Introduction to Thin Film Technology

Verfahrenstechnik
der
Oberflächenmodifikationen

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Lecture

Institut für Werkstofftechnik der Uni-Siegen

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FACHBEREICH MASCHINENBAU

Institut für Energietechnik

Institut für Fertigungstechnik

Institut für Fluid- und Thermodynamik

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Forschungsschwerpunkte des LOT

Schichtsysteme

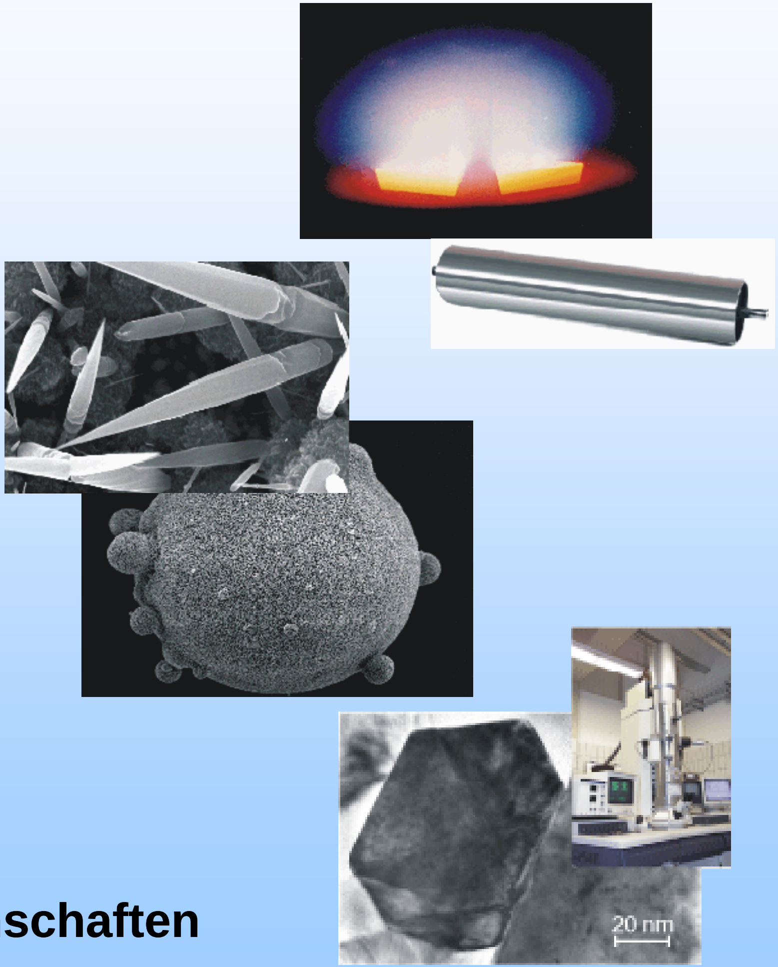
Superharte Schichten
Funktionsschichten
Kompositschichten

Nanomaterialien

Kohlenstoffbasierte Nanostrukturen
Nanokomposite
Galvanische Nanostrukturen

Werkstoffanalytik

Strukturuntersuchungen
Bestimmung von Material/Systemeigenschaften



Stil der Vorlesung

- Skript: Kopie der Folien (Internet)
- Vorlesung mit PP-Präsentation, überwiegend auf Englisch

-Prüfung (mündlich)

Zeit und Raum werden vereinbart

Contents

- 1. Introduction and Application Examples (2h)
- 2. Vacuum Technique (1h)
  - 2.1 Kinetics of Gases
  - 2.2 Transport and Pumping of Gases
  - 2.3 Pumping Systems
- Preparation of Thin Films by PVD (Physical Vapor Deposition) (10h)
  - 2.2 Evaporation (3h)
  - 2.1.1 Thermal Evaporation
  - 2.1.2 Evaporation of alloy and compound films
  - 2.1.3 Reactive Evaporation
  - 2.1.4 Activated Reactive Evaporation
  - 2.1.5 Other modern Evaporation Techniques
  - 2.3 Sputtering (4h)
    - 2.2.1 Physical Principals of the Processes
    - 2.2.2 Further Processes in Film Growth by Sputtering
    - 2.2.3 Sputtering of Alloys
    - 2.2.4 Reactive Sputtering
    - 2.2.5 Technical Setups of Sputtering
  - 2.4 Production of Thin Films by Ions and ionized Clusters (0,5h)
  - 2.5 Characteristic Data of the Particles and their Influences on the Growth of the thin films (1,5h)
- 3 Preparation of Thin Films by CVD (Chemical Vapor Deposition) (4h)
  - 3.1 Conventional CVD Processes
  - 3.2 Plasma-Assisted CVD
    - Plasma Decomposition (a-C:H, a-Si:H)
    - Microwave-Plasma-Assisted Diamond Deposition
- 4 Important Film Systems (2h)

Literatures

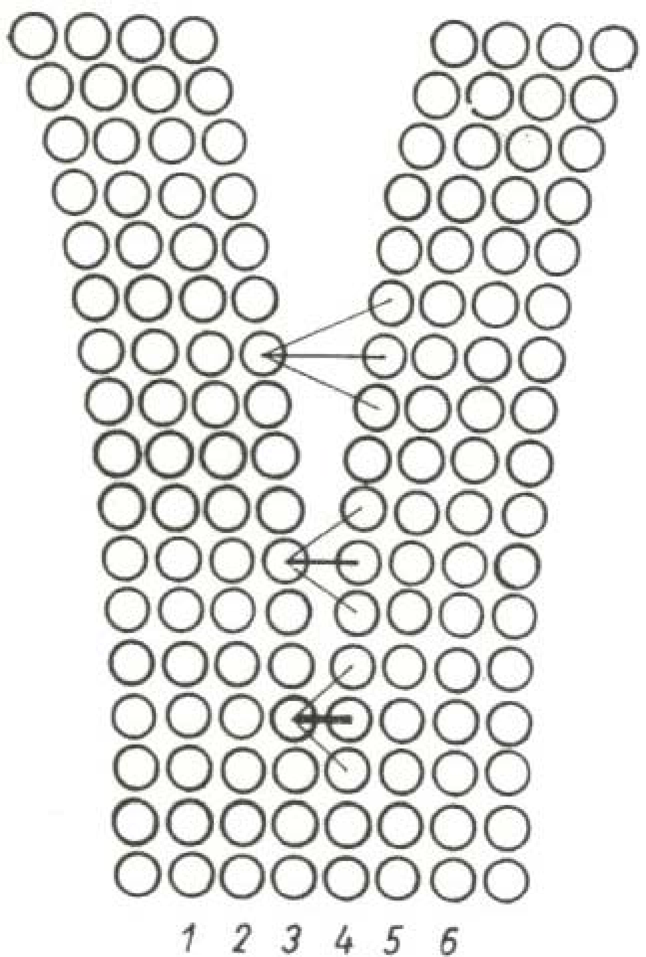
1. M. Ohring, "The materials science of thin films" (Academic Press 1992).
2. R. Kern et al., „Basic Mechanisms in the early stages of epitaxy“ in *Current Topics in Materials Science,* vol 3, series Editor E. Kaldis, p.153-410.
3. 17. IFF-Ferienkurs „Dünne Schichten“, März 1986.
4. H. K. Pulker, Coatings on Glass, Thin Films Science and Technology, 6, Elsevier 1984.
5. K. Reichelt and X. Jiang, Thin Solid Films 191, 91-126 (1990).

Definition

- How is the "Thin Film" defined?
- Which topics are included in the "Surface Technology"?

The cleavage of a crystal:

creation of new surfaces

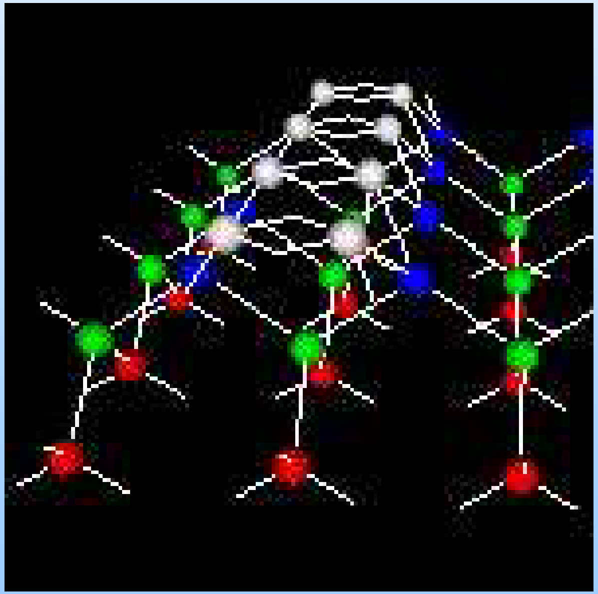


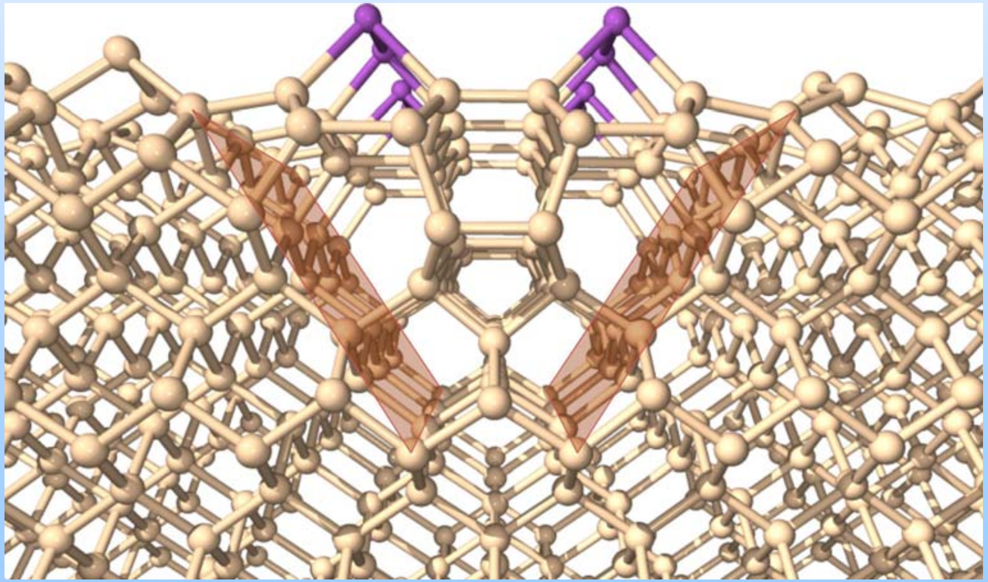
- Break of the bonds
- Reconstruction of the surface atom

Section perpendicular to the line of cleavage

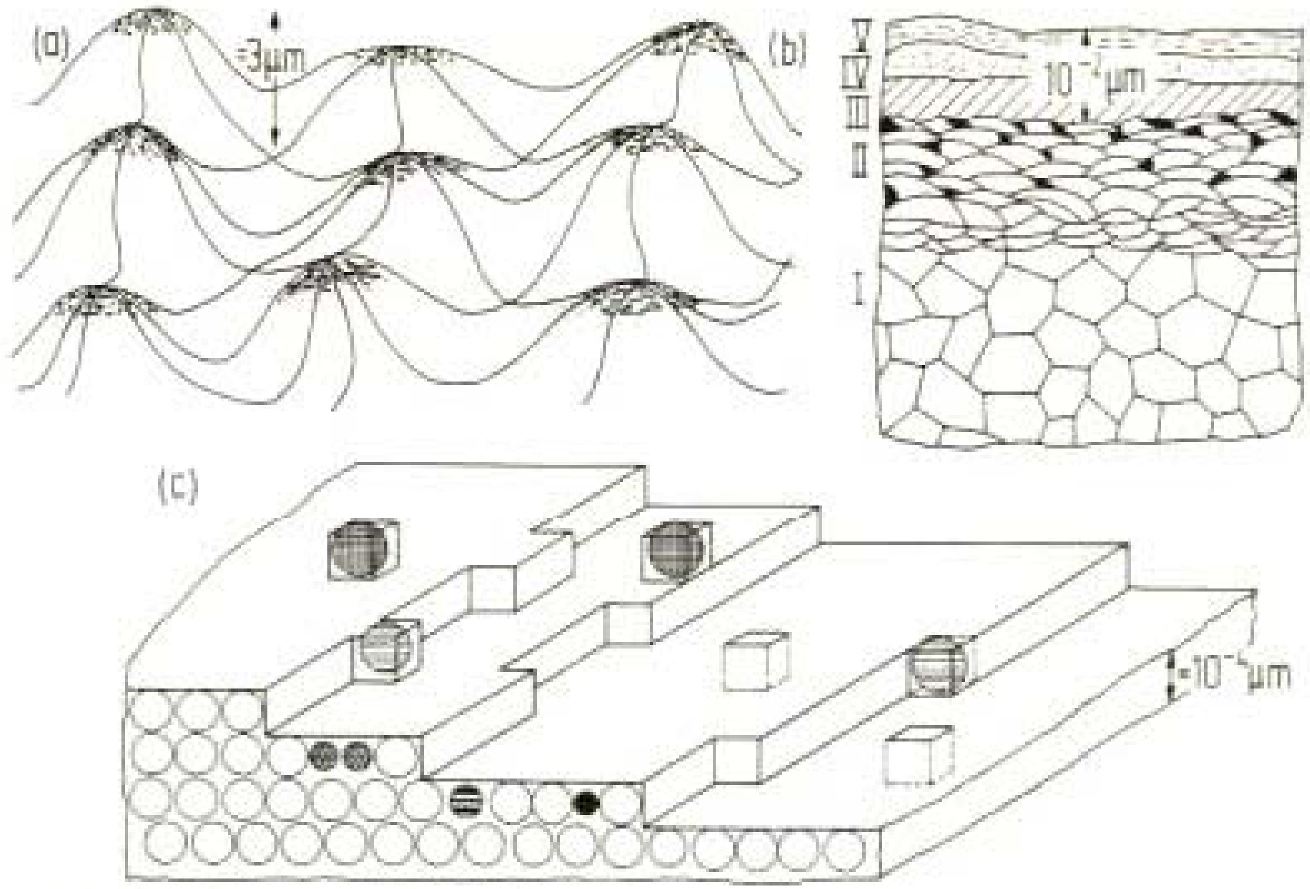
Surface reconstruction

The real crystal has broken (unoccupied) bonds on its surface which may lead to the surface reconstruction. (100) Si surface before reconstruction (rotated 4x4x2 and 6x6x2 lattices). White and blue balls show two FCC sublattices of Si. 2x1 reconstruction of (100) Si surface (RGBW colored and 6x6x2 lattices).





Real surface topography of metals

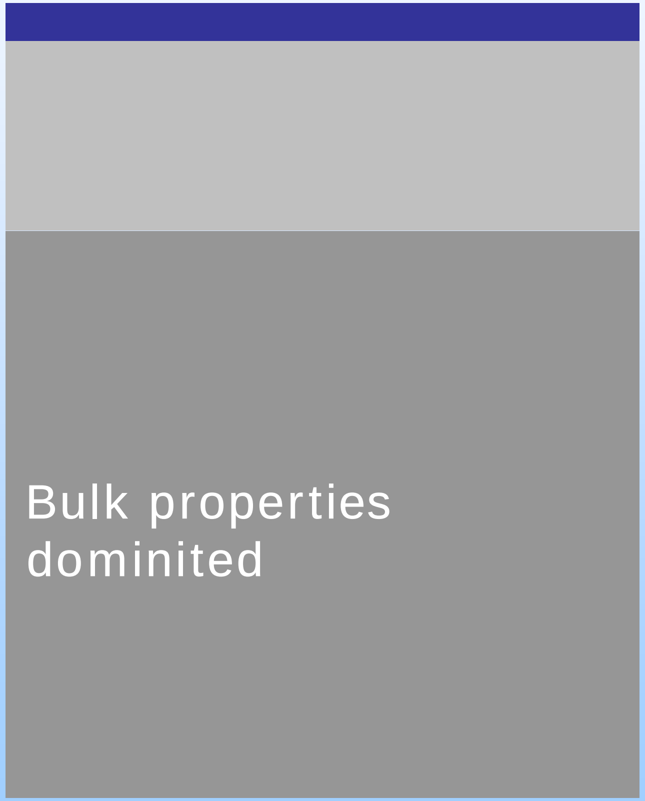


(V) Contamination layer
(IV) Adsorption layer
(III) Reaction layer

(II) Deformations layer

(I) Volume

Scientific areas

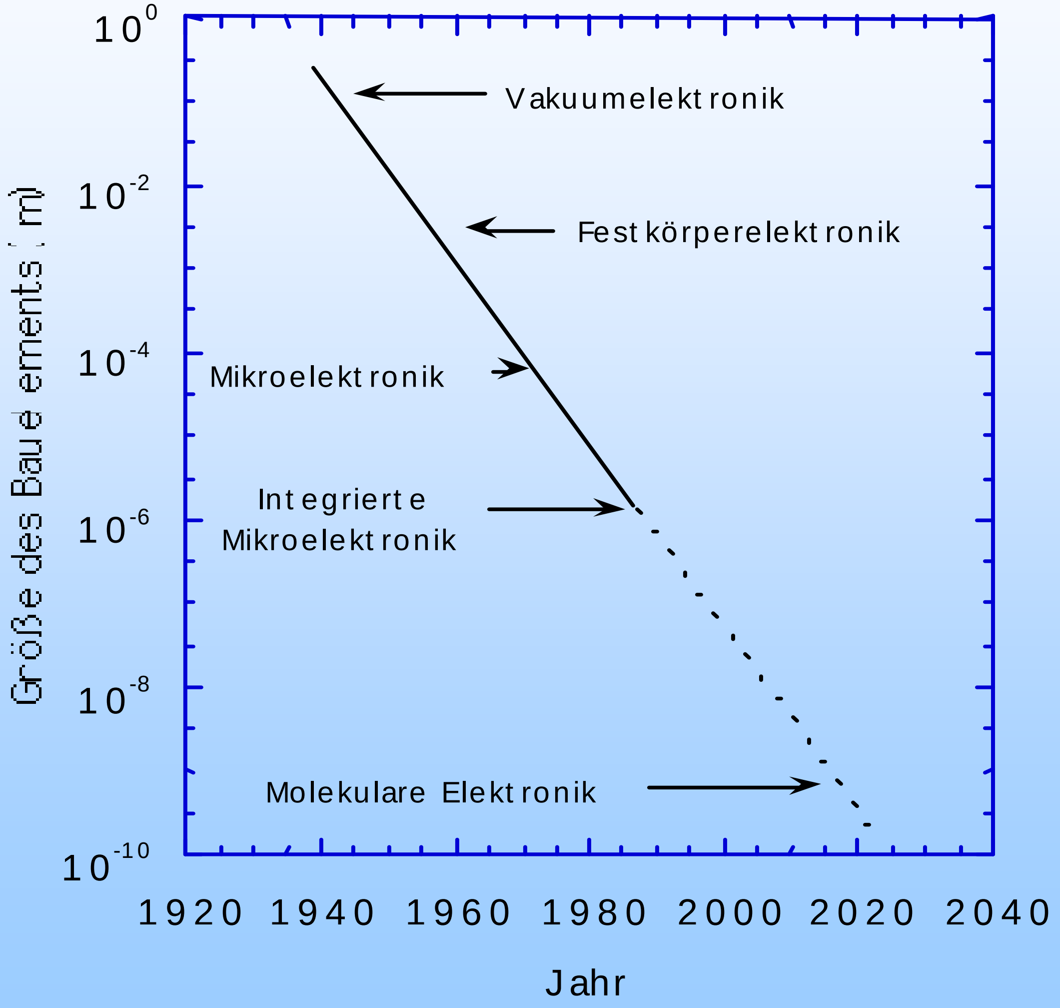


Å to nm ► surface physics/chemistry/technique

nm to µm ► physics/chemistry/technique of thin films

Bulk material ► solid state physics/chemistry/technique

Development of electronics



Introduction to Thin Film Technology

- The course provides foundations in thin film deposition; emphases the most used techniques.
- Modern thin film technology has evolved into a sophisticated set of techniques used to increase performance and aesthetic value of many products and make new functional systems and devices.
- There are following categories of thin film deposition
  - Physical vapor deposition (PVD)
  - Chemical vapor deposition (CVD)
  - Chemical methods
  - Electrochemical methods
- Combinations of these methods gives a large number of deposition techniques with unique impact on the thin film formation.

Thin Films and Deposition

Thin films

- Monolayer - several micrometers
- Thin film properties may be different from those of bulk
- Quantum confinement effect: quantum and size surface/area ratio effects– quantum dots

Thin Film Deposition

- **Thin films can be deposited under non-equilibrium conditions**
- Solid - Melting -Vaporization- Condensation-Solidification
- Vapor - Reaction -Condensation-Solidification
- Gas/vapor- Plasma- Reaction-Condensation-Solidification

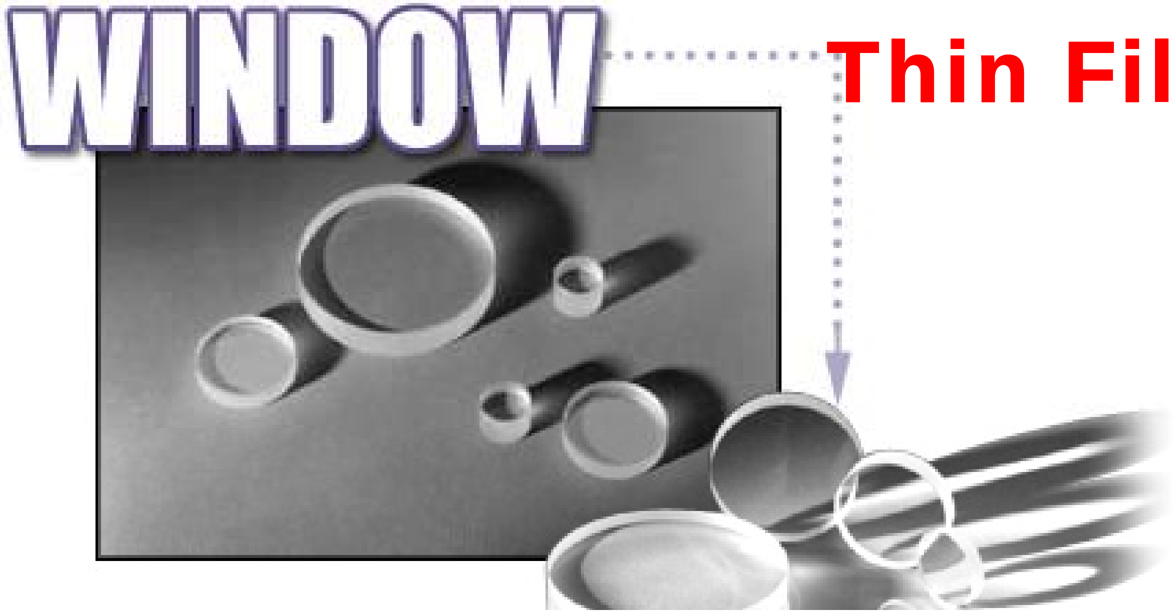
Application areas of thin films and surface engineering

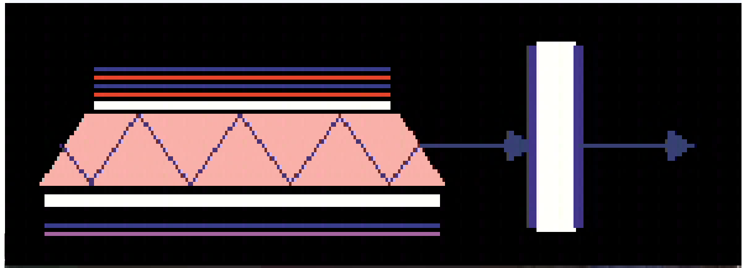
- **Electronics**
  - Flexible Polymer Light Emitting Displays
- **Optical coatings**
  - Anti-reflex films for liens systems und umbrella glass
- **Supra-conductive films**
  - SQUIDs
- **Magnetic films**
  - Storage & reading
- **Environment & energy technique**
  - low E window glass coating
- **Heat prevention & corrosion resistance**
  - Turbine blade coating
- **Super hard coatings**
  - Wear resistance of machine parts and tools

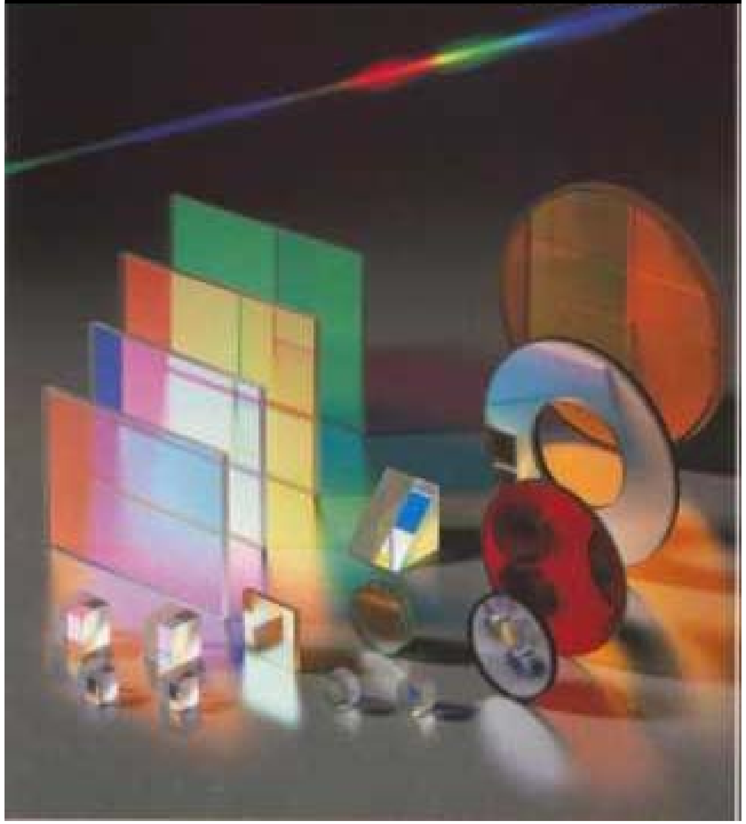
Thin Film Applications

Variety of tool coatings:
DLC / TiC / TiN, graphitic i-C, TiAlN, etc

Thin Film Applications

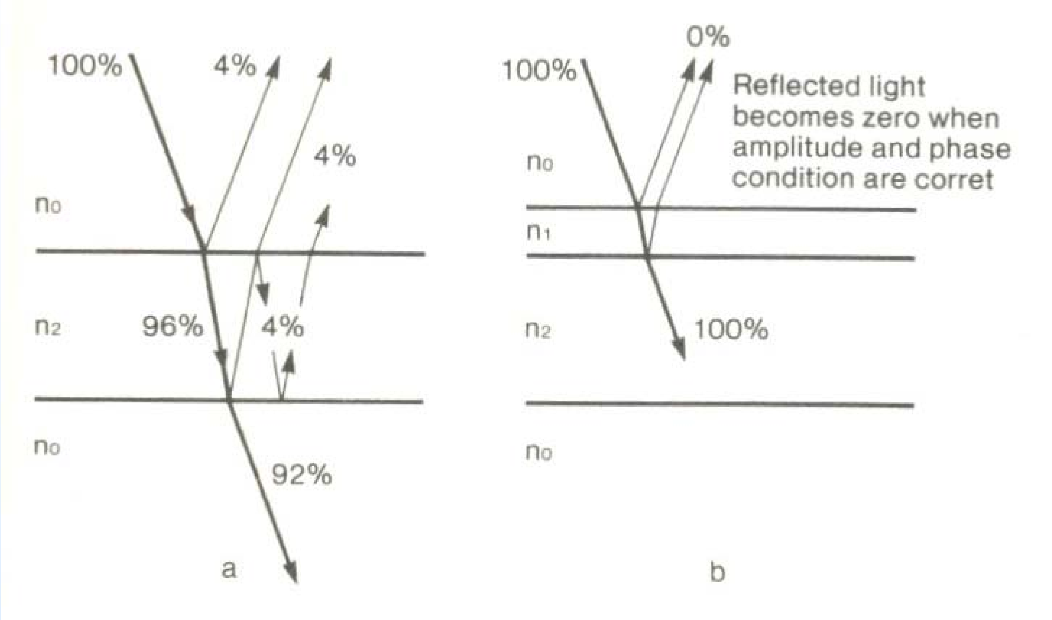






Optical functional films – Anti-reflex films

$$R = \left(\frac{n_0 - n_2}{n_0 + n_2} \right)^2$$



R = $I_{refl.}$/ $I_{inc.}$

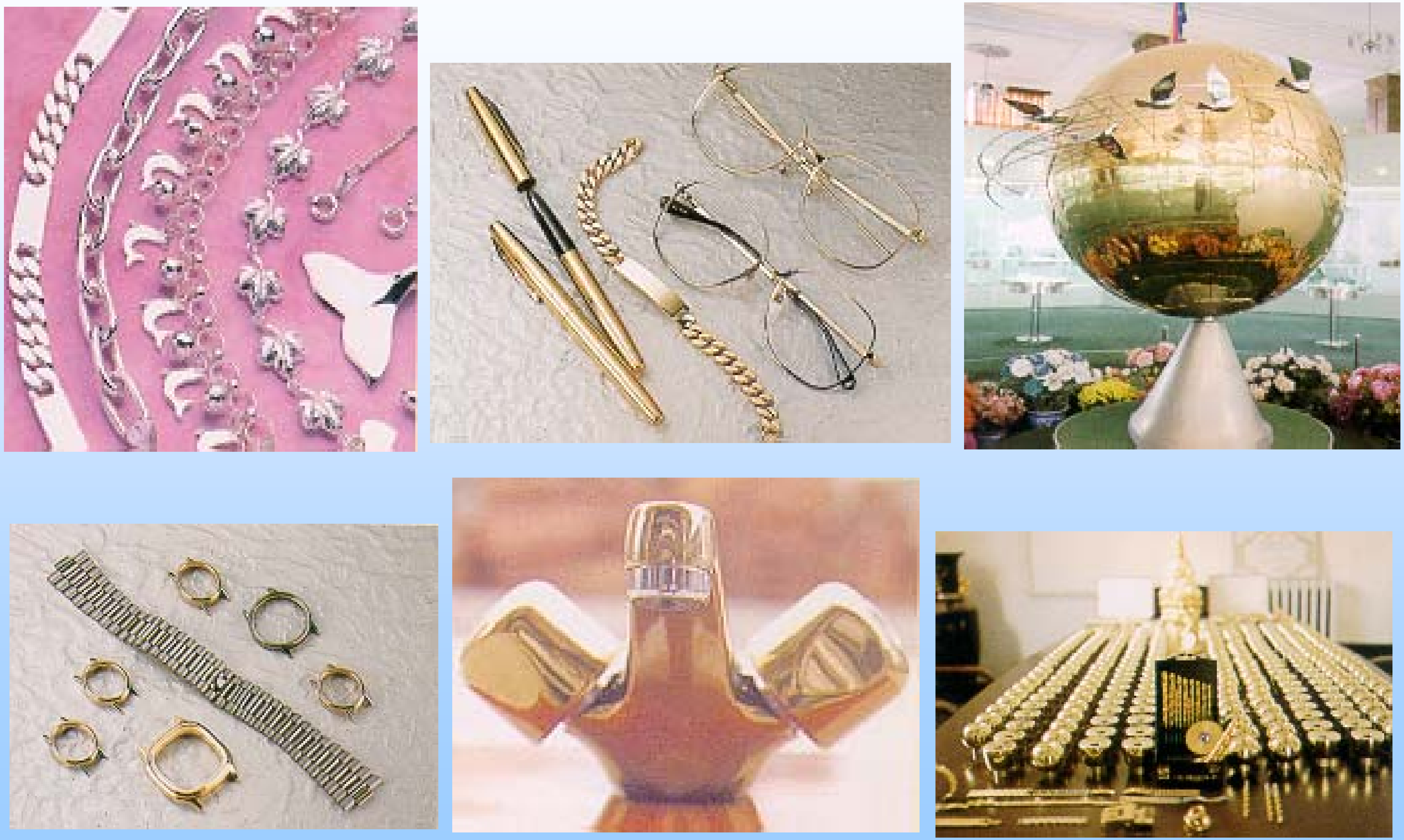
n_2=1,52 refraction index for glass

n_2 = 1,0 refraction index for vacuum

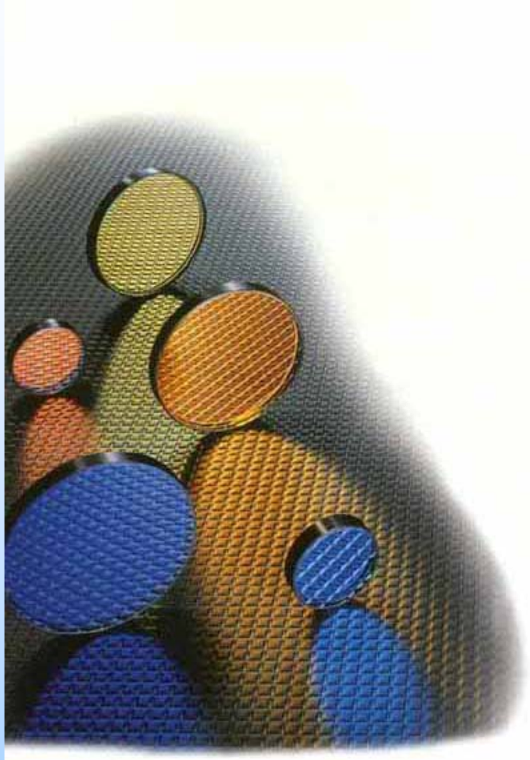
> 8% light lost by reflection. The reflection will be reduced by coating a selected film (MgF_2) of certain fraction index (n_1 = 1,38) and thickness:

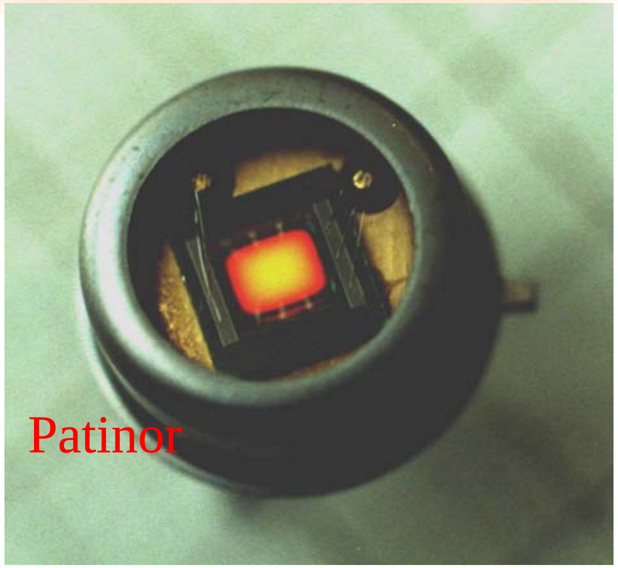
$$n_1 = \sqrt{n_0 \bullet n_2} \qquad t = \frac{\lambda}{4}$$

Thin Film Applications

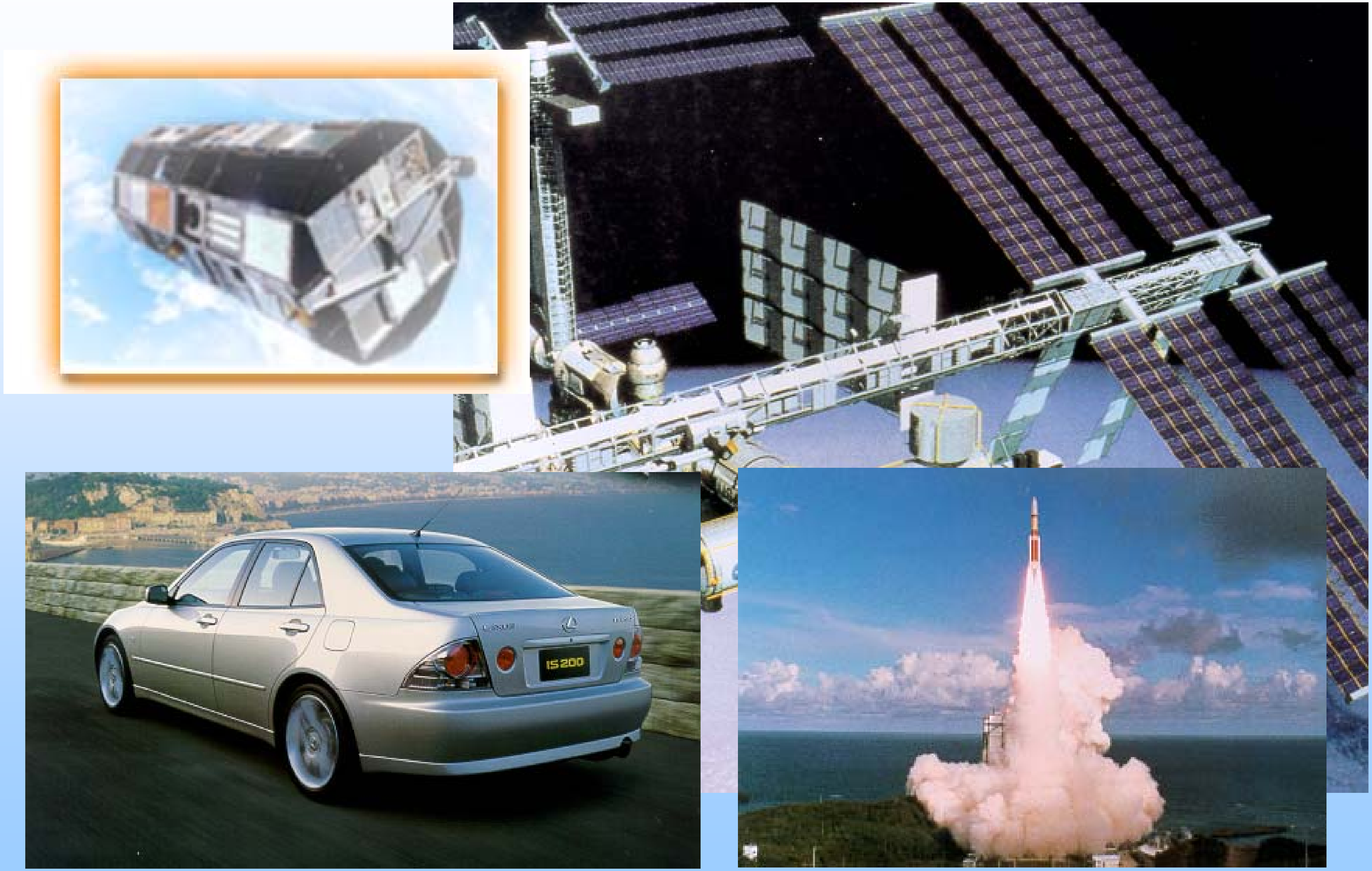


Thin Film Applications

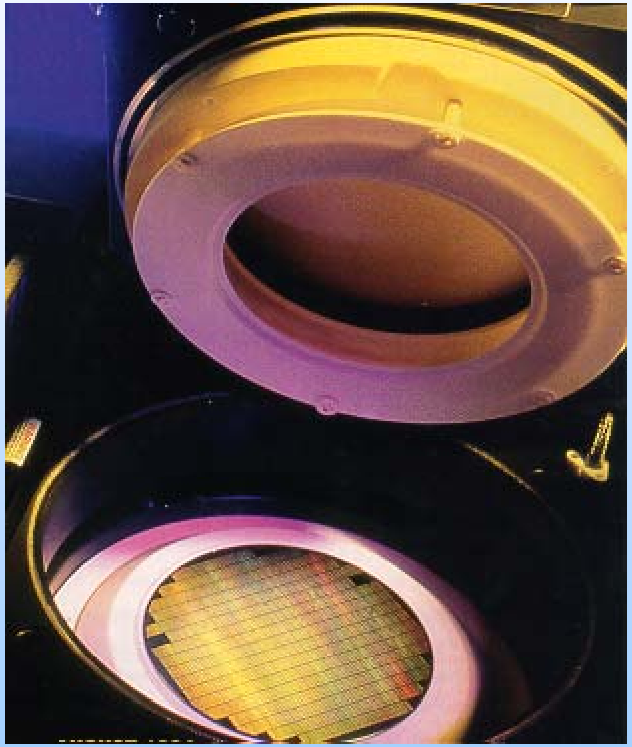


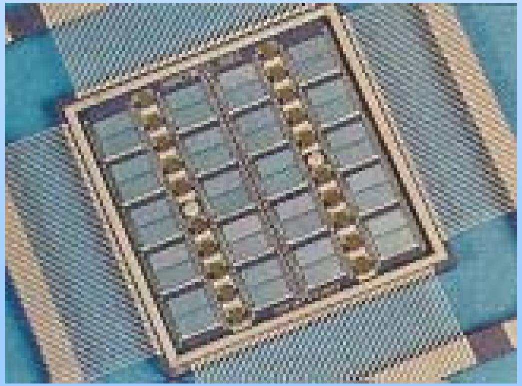


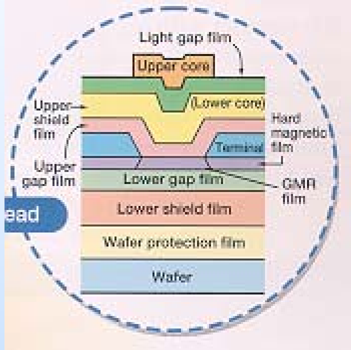
Thin Film Applications

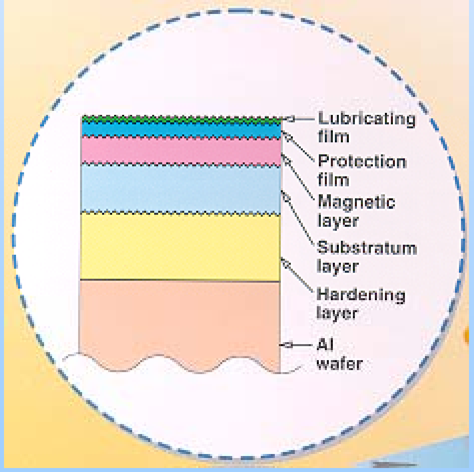


Thin Film Applications









Tools coated with a-C:H filma

Films for the energy technique

Glass

Oxide block layer

Ag layer

HAUS-TECHNIK

Gute Isoliereigenschaften bei modernen Fenstern

Neben einem guten Einbruch- und Hagelschutz müssen moderne Fenster heute vor allem gute Dämmeigenschaften haben. Der Hamburger Spezialhersteller von Dachflächenfenstern Velux hat jetzt diese Eigenschaften entscheidend verbessert: Mit einem Wärmedämmwert (k-Wert) von 1,4 W/qmk entsprechen die Fenster jetzt den Anforderungen für Niedrigenergie-Häuser. Ein Hitzeschutzwert (g-Wert) von 44 Prozent sorgt im Sommer dafür, daß die Hitze draußen bleibt. Mit einem verbesserten Schallschutzwert (Rw-Wert) von 37 dB entsprechen die Fenster der Schallschutzklasse 3.

Der große europäische Isolierglashersteller Isolar Glas formuliert die Anforderungen an moderne Verglasung folgendermaßen: „Relativ hohe Durchlässigkeit für den sichtbaren Bereich des Lichtes bei gleichzeitiger Reduktion der hindurchtretenden wärmewirksamen Sonnenstrahlung sowie ausgezeichnete Wärmedämmung".

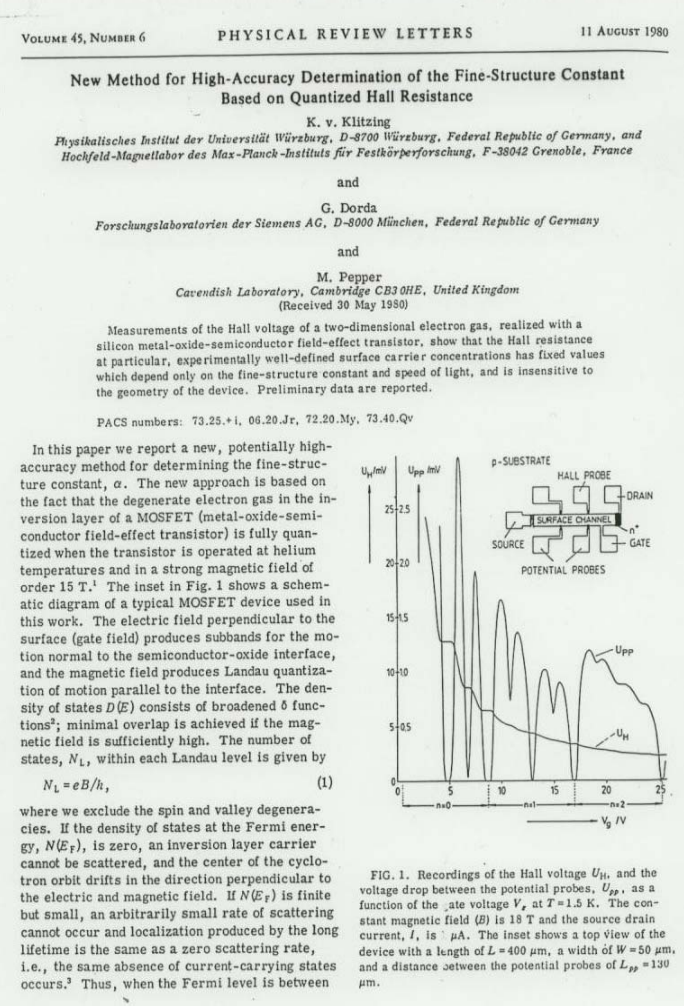
Noch einen Schritt weiter geht das Forschungsvorhaben Övolution, bei dem die Sonnenwärme bewußt in das Heizungskonzept mit einbezogen wird: Die Vereinigten Glaswerke Vegla liefern hier eine Fensterverglasung mit einem k-Wert von 1,2 W/qmk beim „Övolutions-Haus" und mit einem k-Wert von 0,8 W/qmk beim Haus „ÖvolutionPlus".

Das muß modernes Isolierglas leisten: Relativ hohe Durchlässigkeit für den sichtbaren Bereich des Lichtes bei gleichzeitiger Reduktion der hindurchtretenden wärmewirksamen Sonnenstrahlung sowie ausgezeichnete Wärmedämmung

Research

- **Fundamental**
  - **Development of new materials**
  - **Material behavior**
- **Applied**
  - **Development of new products devices and systems**
  - **Enhancement of the product performance**
  - **Increase of product value including aesthetic value**

Films and surface technology in the research



Volume 45, Number 6 PHYSICAL REVIEW LETTERS 11 August 1980

New Method for High-Accuracy Determination of the Fine-Structure Constant Based on Quantized Hall Resistance

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(Received 30 May 1980)

Measurements of the Hall voltage of a two-dimensional electron gas, realized with a silicon metal-oxide-semiconductor field-effect transistor, show that the Hall resistance at particular, experimentally well-defined surface carrier concentrations has fixed values which depend only on the fine-structure constant and speed of light, and is insensitive to the geometry of the device. Preliminary data are reported.

PACS numbers: 73.25.+i, 06.20.Jr, 72.20.My, 73.40.Qv

In this paper we report a new, potentially high-accuracy method for determining the fine-structure constant, α. The new approach is based on the fact that the degenerate electron gas in the inversion layer of a MOSFET (metal-oxide-semiconductor field-effect transistor) is fully quantized when the transistor is operated at helium temperatures and in a strong magnetic field of order 15 T.[1] The inset in Fig. 1 shows a schematic diagram of a typical MOSFET device used in this work. The electric field perpendicular to the surface (gate field) produces subbands for the motion normal to the semiconductor-oxide interface, and the magnetic field produces Landau quantization of motion parallel to the interface. The density of states $D(E)$ consists of broadened δ functions[2]; minimal overlap is achieved if the magnetic field is sufficiently high. The number of states, N_L, within each Landau level is given by

$$N_L = eB/h, \qquad (1)$$

where we exclude the spin and valley degeneracies. If the density of states at the Fermi energy, $N(E_F)$, is zero, an inversion layer carrier cannot be scattered, and the center of the cyclotron orbit drifts in the direction perpendicular to the electric and magnetic field. If $N(E_F)$ is finite but small, an arbitrarily small rate of scattering cannot occur and localization produced by the long lifetime is the same as a zero scattering rate, i.e., the same absence of current-carrying states occurs.[3] Thus, when the Fermi level is between

FIG. 1. Recordings of the Hall voltage U_H, and the voltage drop between the potential probes, U_{pp}, as a function of the gate voltage V_g at $T = 1.5$ K. The constant magnetic field (B) is 18 T and the source drain current, I, is μA. The inset shows a top view of the device with a length of $L = 400$ μm, a width of $W = 50$ μm, and a distance between the potential probes of $L_{pp} = 130$ μm.

Quanten Hall-Effekt

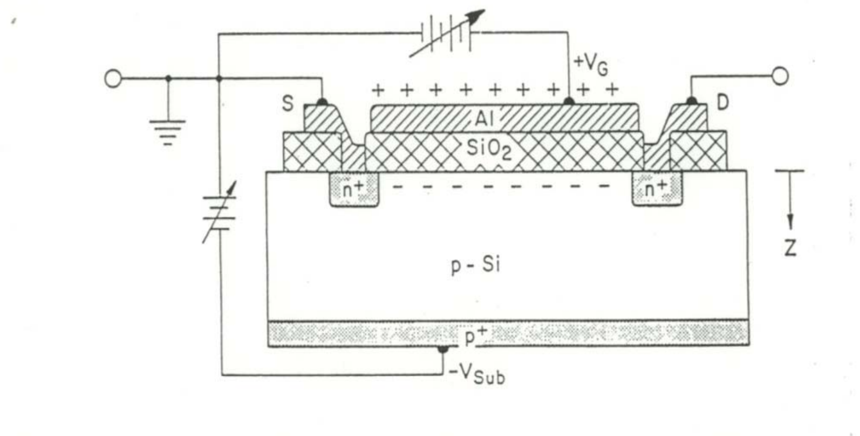

Bild 32.1 Schematischer Aufbau eines Silizium–MOS–Feldeffekttransistors. S source, D drain, V_G Gate–Spannung

Band discontinuity of the semiconductor