin Film Magnetism
- fundamentals of band magnetism
- magnetic impurities
- surface, interface and shape anisotropy
- exchange coupling and the GMR effect
- atomic scale magnetism
- magnetic imaging
7. Ion Beam Processes at Surfaces
- sputtering and collision cascades
- linear stability analysis and pattern formation
- implantation
- applications (SIMS, Smartcut, FIB)

8. Clusters
- cluster preparation
- cluster properties (magnetic, catalytic, electronic)
- applications
Script and Overheads
http://www.ph2.uni-koeln.de/de/lehre/
user: Master
password: nano
Literature
• H. Ibach: Physics of Surfaces and Interfaces, Springer, 80 €
in depth treatment, partly difficult, special attention to electrochemical interfaces
• K. Oura et al: Surface Science, Springer, 96 €
easy introduction, sometimes a little cursory
• M. Prutton: Introduction to Surface Physics, Oxford University Press, 39 €
simple, often too simple introduction, written for undergraduates, but an easy starting point
• H. Lüth: Solid Surfaces, Interfaces and Thin Films, Springer, 68 €
emphasis on electronic structure and semiconductor interfaces
• M. Henzler/ W. Göpel: Oberflächenphysik des Festkörpers, 45 €
cheap, slightly outdated but reasonable introduction, ugly pictures
• A. Zangwill: Physics at surfaces, 52 €
introduction from the theoretical point of view
• J. Venables: Introduction to Surface and Thin Film Processes, 51 €
not really a textbook, more like a collection of ideas and concepts
• G. Ertl J. Küppers: Low Energy Electrons and Surface Chemistry, antiquarian
mainly on techniques, well written but somewhat outdated