Physical methods for production of new materials

List of topics

1. Bulk ultrafine-grained and nanocrystalline materials
Classification of the processing of bulk ultrafine-grained materials. Bottom-up and top-down approaches. Grain-refinement by plastic deformation. Unique mechanical properties of ultrafine-grained and nanocrystalline materials (yield strength, ductility, superplastic deformation).

2. Processing of bulk ultrafine-grained metals and alloys by powder metallurgy
The main steps of powder metallurgy. Methods for production of nanodisperse powders. Inert gas condensation. Laser ablation. RF plasma synthesis. Cryogenic melting. Electro-explosion of wire. Liquid Atomization. Milling. Changes in microstructure during milling. Mechanical alloying. Formation of non-equilibrium crystalline phases. Mechanical amorphization. Powder consolidation methods. Shock wave consolidation. Transformation assisted consolidation Sintering. Hot pressing. Sinter forging. Hot Isostatic Pressing. Spark Plasma Sintering. Plasma spraying. Effect of oxide phase on the mechanical performance of sintered UFG materials. Application of sintered UFG materials. Special effects during sintering of blends of coarse-grained and nanocrystalline powders.

3. Processing of bulk UFG materials by severe plastic deformation
Severe plastic deformation methods. ECAP. Dissimilar-Channel Angular Pressing. HPT. Multi-directional forging. Cyclic extrusion and compression. Twist extrusion. Accumulative Roll Bonding. Repetitive Corrugation and Straightening. Evolution of the microstructure during ECAP. Effect of alloying on the microstructure evolution during SPD. Application of UFG metals processed by SPD.

4. Nanocrystallization of bulk metallic glasses
Processing of amorphous alloys by quenching. Production methods of metallic glasses. Splat Cooling. Melt-spinning. Copper mould casting. Mechanical properties of BMGs. Processing of bulk nanomaterials from BMGs. Partial or full crystallization by heat treatment. Crystallization by SPD. Influence of nano-quasicrystalline particles on viscosity of BMGs. Effect of partial crystallization on room temperature mechanical properties. Magnetic properties of amorphous-nanocrystalline composites.

5. Nanocomposites
Classification of composites: ex-situ and in-situ composites. Classification according to the types of component materials, matrix material, disperse phase morphology. Effect of fibers on the mechanical properties. Processing methods of ex-situ composites. Polimer-matrix nanocomposites. The influence of disperse phase morphology on the percolation threshold. Carbon nanotube reinforced composites. Types of carbon nanotubes. Chiral vector. Single and multi-wall carbon nanotubes. Nanotube junctions. Processing methods of carbon nanotubes. Arc-discharge. Laser ablation. Catalytic Chemical Vapor Deposition. Unique properties of carbon nanotubes. Metal- and ceramic-matrix nanocomposites. In-situ composites. Exothermic dispersion (XD). Gas-assisted process. Direct metal oxidation (DIMOX). Eutectic solidification. Al-Al2O3 nanocomposite formed during sintering of Al nanopowders. Nanocomposites in nature.

6. Nanoporous materials

Classification of nanoporous materials according to the size of pores: microporous, mesoporous and macroporous materials. Classification of nanoporous materials according to the type of material. Processing of nanoporous materials. Zeolites. Application of nanoporous zeolites. Mesoporous silicates. Nanoporous polymers. MOF (metal organic framework). Application of MOFs. Porous Si as antireflection coating and biosensor.

recommended readings:

R.Z. Valiev, A.P. Zhilyaev, T.G. Langdon: Bulk Nanostructured Materials: Fundamentals and Applications,Wiley, Hoboken, NJ, 2014

V. Viswanathan et al., Materials Science and Engineering R 54 (2006) 121–285

J. Gubicza: Defect structure in nanomaterials, Woodhead Publishing Ltd., Cambridge, UK, 2012

S.Reich, Ch.Thomsen, J.Maultzsch: Carbon Nanotubes, Basic Concepts and Physical Properties, Wiley-VCH, Berlin, 2004