

Materials in human history

Historical perspective:

New materials bring advancement to societies

Stone age

Bronze age

Iron age

Silicon age

Materials in human history - metals



Materials in human history - ceramics

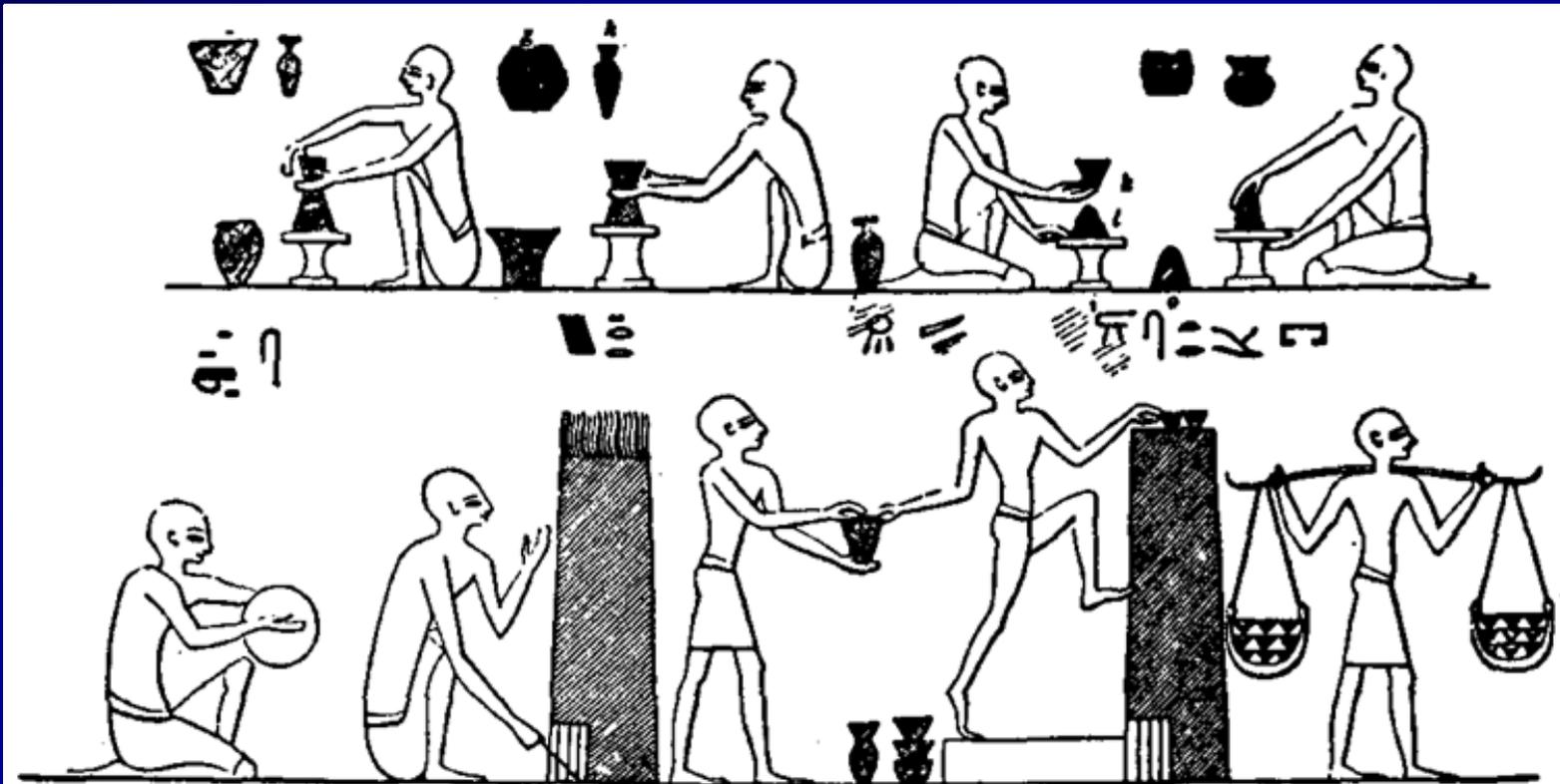
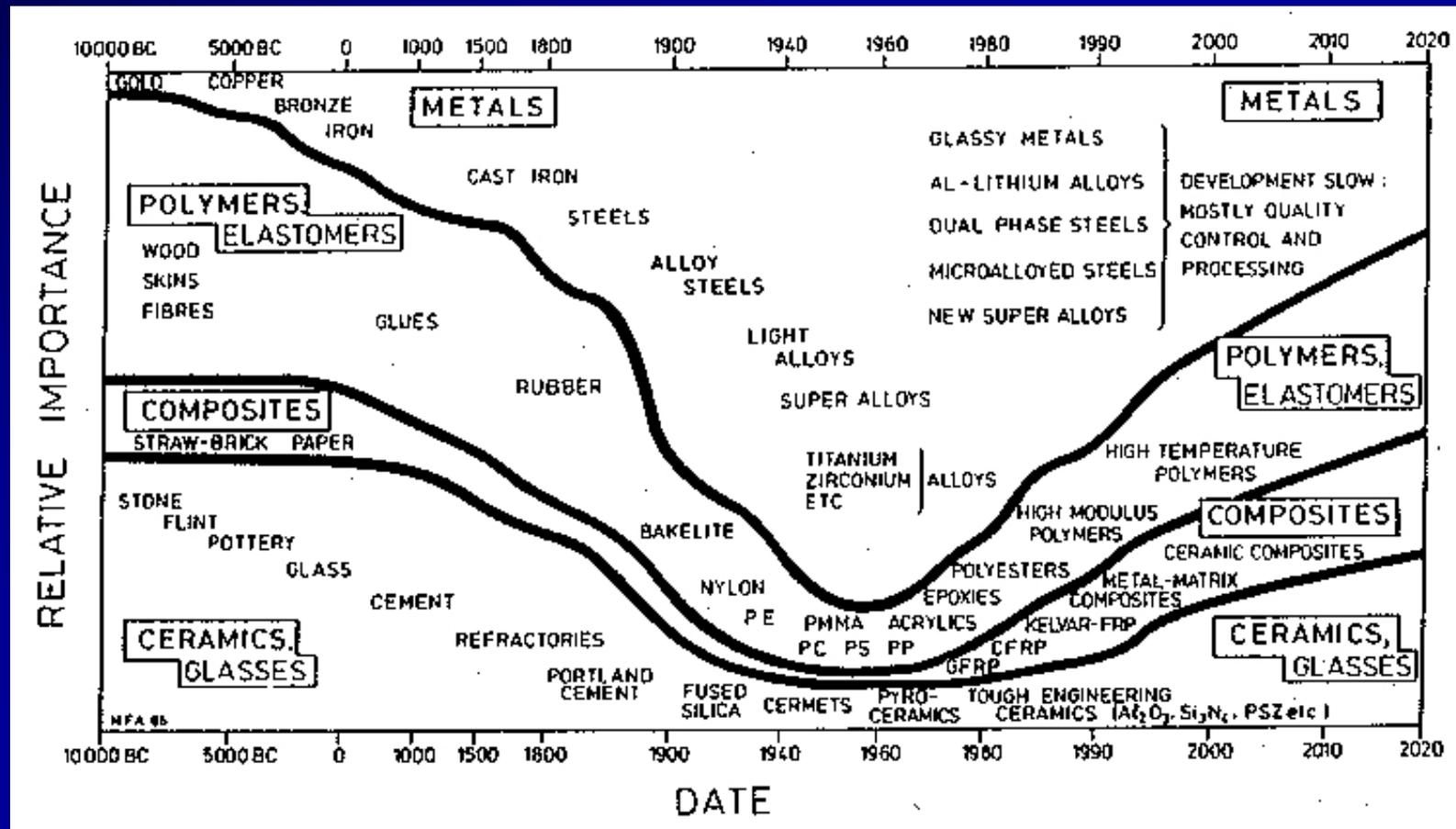


FIG. 12.—EGYPTIANS MAKING POTTERY, WITH FURNACE.
BENI HASAN, 1900 B.C.

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

Fullerenes and Fullerene Tubes

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

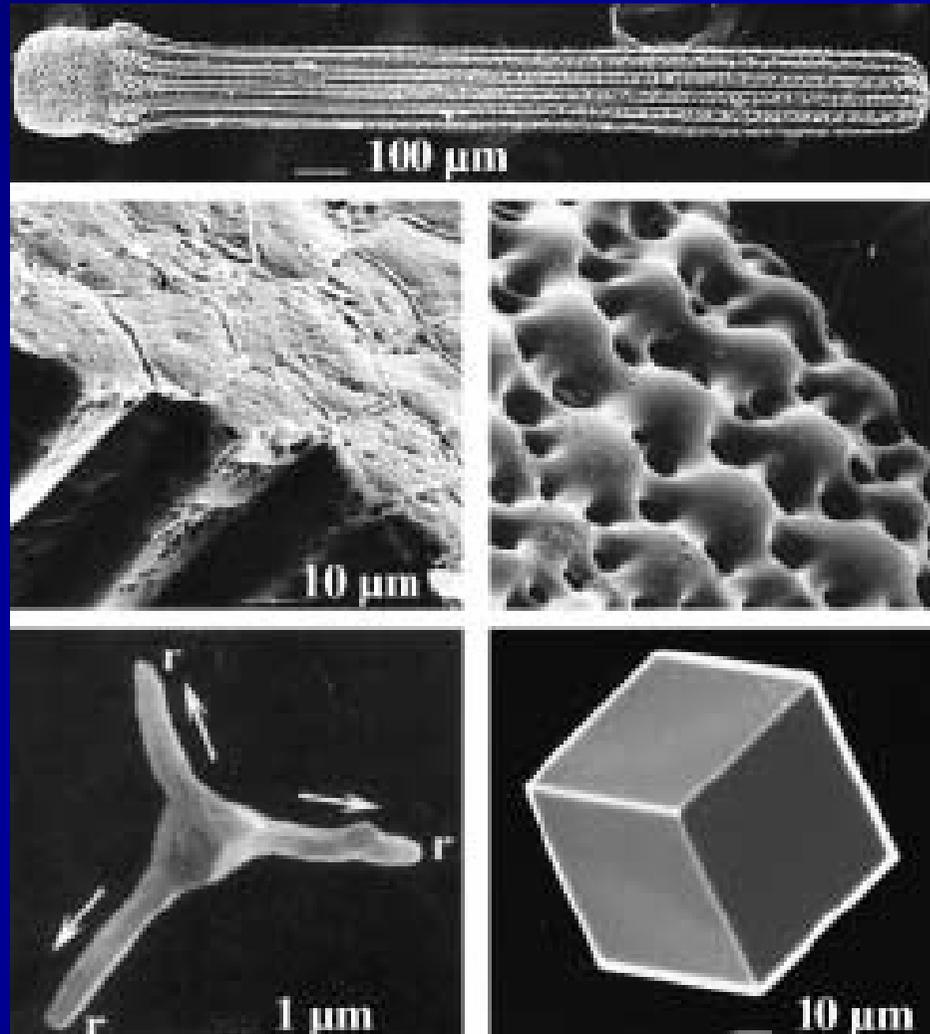
Materials chemistry

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

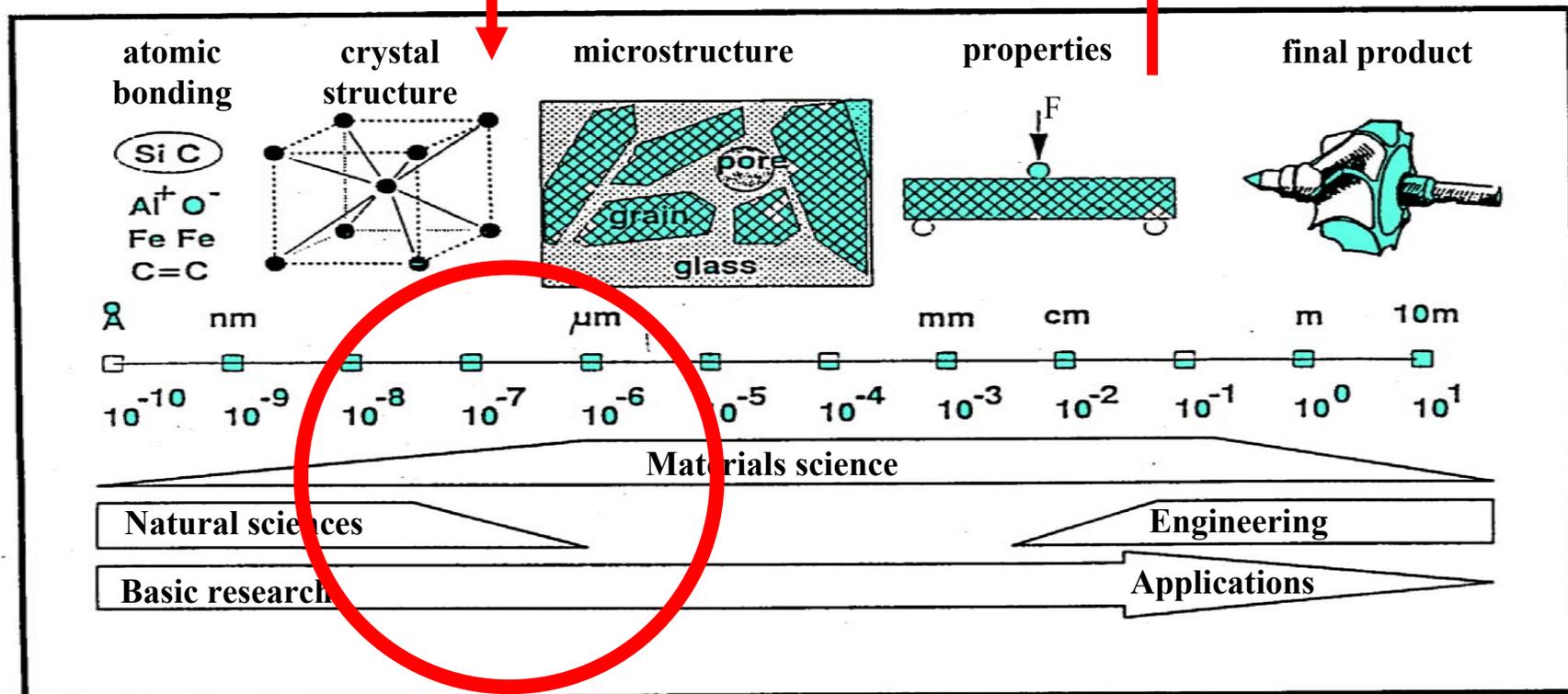
micropores ($< 20 \text{ \AA}$), mesopores (20-500 \AA), macropores ($> 500 \text{ \AA}$)

Micropatterns

Nanostructures – spheres, hollow spheres, rods, wires, tubes, photonic crystals

Self-assembly – supramolecular chemistry: rotaxenes, catenanes, cavitands, carcerands

Materials chemistry among natural and technical sciences



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

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