Materials in Human History

Historical perspective:

New materials bring advancement to societies

- **Stone age**
- **Bronze age**
- **Iron age**
- **Silicon age**

Crescent Axes. The top Syrian, the bottom Egyptian. about 1900 BC

Materials in Human History

50 000 B.C.	Iron oxide pigments Lascaux, Altamira
24 000 B.C.	Ceramics – fat, bone ash, clay
3 500 B.C.	Cu metallurgy
	Glass, Egypt and Mesopotamia
3 200 B.C.	Bronze
1 600 B.C.	Iron metallurgy, Hittites
1 300 B.C.	Steel
1 000 B.C.	Glass production, Greece, Syria
105 B.C.	Paper, China
590 A.D.	Gun powder, China
700 A.D.	Porcelain, China

This is a Hittite dagger-sword made of iron about 1100 B.C. Much of it has turned to rust over the past three thousand years.

Materials in Human History - Metals

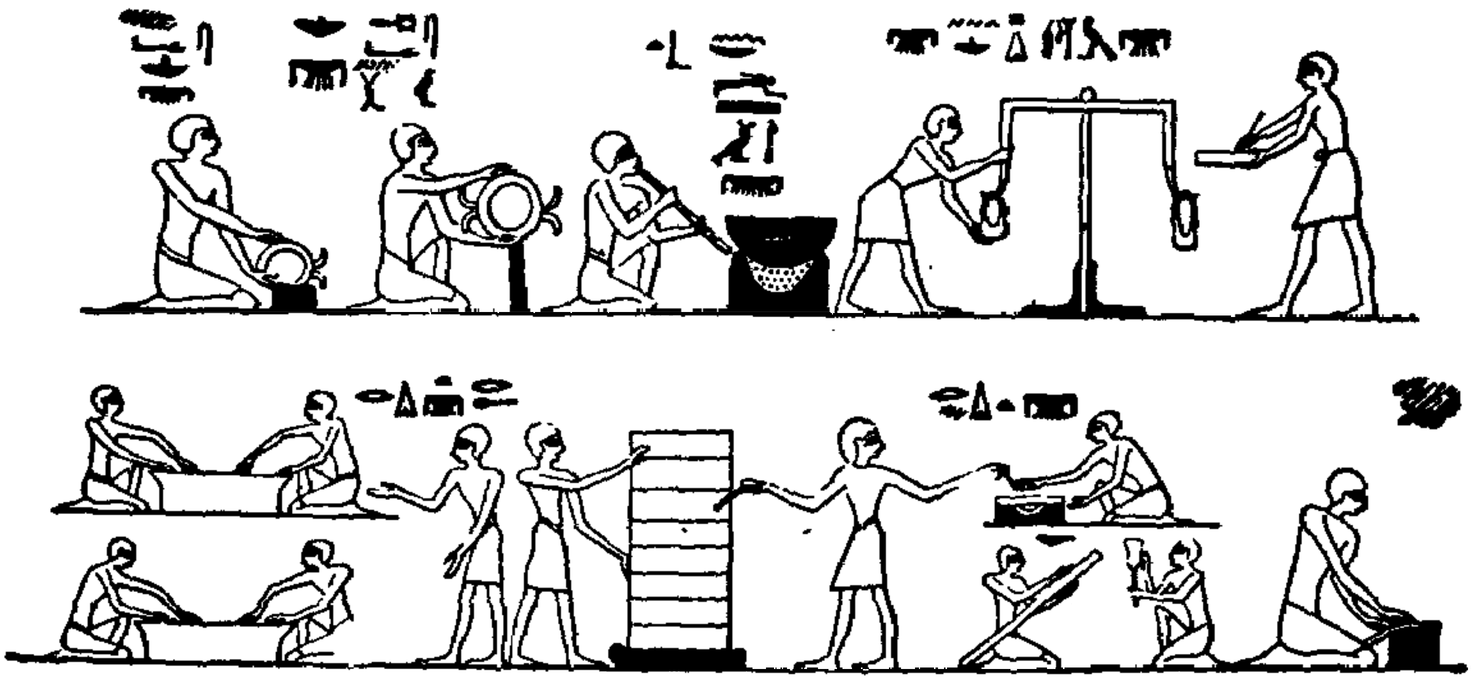


FIG. 11.—EGYPTIAN GOLDSMITHS WASHING, MELTING AND WEIGHING GOLD.

BENI HASAN, 1900 B.C.

Materials in Human History - Ceramics

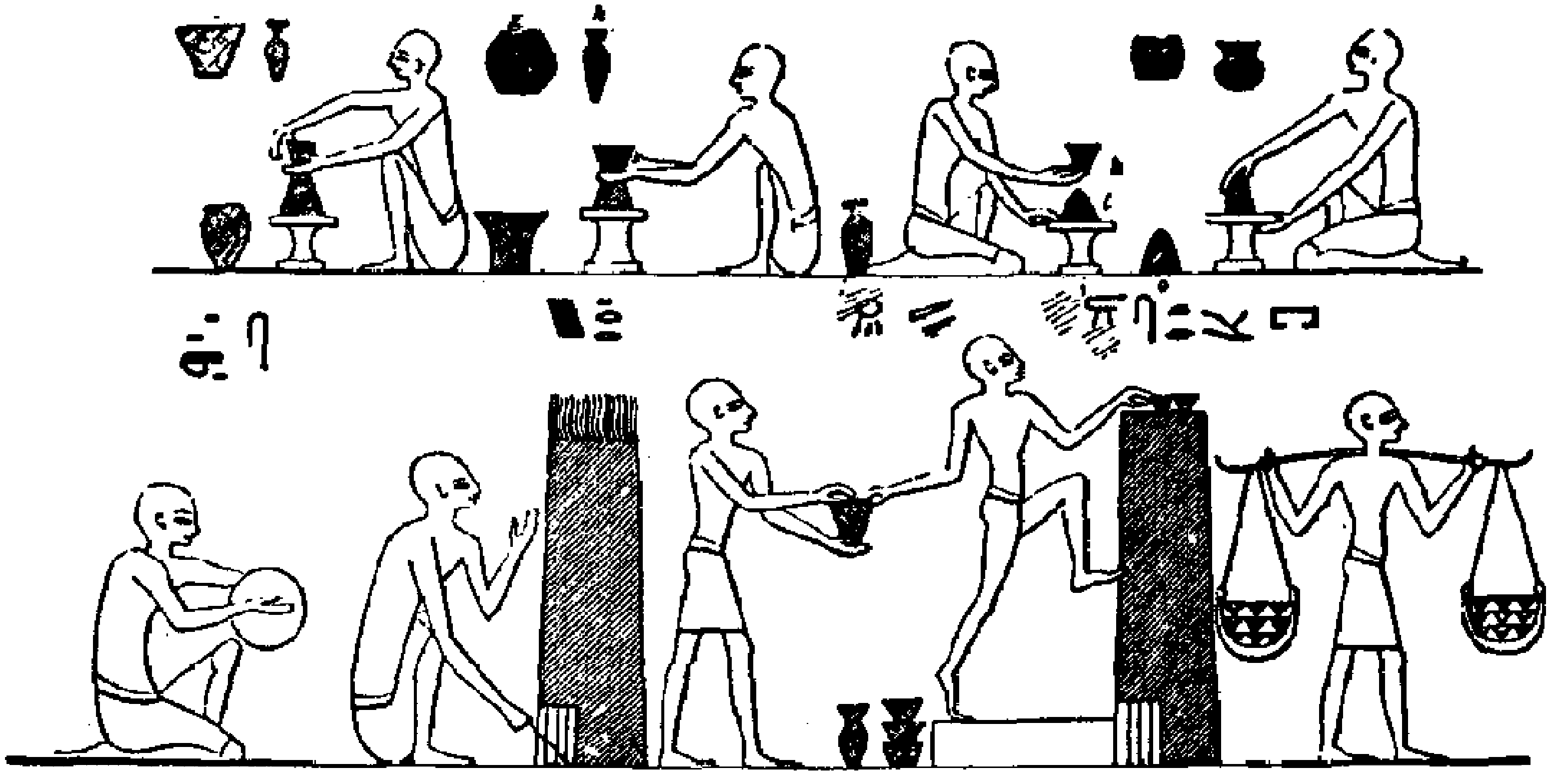
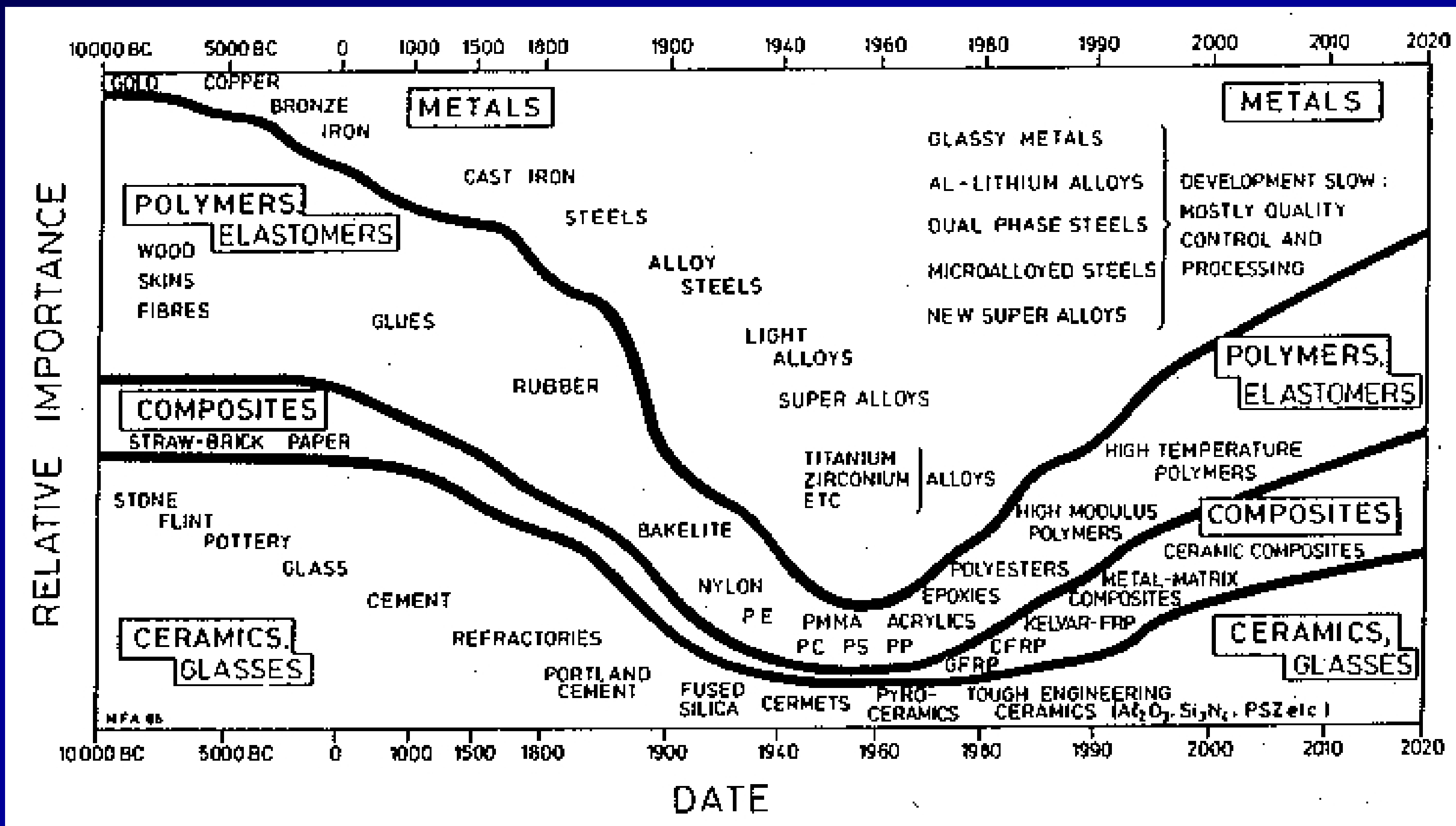


FIG. 12.—EGYPTIANS MAKING POTTERY, WITH FURNACE.
BENI HASAN, 1900 B.C.

Development of Materials in Human History



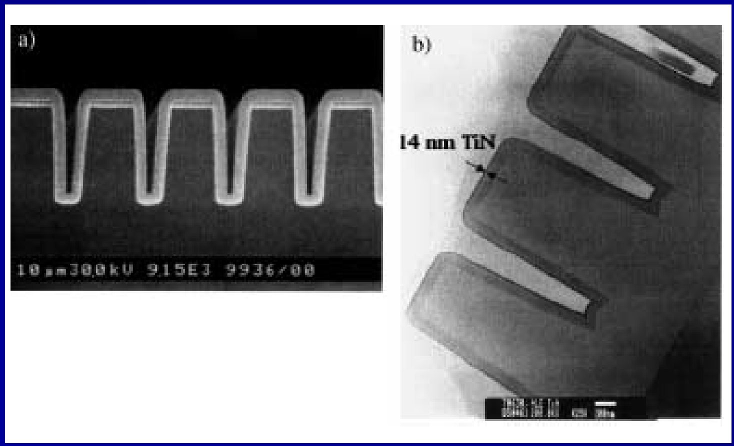
Materials

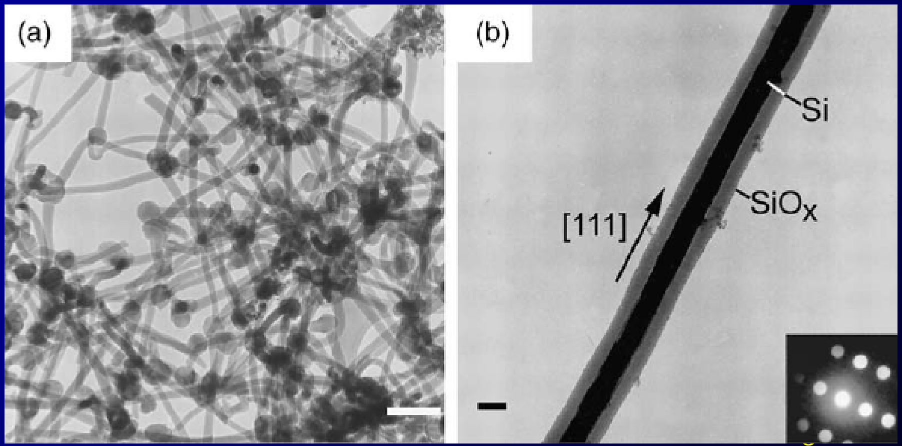
Chemical compounds - single use

pharmaceuticals, fertilizers, fuels

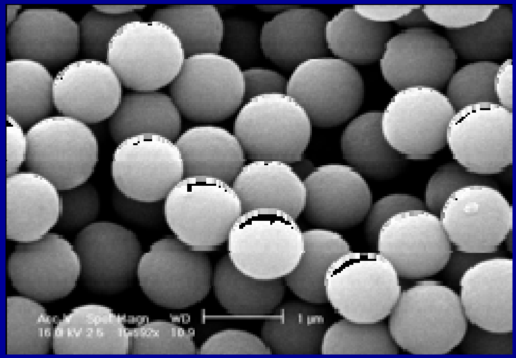
Materials - repeated or continual use

- shaping



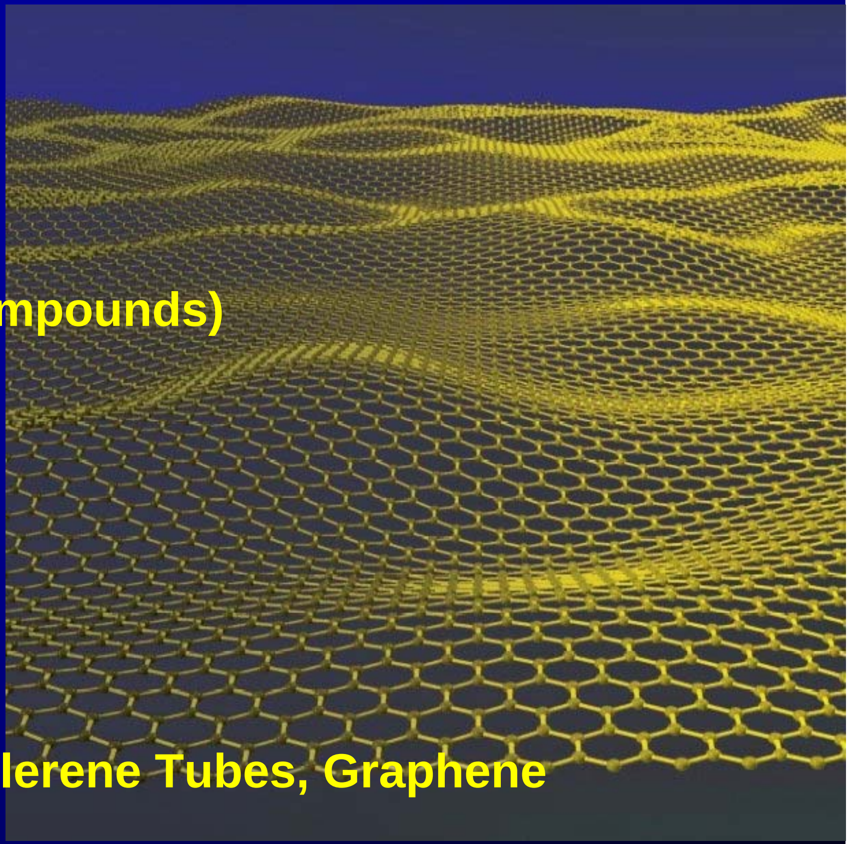


Materials



Ceramics (oxides, carbides, nitrides, borides)

Glasses (oxides, fluorides, chalcogenides, metallic)



Metals, Alloys, Intermetallics

Polymers - inorganic, organic, hybrid

Semiconductors (Si, Ge, 13/15, 12/16 compounds)

Composites, Hybrid Materials

Zeolites, Layer and Inclusion Materials

Biomimetic Materials

Carbon-based Materials: Fullerenes, Fullerene Tubes, Graphene

Properties of Materials

Property = a material trait, the kind and magnitude of response to a specific stimulus

Properties

- **Mechanical**
- **Electrical**
- **Thermal**
- **Magnetic**
- **Optical**
- **Deteriorative (corrosion)**
- **Catalytic**
- **Biocompatibility**

Metals	Ceramics	Polymers
Strong	Strong	Usually not strong
Ductile	Brittle	Very ductile
Electrical Conductor	Electrical Insulator	Electrical Insulator
Heat Conductor	Thermal Insulator	Thermal Insulator
Not transparent	May be transparent	Not transparent
Shiny	Heat Resistant	Low Densities

Materials Science

Materials Science:

Studies relationships between the structure and properties of materials

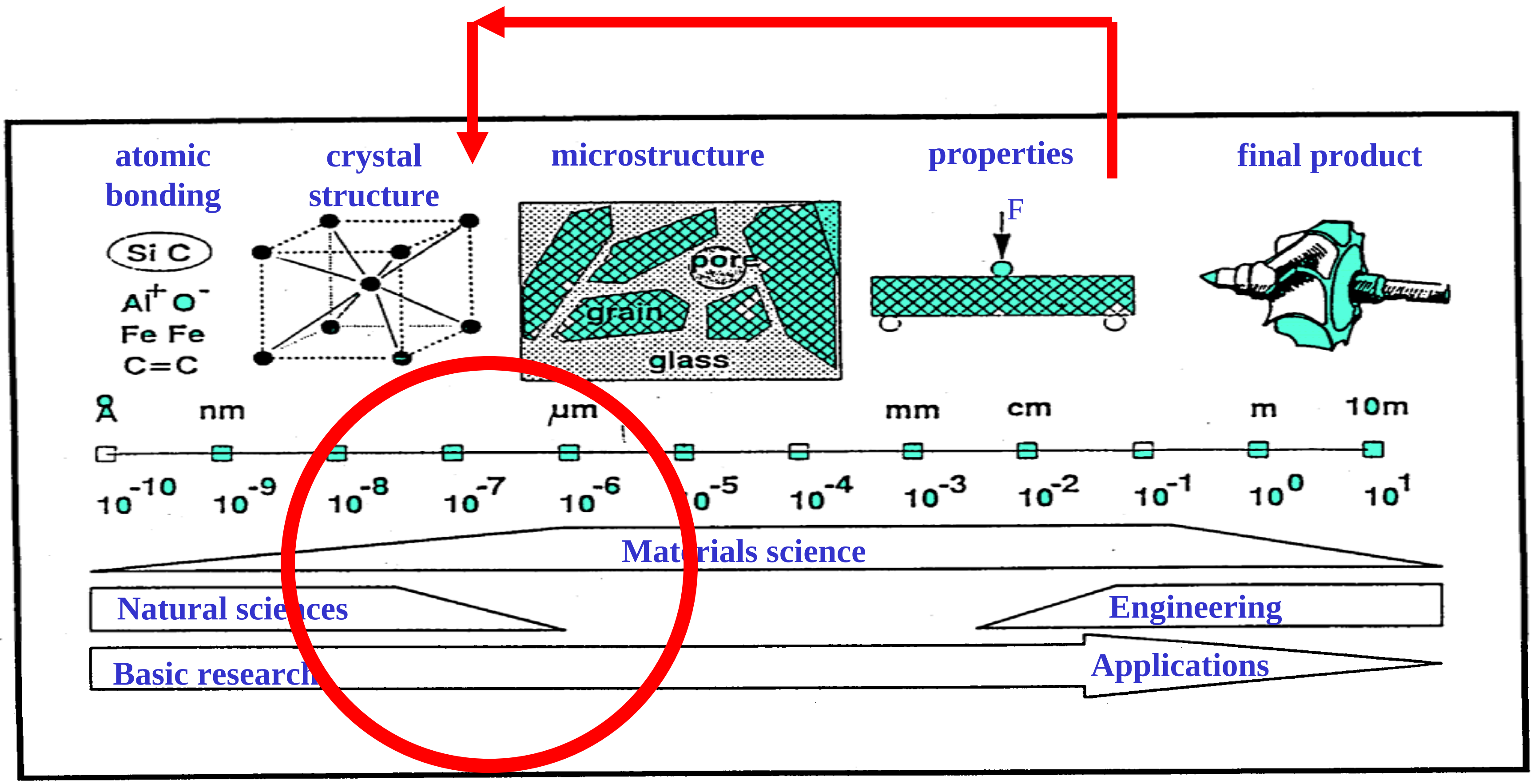
Materials Engineering:

Designing and engineering the structure of a material to produce a predetermined set of properties

Materials Science

Processing **Structure** **Properties** **Function**

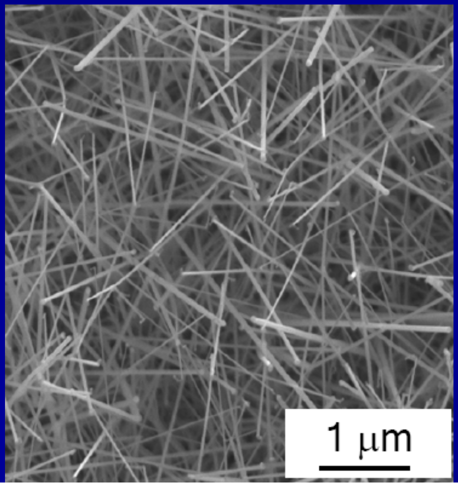
Materials Chemistry among Natural and Technical Sciences

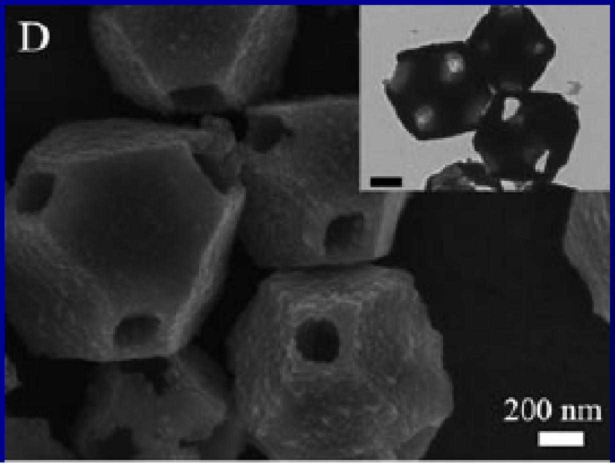


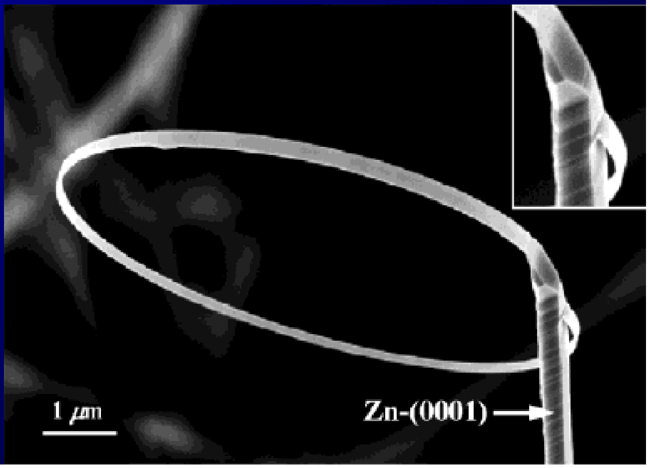
Materials Chemistry

Role of Materials Chemistry

- **Synthesis of new materials – new atom architecture**
- **Preparation of high purity materials**
- **Fabrication techniques for tailored shapes, morphologies, and size**

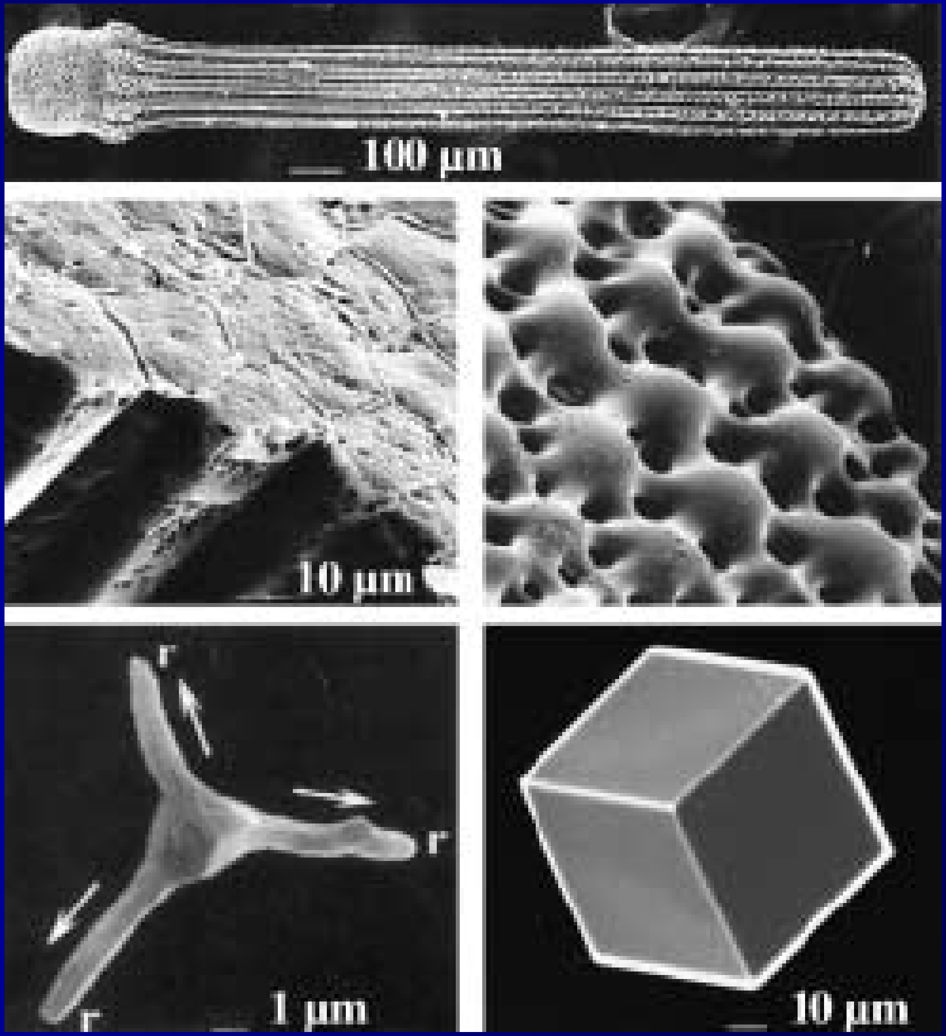






Natural and Synthetic Single Crystals

Calcite $CaCO_3$



Materials Chemistry

Single crystals, defects, dopants, non-stoichiometry
Monoliths
Coatings
Thin or thick films - singlecrystalline, polycrystalline, amorphous, epitaxial
Fibers, Wires, Tubes
Powders – primary particles, aggregates, agglomerates
polycrystalline, amorphous, nanocrystalline (1-100 nm)
Porous materials
micropores (< 20 Å), mesopores (20-500 Å), macropores (> 500 Å)
Micropatterns
Nanostructures – spheres, hollow spheres, rods, wires, tubes, photonic crystals
Self-assembly – supramolecular chemistry: rotaxenes, catenanes, cavitands, carcerands

Materials Chemistry

Direct reactions of solids – „heat-and-beat“

Precursor methods

Chimie douce, soft-chemistry methods, synthesis of novel metastable materials, such as open framework phases

Ion-exchange methods, solution, melt

Intercalation: chemical, electrochemical, pressure, exfoliation-reassembly

Crystallization techniques, solutions, melts, glasses, gels, hydrothermal, molten salt, high P/T

Vapor phase transport, synthesis, purification, crystal growth, doping

Materials Chemistry

Electrochemical synthesis, redox preparations, anodic oxidation, oxidative polymerization

Preparation of thin films and superlattices, chemical, electrochemical, physical, self-assembling mono- and multilayers

Growth of single crystals, vapor, liquid, solid phase chemical, electrochemical

High pressure methods, hydrothermal, diamond anvils

Combinatorial materials chemistry, creation and rapid evaluation of gigantic libraries of related materials

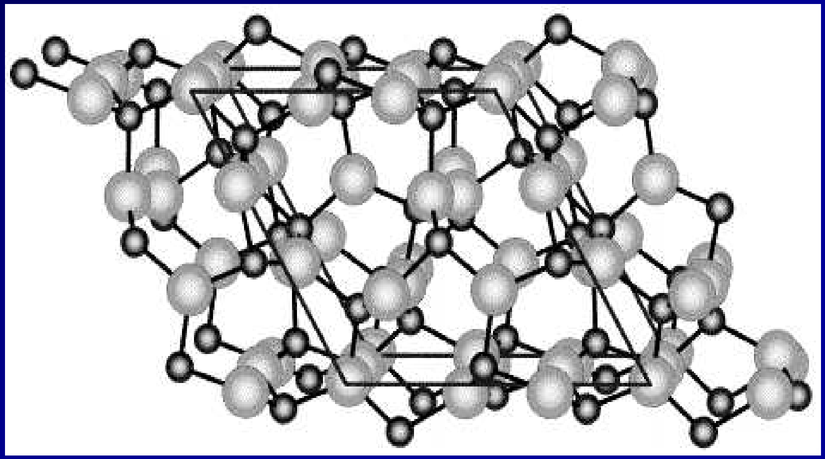
Si_3N_4

Hexagonal

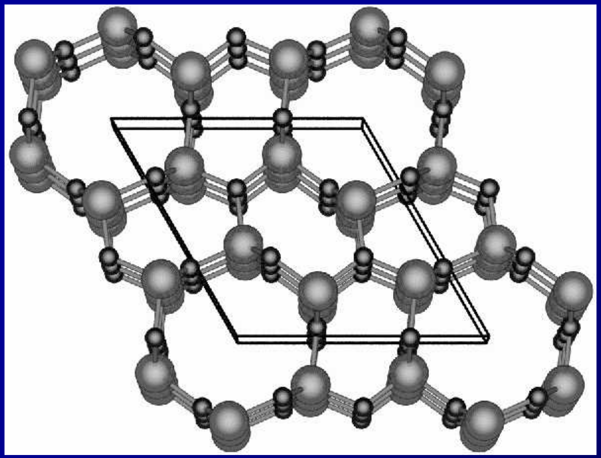
Si

N

a modification



b modification



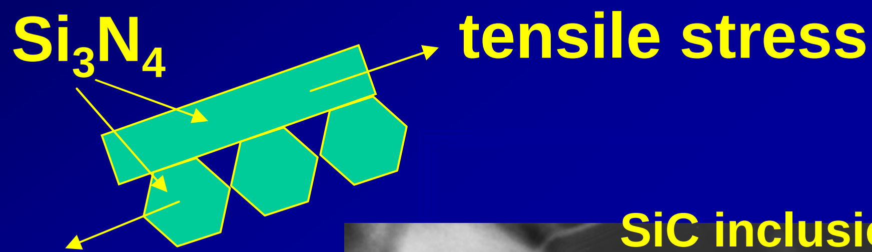
- Strong covalent bond (4.9 eV)
- Hardness (a-monocrystal, Vickers 21 GPa)
- Tensile Strength 1.5 GPa (b-whisker)
- Young modulus 350 GPa
- Decomposition temp. 1840 °C/1 atm N_2
- Density 3.2 g cm^{-3}

Si_3N_4 Ceramics

Microstructure of Materials

Microstructure vs. Material Properties

Sliding of grains



Sliding of grains slowed down improved mechanical properties