ADVANCED MATERIALS

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Our Age is based on Materials and Processes

They are created by PHYSICS and CHEMISTRY

Materials Science

CONDENSED MATTER
(Quant Mech + Stat Phys)

Materials

Properties: mechanical, electric, thermal, optical and magnetic

Derived from:

ATOMIC STRUCTURE and ELECTRONIC STRUCTURE

MATTER AGGREGATION
and
CHEMICAL BONDING

Building up MATERIALS from ATOMIC CONSTITUENTS

Nanostructures, Nano-Objects, Clusters

NANOSCIENCE

CLASSICAL AGE

→ ~1950

A few simple

METALS and INSULATORS

QUANTAL FLUIDS:
SUPERFLUIDS, SUPERCONDUCTORS,
ELECTRON LIQUID

REAL GASES, COMPLEX FLUIDS,
ELECTRIC PLASMA?

The TRANSISTOR 1948

MODERN AGE: Birth of Mats Science

THREE POINTS:

1 SEMICONDUCTING MATS

Si, Ge; GaAs, SiGe, GaN

Integrated circuits, Solid-State Lasers,

Light-Emitting Diodes

Computers and Telecommunication

2 MINIATURIZATION

The END?

3 LOW-DIMENSIONAL MATERIALS and STRUCTURES

Layered, Two-Dimensional,
Quasi-One-Dimensional
Man-made, Fabricated or
Naturally Synthesized

BASIC PHYSICS

GLASS, Glassy State, AMORPHOUS Mats

Localization, Disorder, Solid-Liquid Transition

SiO_2 Optical Fibres

CERAMICS

Metal - non-metal, hard, brittle, insulators

COMPOSITES

Carbon Fibers, Superalloys Ni+Al, Ti, Cr,
High Strength, Turbines Blades
Ni-Fe Magnetoresistive Thin Films Reading
Heads, Magnetically Stored Data
Permanent Magnets Nd-Fe-B

MICROSTRUCTURE

Grains, Dendrites, Cracks, Faults,
Fracture, Friction
Non-Equilibrium Synthesis

CHEMISTRY

ORGANICS

LIQUID CRYSTALS

Molecular Ordering under Electric Field,
Switch on/off the passing of polarized light

Flat Display panels
LapTops

PLASTICS and POLYMERS

SOFT, COMPLEX MATER

BioMaterials, CDs-Polymers with atomic inprints, read by semicond Lasers

STRONG, Kevlar-bulletproof Vests

1970 BREAKTHROUGH: CONDUCTING POLYMERS

Chains of Polyacetilene doped with Iodine

Organic ELECTRONICS

CONTEMPORARY AGE

Optical, Electron Lithography
Molecular Beam Epitaxy
Scanning Probe Microscope

Fractional Quantal Hall Effect
HighTc Superconductivity
Fullerene and Nanotubes
Atomic Clusters
Bose-Einstein Condensation

Fractional Quantal Hall Effect

Two Dimensional Electrons
GaAs-Al-GaAs Heterostructure
Coulomb Interaction, Highly Correlated
Low Temperature
Good Quality Heterostructure

Integral Quantal Hall Effect
MOS, Disorder

High Tc Superconductivity

Powerful Magnets

NMR Imaging

YBaCuO, BiSrCuO ceramics

Liquid Nitrogen, Less expensive

Strong Interaction with Local Modes of Vibration

Overall Cooper Pairing

Complex Details, may improve

Fullerene

Super-molecule
60 C atoms, Highly Symmetric
New form of carbon
Route to Nanostructures

C Nanotubes

Nanowires, Nanocircuits

Atomic Clusters

10-100-1000- atoms - Aggregation?
Nanopharmaceuticals
Nanoelectronics
Nano-miniaturization,
Bottom-up approach,
From molecules to
functional atomic aggregtates

Bose-Einstein Condensation

Laser Cooling, Magnetic Traps
Atoms at very Low Temperatures
Bose-Einstein Condensation
Atomic Droplets of Superfluids
Non-local Instantaneous Communication?
Teleportation?

NEUTRON SCATTERING

Nuclear Reactors

SYNCHROTRON RADIATION

Accelerators