Solid State Chemistry SS/10-11

Oxide Nanomaterials: Synthetic Developments, Mechanistic Studies, and Technological Innovations

Important oxides:

TiO₂: nontoxicity, low chemical reactivity and outstanding chemical properties give opportunity to use it in paint production, cosmetics, gas sensors, photocatalysts and self-cleaning surfaces production.

ZnO: large band gap produces unique optical and electronic properties; used in medicine, concrete industry, rubber production, , etc.

SnO₂: n-type conductor, wide band gap offers a balanced combination of chemical, optical and electronic properties result in wide range of applications such as catalysts, heat mirrors, transparent electrodes for solar cells, liquid crystal displays, gas sensors, etc.

Synthetic methods for Oxide Nanomaterials:

1. Hydrothermal Method (most common in laboratories and industry)

Hydrothermal synthesis is a crystal synthesis and a crystal growth under various temperatures and pressures in aqueous conditions.

2. Microwave - solvothermal process

The mixture is heated rapidly and homogeneously to desired temperature by microwave irradiation.

3. Synthesis with Ionic Liquids (IL) / "green" solvents

(1) ILs have low interface tensions in spite of their polar features, which results in high nucleation rate

(2) ILs can react with products via some interaction (e.g., hydrogen bond) and accordingly affect the shape of the products

(3) ILs are immiscible with a number of organic solvents and can provide a non-aqueous and polar alternative for the two phase systems

4. Combined approach: Microwave assisted synthesis in combination with Ionic liquids

Due to presence of large organic cations, ILs are strong microwave-absorbing agents for their ionic polarizability and conductivity. The polarization of ions under the electric field of microwave results in the anisotropic growth of crystals

In-situ methods for mechanism investigation:

- 1. EDXRD: kinetics, growth steps and phase changes of solid state syntheses via time-dependent evolution of diffraction pattern.
- 2. XANES: Coordination environment and oxidation state.
- 3. SAXS: size and size distribution evaluation of particles of size around 100 nm. Suitable for analysis of amorphous materials.
- 4. IR/RAMAN: nanoparticles formation in non-aqueous media.

Innovative applications:

1. Magnetic separation and regeneration of catalysts.

Magnetically separable heterogeneous nanocatalysts. (e.g. attempts to couple ${\rm TiO_2}$ to silica coated magnetic cores)

2. One-dimensional photonic crystals.

Optical nanostructures that have layers of different dielectric constants which affect the motion of photons, disallowing certain wavelengths to pass. (e.g. Bragg grating)

References:

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