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NANOTECHNOLOGY IN MODERN LIFE AND ENVIRONMENTAL PROTECTION

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Summary:
Nano- (symbol n) is derived from the Greek meaning dwarf. This prefix in the metric system denotes a factor of 10^{-9}. Nanostructured materials have shown an explosion of scientific and industrial interest over the last few decades worldwide. These unique materials are distinguished from conventional polycrystalline materials by their fine crystallite sizes. Nomenclature for the synthesis of nanoparticles by spray pyrolysis is very different in literature: solution aerosol thermolysis, evaporative decomposition of solutions, ultrasonic spray decomposition, mist decomposition, spray roasting, chemical reactions with aerosols, plasma vaporizations of solutions, aerosol decomposition, spray hydrolysis. As relatively inexpensive and quite versatile technique spray pyrolysis is promising aerosol process to produce fine metallic, oxidic, composite nanoparticles of precisely controlled morphology and defined chemical compositions from water solution using different metal salts and their mixtures. Nanoparticles occur as dust in the air, as suspended particles that make river water slightly murky, in soil, in volcanic ash, in our bodies, and in different technological applications such as medicine, microelectronics, automobile industry, catalysis.

Key Words: *nanotechnology, environmental protection, ultrasonic spray pyrolysis*

1. INTRODUCTION

Nano- (symbol n) is derived from the Greek meaning *dwarf*, and was officially confirmed as standard in 1960. This prefix in the metric system denotes a factor of 10^{-9} or 0.000000001. It is frequently encountered in science and electronics for prefixing units of time and length. Nanostructured materials have shown an explosion of scientific and industrial interest over the last few decades [1-9]. These unique materials are distinguished from conventional polycrystalline materials by their fine crystallite sizes. A significant higher fraction of atoms are located at the surface of nanosized particulates as compared to conventional powders. This structural characteristic is responsible for the enhanced reactivity of nanoparticles compared to conventional materials. Changes in material properties at the nanocrystalline-size are especially shown in the following characteristics: electrical (higher electrical conductivity in ceramics), magnetic (increase of magnetic coercivity down to a critical grain size), mechanical (enhanced ductility, toughness, and formability of ceramics), optical (increase in luminescent efficiency of semiconductors).

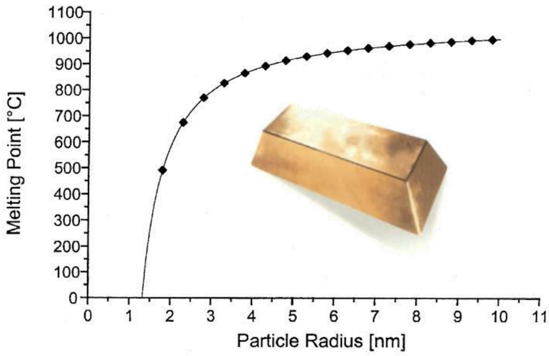


Fig. 1: Relationship between nanoparticle radius of gold and the melting point [1]

As shown at Fig. 1 a decrease of nanoparticle radius decreases the melting point of gold.

2. SYNTHESIS OF NANOSIZED PARTICLES

Synthesis of nanoparticles contains two different strategies: „Top-Down"and „Bottom-Up". The meaning of „Top-Down" is based on mechanical grinding of initial materials to small dimensions. It is necessary to decrease the powder size in order to perform Hall-Petch strengthening and apply a severe plastic deformation to powder particles to perform work hardening. High energy milling has a potential for realizing the new ideas of materials designers. The meaning of „Bottom-Up" is related to the physico-chemical preparation methods. The precipitation methods are usually used for the purification of spent solution. Hydrothermal process was applied under high pressure and temperature aiming to the dissolution of metal from different solid materials. From precursors such as metal alkoxides and metal chlorides the ceramic materials were produced by sol gel method.

Powder synthesis through aerosol routes enable the generation of fine, submicron to nanoscaled powders from a variety of precursor solution. The process involves formation of discret droplets of precursor solution in the form of aerosol followed by thermal decomposition in order to produce metal powders. Because of its simplicity, easy to produce multicomponent materials, generation of spherical und non-agglomerated powders and use of a variety of commercially available (inexpensive) precursor: metal nitrates, chlorides, acetates, sulphates, etc. spray pyrolysis is chosen for the technique for synthesis of nanopowders. Spray pyrolysis is a useful tool for large-scale or small-scale production of particles with controlled particle size because the final product properties can be controlled through the choice of precursor and solution concentration or by changing aerosol decomposition parameters. Generally, in a spray pyrolysis process, reaction temperature and carrier gas are basic operating variables. In addition, solution properties such as precursor composition, concentration, or reducing agent may be crucial to achieve the desired product composition and morphology. Preparation of metal particles by spray pyrolysis of metal salts is especially challenging. Using aerosol synthesis, a single-step preparation process of catalytic materials is possible, thus avoiding several steps like drying, shrinkage, solute precipitation, thermolysis, and sintering to form uniform spherical particles of nanometre scale between 10 and 100 nm and calcinations that are needed in "traditional" wet chemistry processes. As reported in the study of Milosevic et al. [10] the targeting three dimensional nanostructure can be reached using next route:

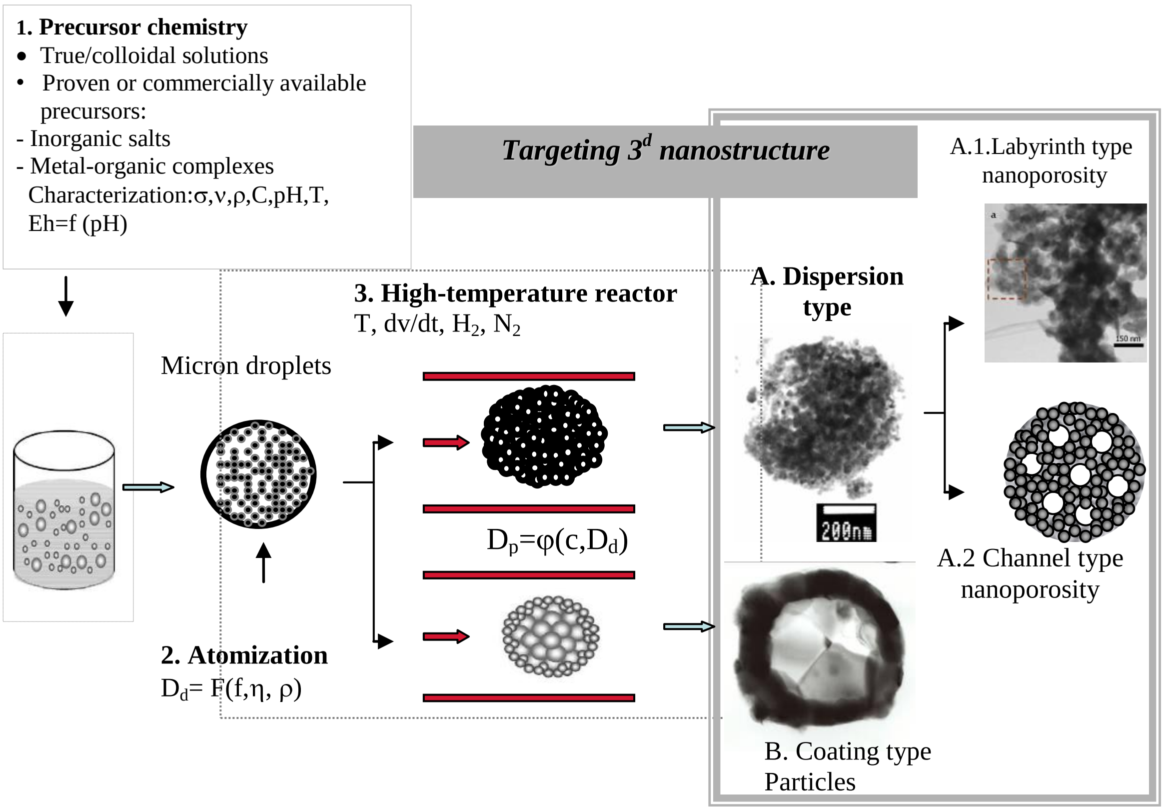


Fig. 2: Aerosol route for nanoparticle synthesis

Figure 2 represents the basic methodology which was used for the synthesis of nanosized particles at the IME Process Metallurgy and Metal Recycling of the RWTH Aachen University. The methodology is basically consisted of three parts:

1. Precursor chemistry, where the assessment of precursors and precursor solution,
2. Atomization, where the starting solution was transformed into aerosol droplets and
3. Thermal decomposition in a high tubular flow reactor, where the aerosol droplets were transformed into fine particles.

3. SYNTHESIS BY ULTRASONIC SPRAY PYROLYSIS METHOD

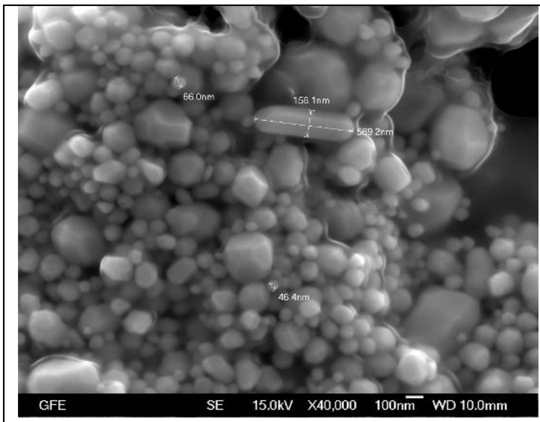
In last seven years an ultrasonic pyrolysis synthesis was developed at the IME Process Metallurgy and Metal Recycling of the RWTH Aachen University. Different organic and anorganic salts were used as precursor material for preparation of metallic, oxidic and composite nanopowders by ultrasonic spray pyrolysis, using the equipment shown in Figure 3. Temperature and pressure control was maintained using a thermostat and a vacuum pump. Atomization of the feed solution based on metal salts took place in an ultrasonic atomizer (Gapusol 9001, RBI/ France) with one transducer to create the aerosol. The used resonant frequencies were selected between 0.8 and 2.5 MHz. Under spray pyrolysis conditions neutral gas (nitrogen, argon) was flushed to remove aerosol from the system and the gas mix overpassed continuously a quartz tube (reaction zone d= 0.042 m, l= 1.5 m) at different flow rate of carrier gas. After thermal decomposition of the transported aerosol the formed nanopowder was collected in an electrostatic field of new system developed at the IME, RWTH Aachen University in a cooperation with Eltex, Germany. This collection system operates with voltage between 12 kV and 30 kV with current intensity between 0.08 and 0.14 mA.

Fig. 3: Ultrasonic Spray Pyrolysis Synthesis at the RWTH Aachen University

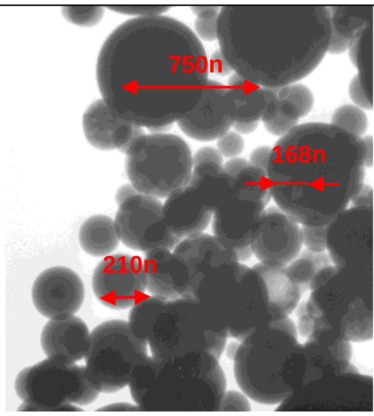
Three groups of nanopowders were prepared at the IME Process Metallurgy and Metal Recycling:

1. metals (Au, Ag, Co, Cu, Zn, Ni, Fe, Ru)
2. oxide (TiO_2, ZnO, Al_2O_3, RuO_2)
3. core shell materials (CuNi, FeCo, NiCo, RuO_2/TiO_2, $La_{0.6}Sr_{0.4}CoO_3$, C/$LiFePO_4$, Au/TiO_2, Ag/TiO_2)

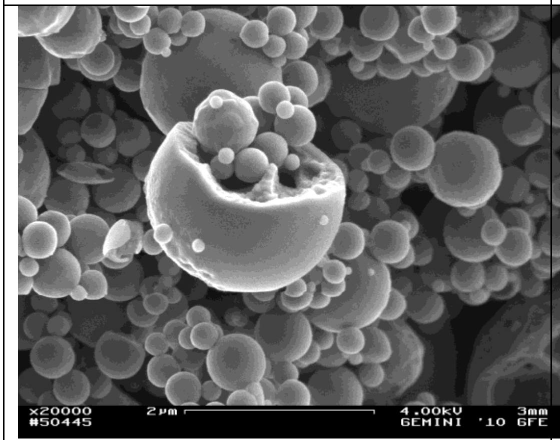
Some of our prepared particles are shown at Fig. 4.



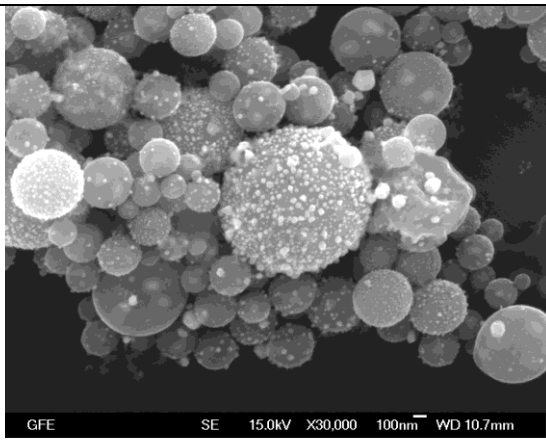
Nanogold obtained at 280°C [11]



$LiFePO_4$ obtained at 800°C [12]



TiO_2 obtained at 800°C [13]



Au/TiO_2 obtained at 800°C

Fig. 4: Synthesis of nanosized powders by ultrasonic spray pyrolyis at the IME, RWTH Aachen University

4. NANOPARTICLES IN MODERN LIFE

Nanoparticles exhibit a high number of special properties relative to bulk material. Gold nanoparticles are of high interest because of their potential application of electrochemistry, in medicine and producing nanodevices. Reasons for the high reactivity of these nanoparticles, so-called clusters, are assumed to be hidden in their atomic structure. As the active nanoparticles are smaller than the wavelength of visible light their structure cannot be inspected using an optical microscope. In the recent past, the structure of charged gold clusters had been determined, but that of the neutral clusters, thought to be more relevant for the catalytic activity, remained elusive. Interaction between gold nanoparticles and biological species found in aqueous solution are being used as a basis for the development of biosensors. As reported by Baker and his colleagues at the University of Michigan [14] by combining chemical and physical therapy, gold nanoparticles with branching polymers could attack tumors in multiple ways. The nanoparticles are gathered inside cancer cells. Once that concentration is high enough, gold nanoparticles nestled inside the dendrimer are heated up by laser or infrared light in order to destroy cancer cells like "thermal scalpel".

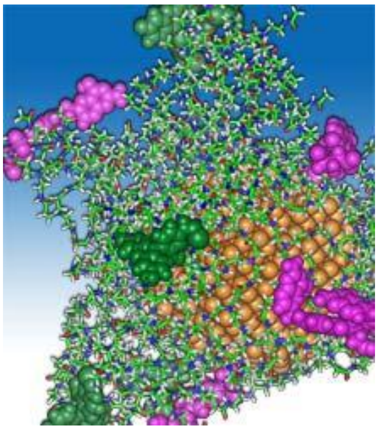


Fig. 5: Gold nanoparticles with branching polymers ("thermal scalpel nanoparticles") [14]

Because of the good biocompatibility gold nanoparticles enveloped in treelike polymer branches could act as a multipurpose tool for fighting cancer. Folic acid (pink) and fluorescent dye (green) were attached to the nanoparticle in order to target and image tumors. Then tumor cells could be killed with cancer drugs, which are attached to the particle, and with lasers that heat up the gold nanoparticles.

Copper nanoparticles smaller than 50 nm are considered super hard materials that do not exhibit the same malleability and ductility as bulk copper. The change in properties is not always desirable. Ferroelectric materials smaller than 10 nm can switch their magnetization direction using room temperature thermal energy, thus making them useless for memory storage. Suspensions of nanoparticles are possible because the interaction of the particle surface with the solvent is strong enough to overcome differences in density, which usually result in a material either sinking or floating in a liquid.

Nanosilver has become one of the most commonly used material in consumer products. In 2005 Company Samsung released its nanosilver washing machine in Sweden and Australia. They claim that despite low wash temperatures the silver nanoparticles act as a bactericide resulting in clothes that will keep fresh longer. Silver nanoparticles are usually in the size range of 1-50 nm. Their use has also substantially risen in the area of medical devices coatings, would care dressings and as an enhancement of bandages.

5. HEALTH AND ENVIRONMENTAL IMPACT OF NANOTECHNOLOGY

Toxicological assessment of prepared nanoparticles is of the most importance for the new application in different topics. Often nanoparticles are considered as discrete particles with a diameter of less than 250 nm. Ultrafine particles (<2.5 µm) may be important from a health point of view because of the large numbers and high surface area. Particles that are smaller than approx. 2 µm will predominantly be deposited in the lower parts of the respiratory passages and in the lungs. They are the ones most commonly encountered in the air. The mobility of nanoparticles in the gas phase depends highly on their diameter. The measurement of nanoparticles at the working places is performed by Particle Size Classifier and Differential Mobility Analyzer, Company Grimm, Ainring, Germany. The usage of iron nanoparticles can represent a significant qualitative step in the classical technologies of wastewater and drinking water treatment [15]. The extremely reactive iron nanoparticles offer a possibility to solve long-lasting problems with a high content of uranium and arsenic in a variety of localities in the Central Europe. They can be also used for a reduction of the content of heavy metals, nitrates and phosphates in the drinking water. Due to their small size, the particles are very reactive (more reactive than granular iron which is conventionally applied in reactive barriers) and can be used for in situ treatment.

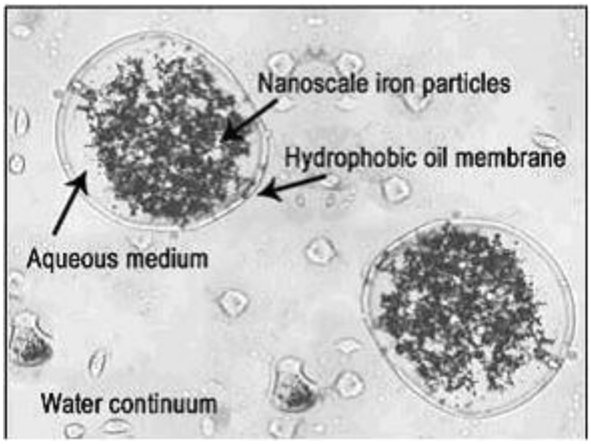


Fig. 6: Structure of the Emulsifed Zero Valent Iron particle [16]

Emulsifed zero valent iron particle EZVI is composed of an iron core of nanoparticles surrounded by water and packed in a droplet surrounded by food-grade surfactants and biodegradable vegetable oil which form a oil liquid membrane. According to the NASA, EZVI particles are quick, very cost-effective, suitable for the working in sites with high dissolved oxygen or under saline conditions. The oil membrane around the iron particles protects them from corrosion. NANO IRON Company, Czech Republic has developed NANOFER 25 product as a solid sorbent, which exhibits a large surface area along with an extraordinary reactivity in contact with pollutants. Nanopowder NANOFER 25P is delivered in the steel containers with maximum capacity of 10kg of the dry product.

6. CONCLUSION

Nanoparticles are of the high interest because of their potential application in catalysis, environmental protection, electrochemistry, automotive industry, and medicine. Reasons for the high reactivity of these nanoparticles are assumed to be hidden in their atomic structure. As the active nanoparticles are smaller than the wavelength of visible light their structure cannot be inspected using an optical microscope. Especially in last years an important use of metal nanopowders is available in the field of medicine for diagnosis and fight against cancer. The interaction of nanoparticles with biomolecules and microorganisms is an expanding field of future research. Within this field, an unexplored area is the interaction of metal nanoparticles with different viruses. As relatively inexpensive and quite versatile technique ultrasonic spray pyrolysis was tested by the IME, Aachen and chosen as promising aerosol process to produce fine metallic, oxidic, composite particles of precisely controlled morphology and defined chemical compositions solution using different metal salts as its precursors. Nanoparticles improve the quality and performance of many consumer products the public employs daily as well as the development of medical therapies and tests. The most important information describing the relative health and environmental risk assessment of prepared nanoparticles are missing. Nanoparticles both pollute our environment and also help keep it cleaner.

7. ACKNOWLEDGEMENT

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