Why Surface Physics ?

- Objects are contacted via their surface.
- Chemical reactions: Catalysis, electrodes of batteries
- Friction and Lubrication
- Nanotechnology is Surface Physics

"Gott schuf das Volumen,

der Teufel die Oberfläche."

(verm. Wolfgang Pauli)

Surface Physics – Since When?

1805, 1806: Discussion of surface tension by T. Young and P.S. de Laplace

1830: C.F. Gauss introduces concept of surface energy

1833: Döbereiner's Feuerzeug

1874: K. F. Brauns Gleichrichter

1877: Thermodynamics by W. Gibbs, including surfaces

1906/32: I. Langmuir, PhD / Nobel prize (surface chemistry)

1927: Electron diffraction by C.J. Davisson & L. Germer
Nobel laureates 1937

1932: Electronic surface states predicted by I. Tamm

Johann Wolfgang Döbereiner 1780–1849

Seit 1780: Fürstenberger Feuerzeug: H_2SO_4 + Zn > H_2 + Funken

1810 A*ußerordentlicher* Professor für Chemie, U Jena

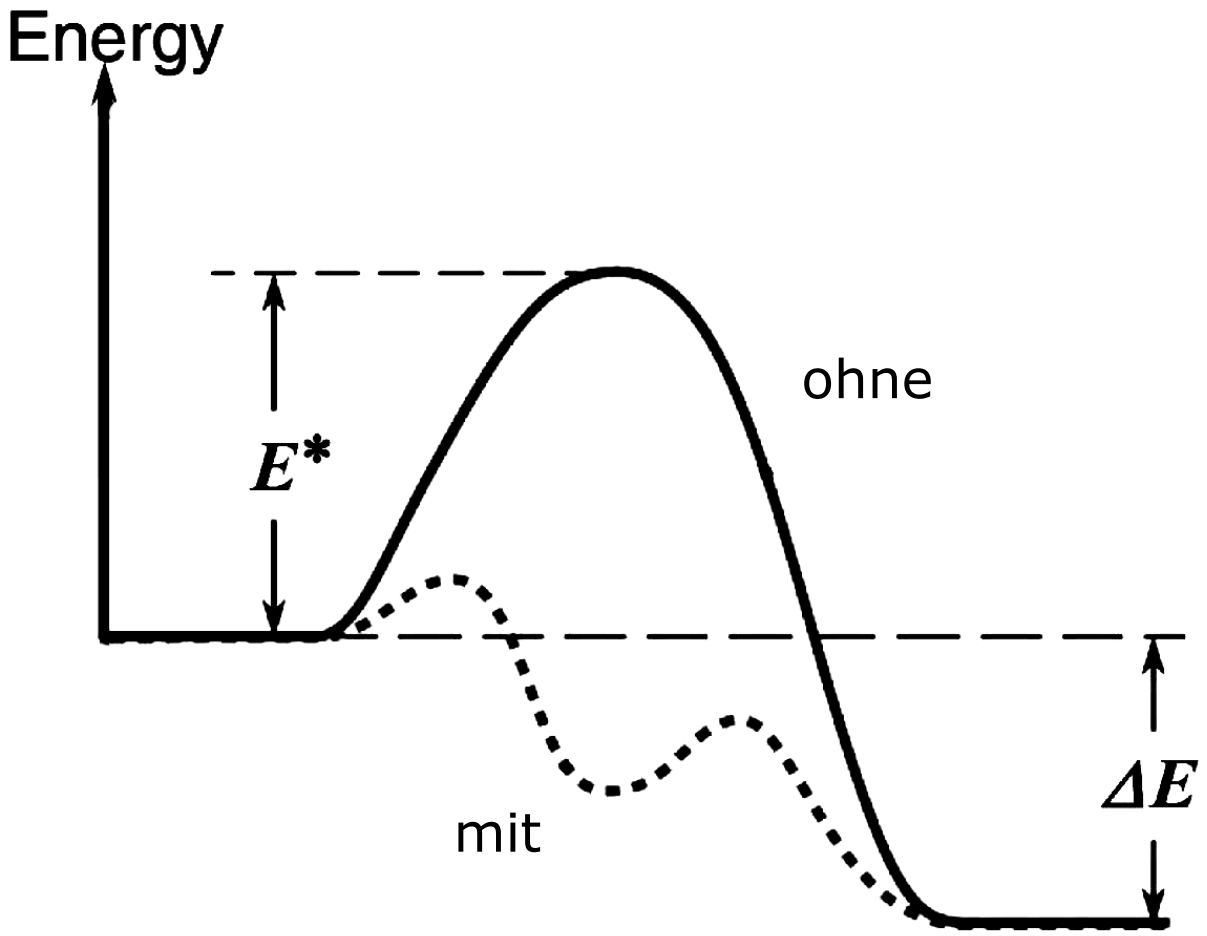
1823 H_2 entzündet sich selbst bei Durchströmen von Pt-Pulver, Pt weißglühend

Später Katalyse benannt (durch Berzelius); Feuerzeug vertrieben in D & GB, 1827 - 1880

Jöns Jakob Berzelius

Döbereiners Feuerzeug

Wirkprinzip eines Katalysators



1874 Karl Ferdinand Braun

Stapel aus C und FeS weicht von ohmschem Gesetz ab

Vermutung: dünne Oberflächenschichten relevant

Gleichrichtung

Irving Langmuir

* 31 January 1881, Brooklyn, NY, USA

+16 August 1957, Falmouth, MA, USA

From: www.nobelprize.org

Dissertation 1906 bei Nernst, Göttingen

Gasdissoziation an heißem Platindraht

3 Jahre später erfindet er N_2-Leuchtstoffröhre (bei GE)

Grundlagenarbeiten zu

Adsorption, Katalyse, Austrittsarbeit

1932 Nobelpreis dafür

Folgende Seiten nach Sommerschule in Santa Barbara, 2006:

Techniques of Surface Science and Catalysis

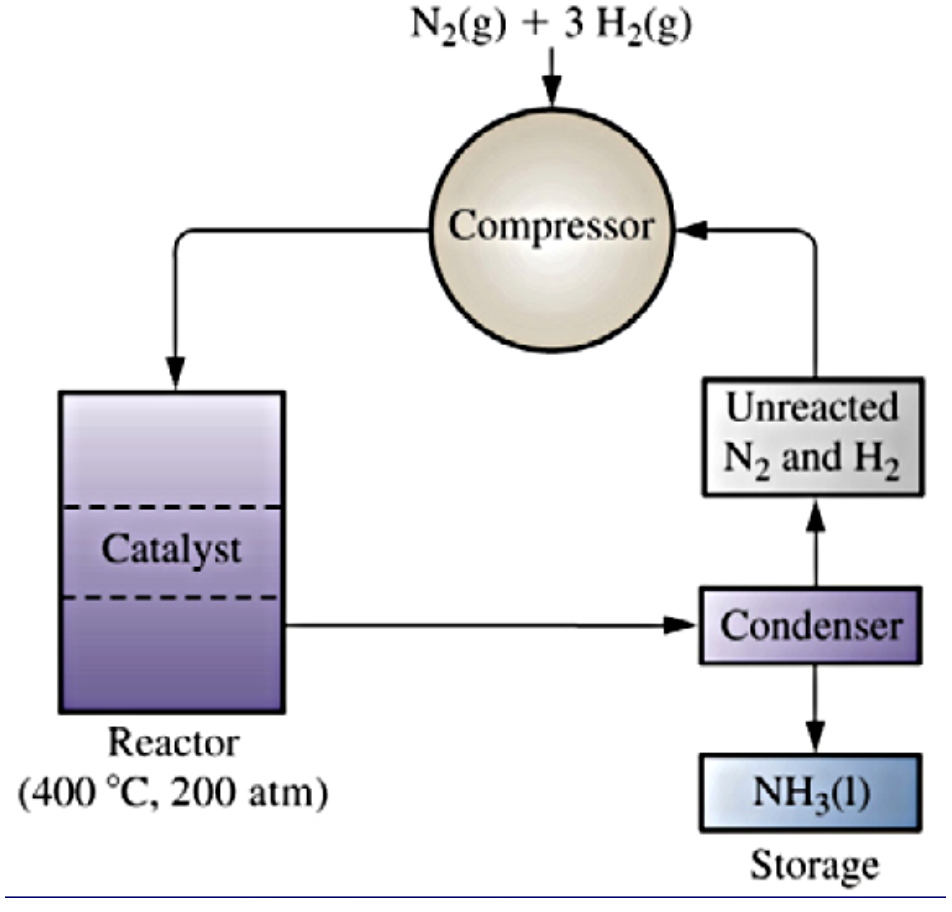
Goals of catalysis research:

- Finding special conditions that speed speed-up normally slow reactions
- Convert cheap and abundant chemicals into useful, high-value ones
- Convert noxious chemicals to harmless ones e.g. N_2 and H_2 to NH_3

"Air to Food Food" - The greatest scientific discovery of last century

- At moderate T and high p, H_2 and N_2 (from thin air) will form NH_3.
- One century after invention, applied all over the world:

  $5x10^8$ t/a of fertilizer sustaining 40% of the worlds population Nature 427 (2004) 498
- 1% of the world's energy budget used for a single reaction Science 297 (1654) 2002
- TWO NOBEL PRIZES FOR ONE REACTION!



Beides wikipedia

Haber-Bosch-Verfahren

Phosgen

Clara

emigrierte 1933 nach Cambridge

Haber-Bosch-Verfahren

Nobelpreise für Chemie

1918 Fritz Haber

1931 Carl Bosch (mit Friedrich Bergius)

Modern Catalysis – New opportunities and challenges

Nano-catalysis

Preparation of supported Au catalysts by gas-phase grafting of Au acethylacetonate for low-T oxidation of CO and H_2, Okumura, Tsubota, Haruta, J. Mol. Catal. (2003)

"When Gold is not noble"

Photocatalysis

First-principles approach to Catalysis

Optimal Catalyst Curves: Connecting DFT Calculations with Industrial Reactor Design and Catalyst Selection

Jacobsen, Dahl, Boisen, Clausen, Topsoe, Logadottir, Nørskov, J. Catal. (2002)

Progress is a by by-product of Science I

But no scientist, no matter how aware he may be of these fruits of his science, cultivates his work, or refrains from it, because of arguments such as these. No scientist can hope to evaluate what his studies, his researches, his experiments may in the end produce for his fellow men, except in one respect – if they are sound, they will produce new knowledge.

J. Robert Oppenheimer lecturing at MIT on November 25, 1947

Progress is a by by-product of Science II

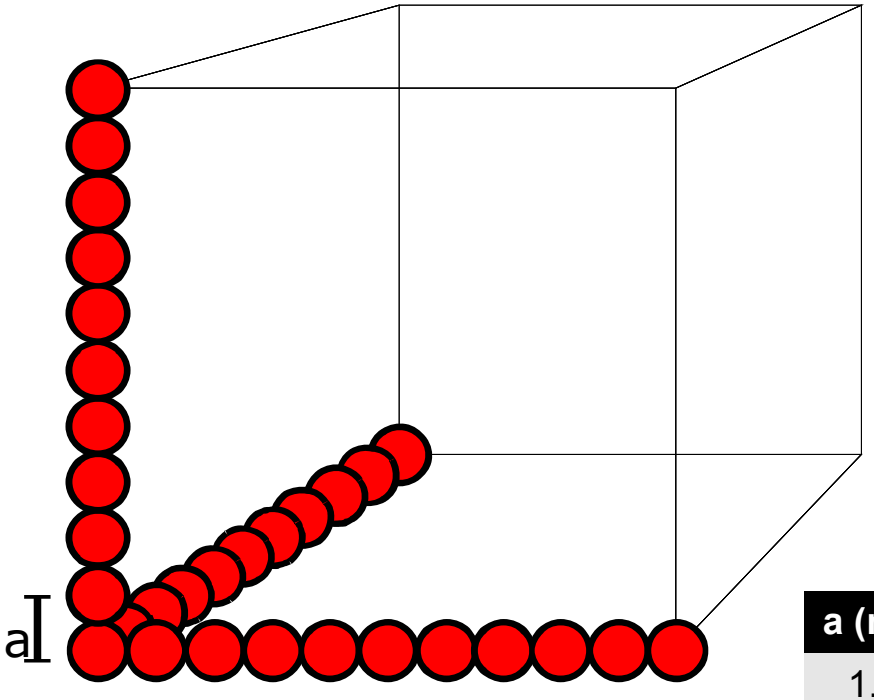
à la Richard Feynmann, Nobel Laureate in Physics 1965

Physics [science] is like sex,

surely it leads to many useful outcomes,

but that is not why we do it.

Surfaces become increasingly important as dimensions shrink

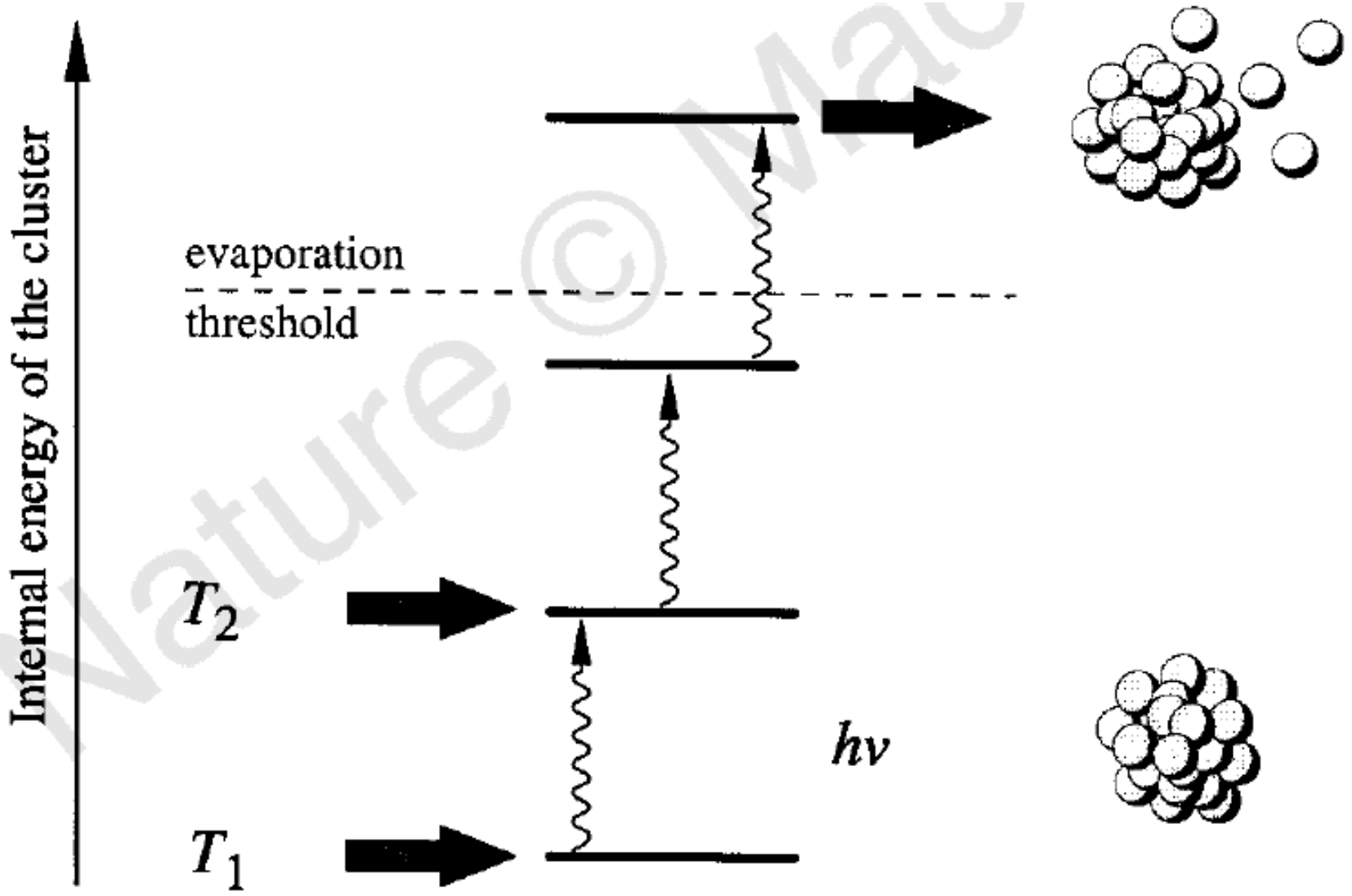


Simple cubic lattice

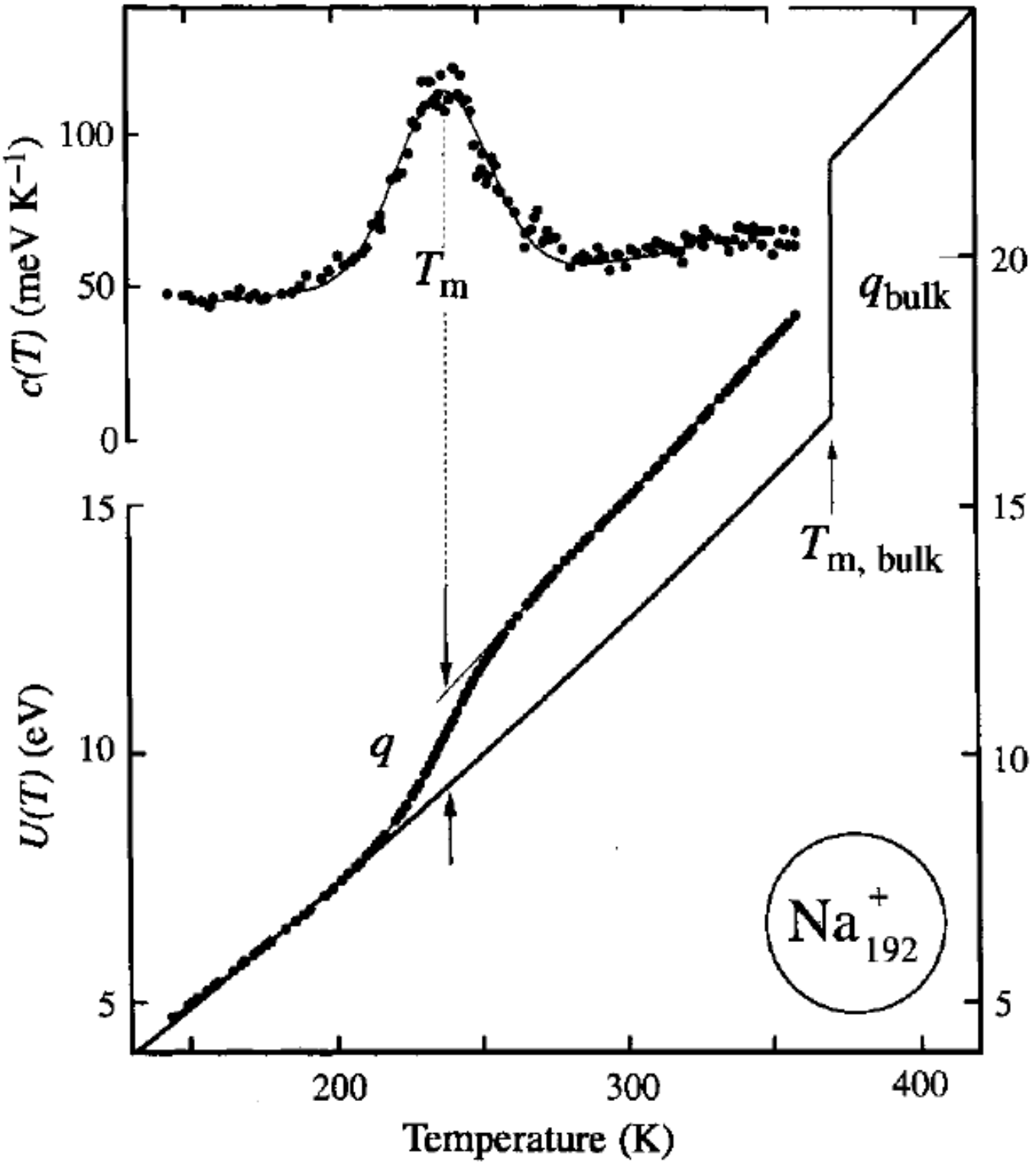
with lattice constant a

a (nm)	atome/kante	Atome insg.	Atome an OF	OF/gesamt
1.000	3.333	37.037.037.037	66.626.675	0,18%
500	1.667	4.629.629.630	16.646.675	0,36%
100	333	37.037.037	662.675	1,79%
50	167	4.629.630	164.675	3,56%
10	33	37.037	6.275	16,94%
5	17	4.630	1.475	31,85%
1	3	37	35	93,60%
	d_atom	0,3		

Melting Point of Size-Selected Clusters

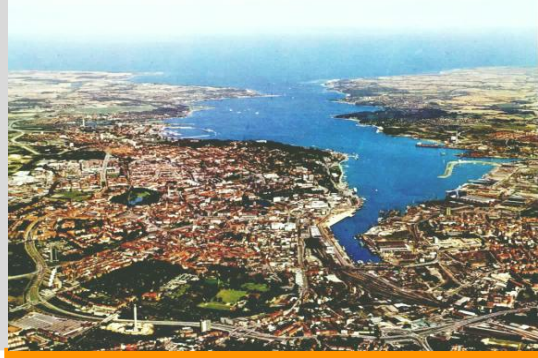


M. Schmidt *et al.*, Nature **393**, 238 (1998).


c(T) (meV K⁻¹)
100
50
0
T_m
q_{bulk}
20
15
$T_{m, bulk}$
15
U(T) (eV)
10
q
10
Na^+_{192}
5
5
200
300
400
Temperature (K)

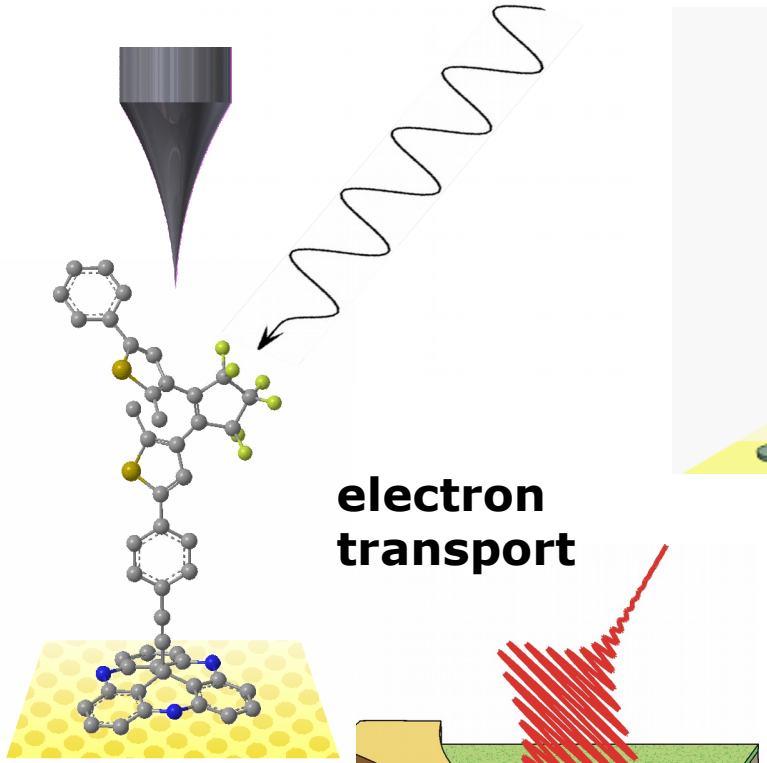
Institut für Experimentelle und Angewandte Physik

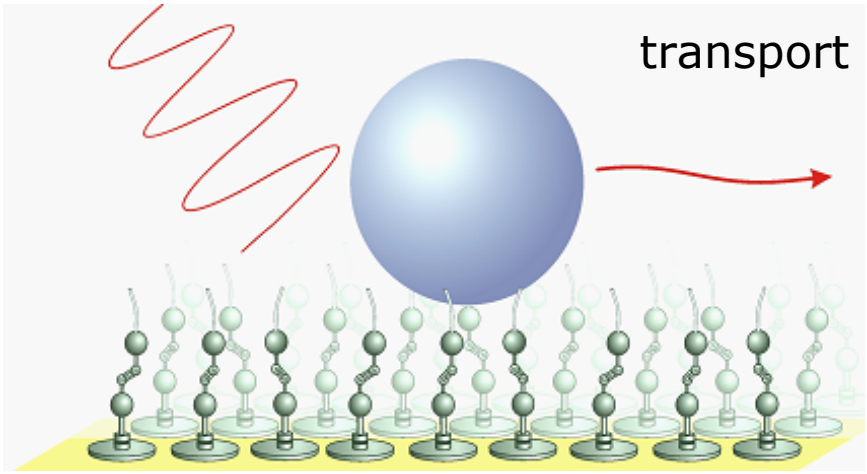
Christian-Albrechts-Universität zu Kiel



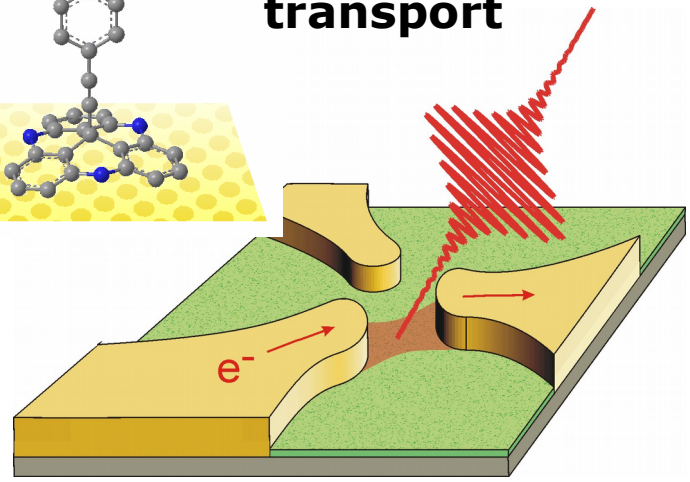
Richard Berndt

Molecular conductors and switches at surfaces

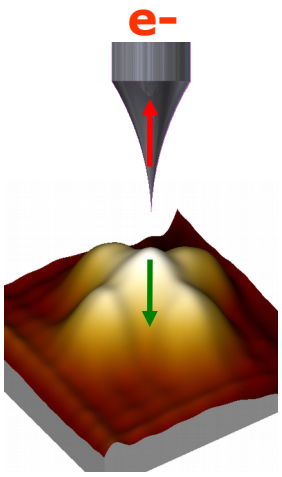


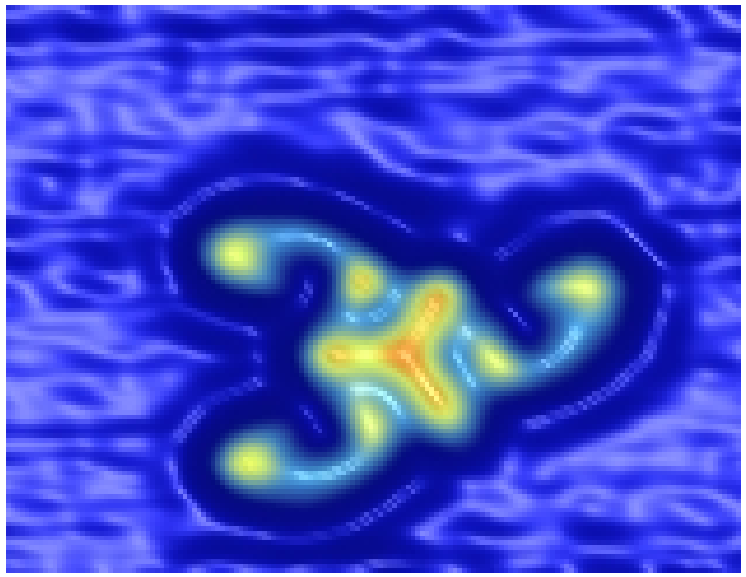


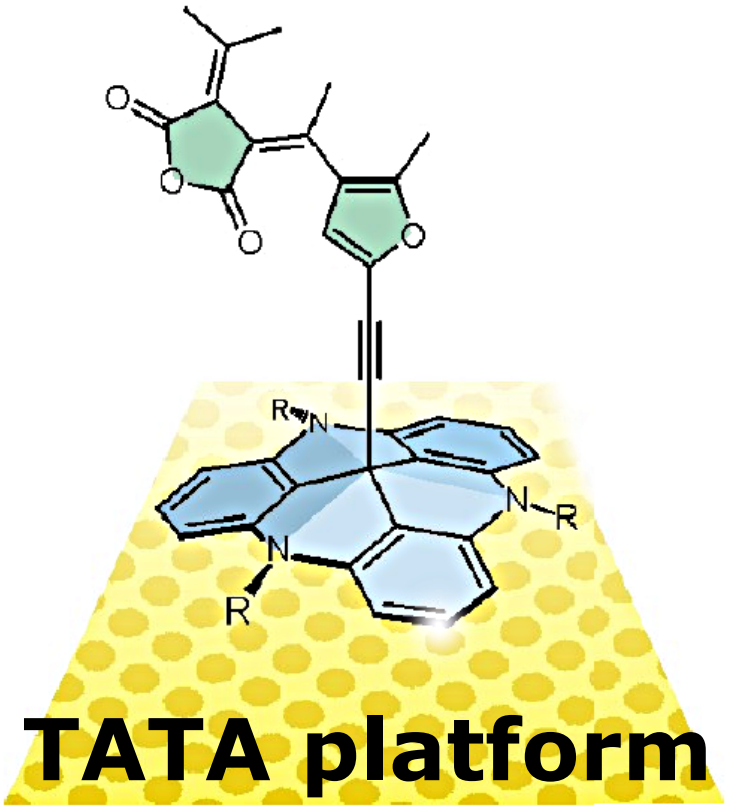
electron transport

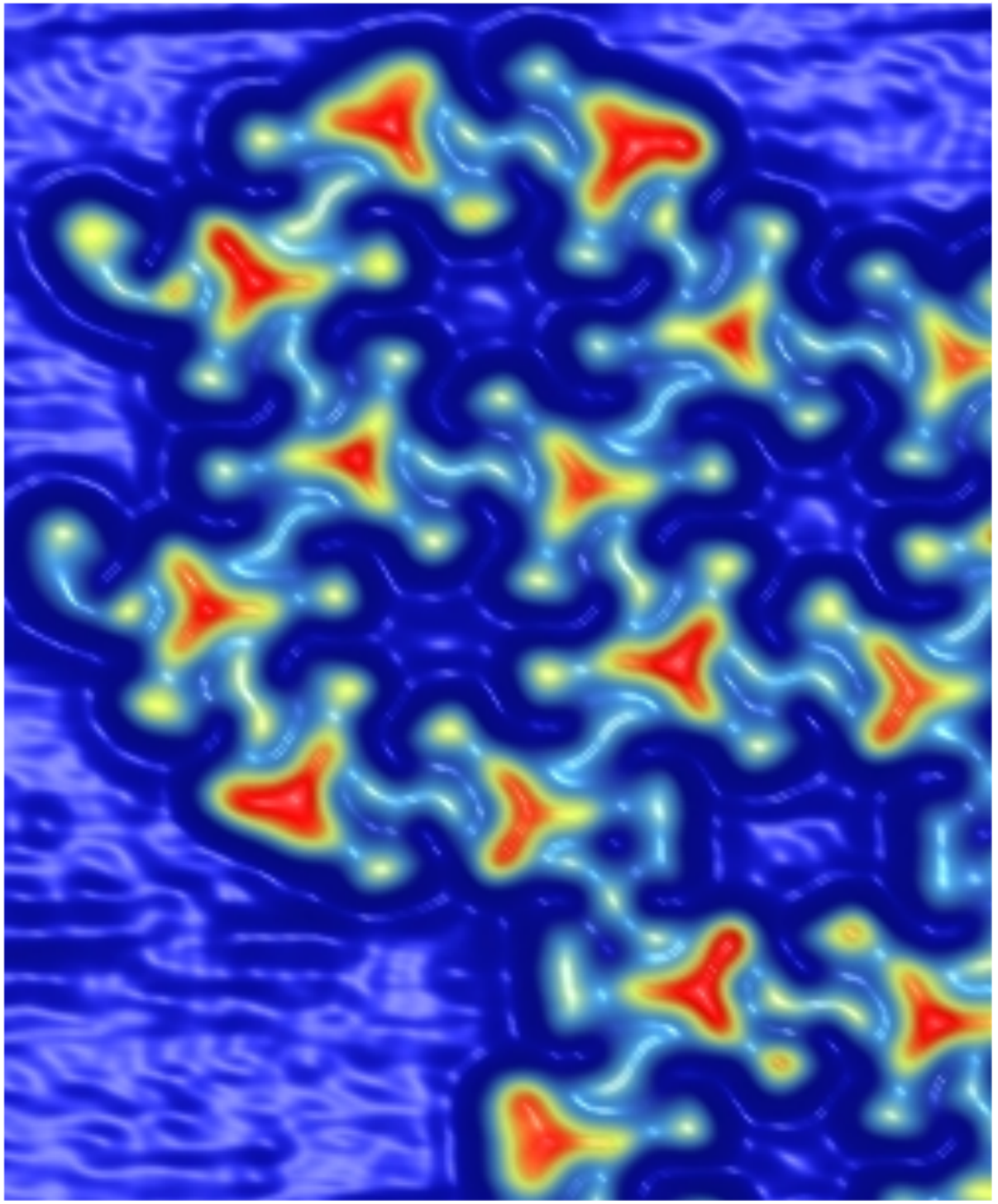


magnetic moment

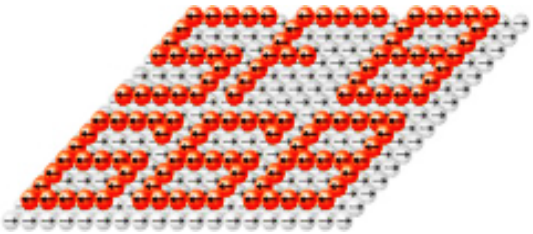


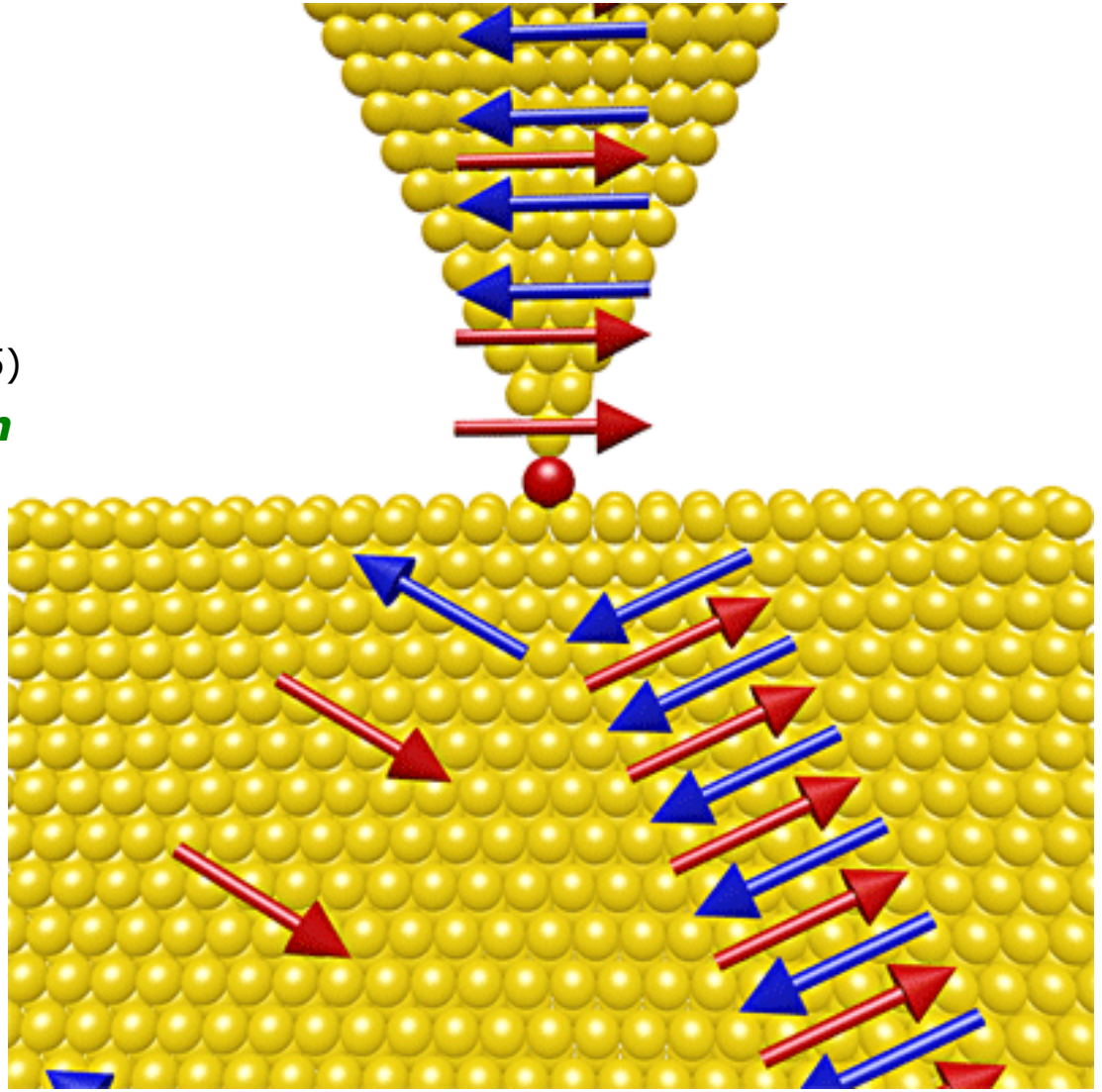






Gopakumar, unpublished

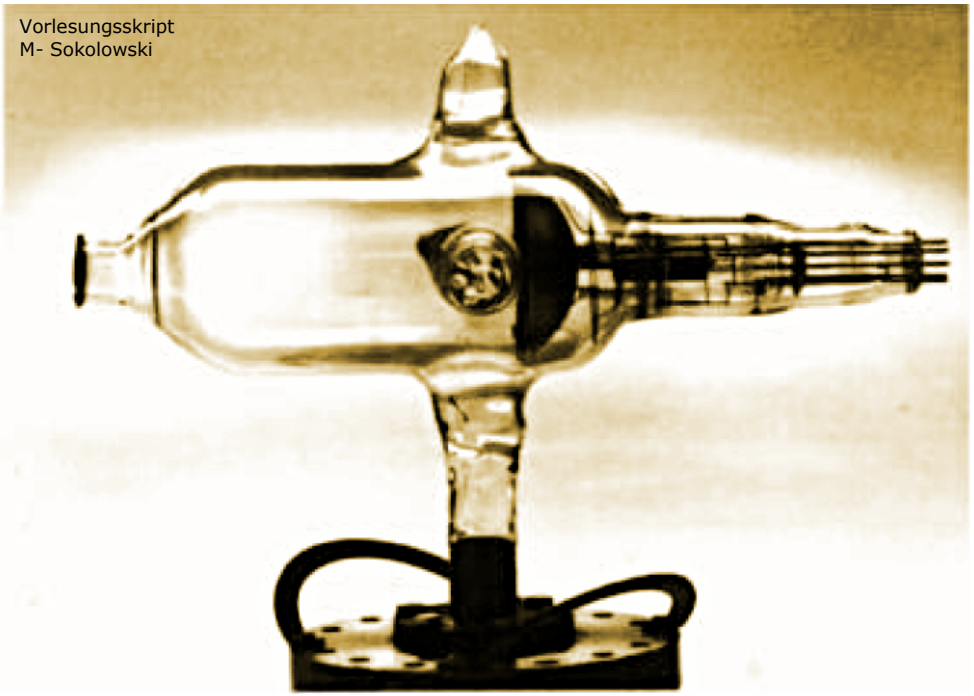




Burtzlaff, Weismann,
Brandbyge, Berndt,
PRL **114**, 016602 (2015)

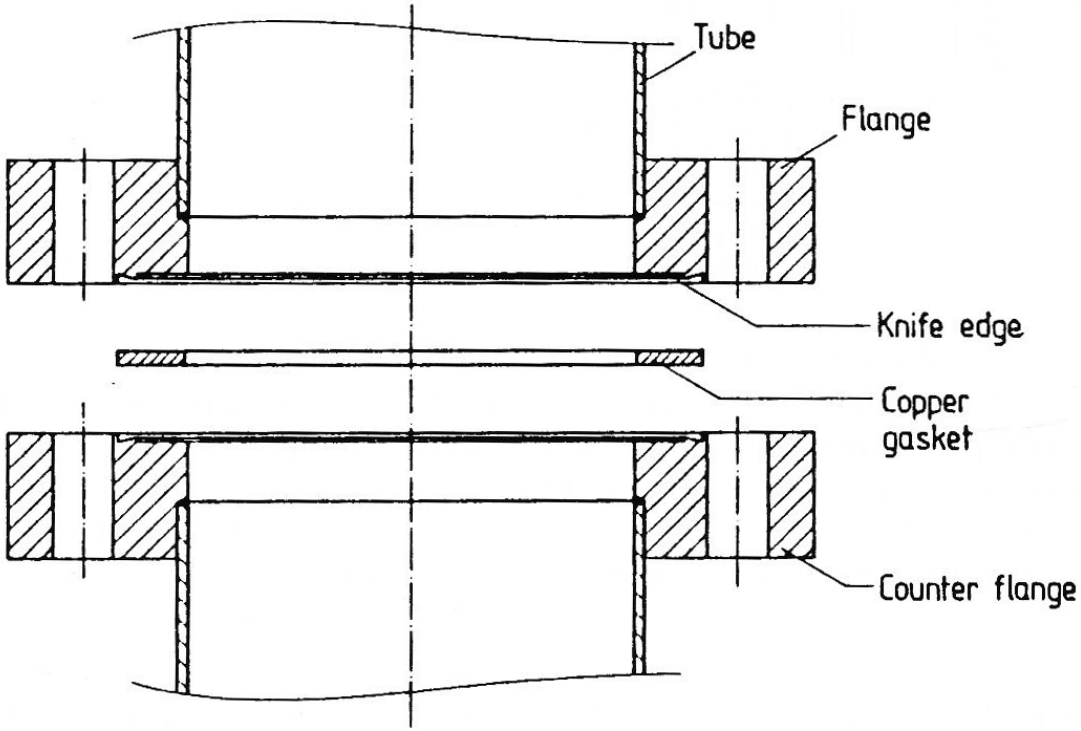
Editors' Suggestion

Vorlesungsskript
M- Sokolowski



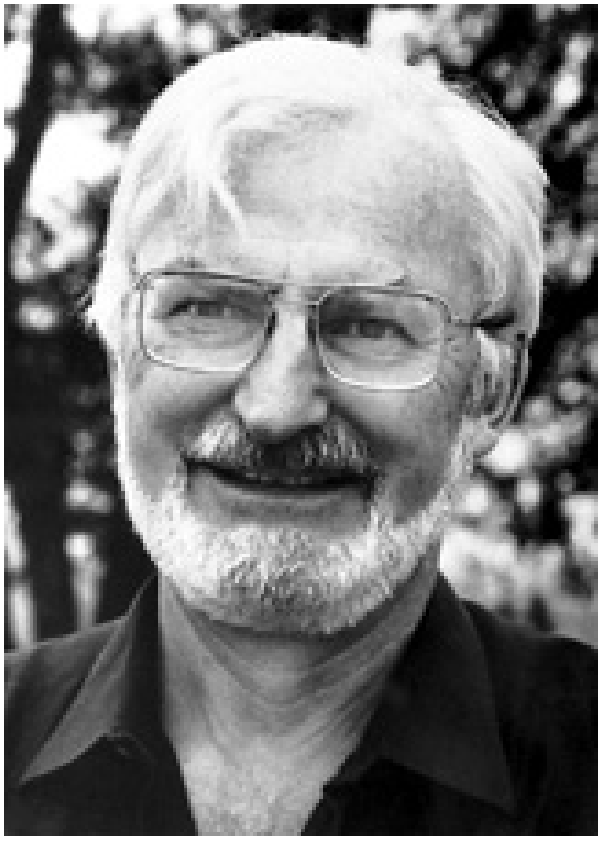
LEED-optics 1960, Prof. Dr. K. Müller, Lehrstuhl für Festkörperphysik, Universität Erlangen-Nürnberg.

A Breakthrough for Surface Science: Ultra-High Vacuum (≥1960)



Nobel Prizes: Physics

Kai M. Siegbahn
Nobel Prize 1981
Development of ESCA



G. Binnig, H. Rohrer
Nobel Prize 1986
Development STM

Albert Fert & Peter Grünberg
Nobel Prize 2007 – Physics
Interfaces

Gerhard Ertl
Nobel Prize 2007 – Chemistry
Surface Chemistry