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Extended Abstracts

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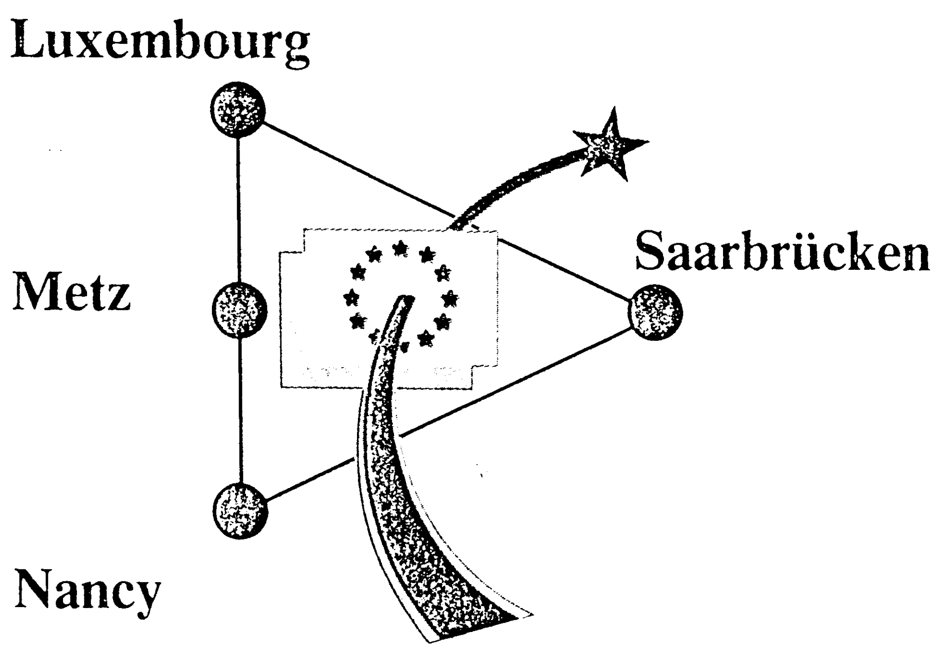

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New Perspectives for economic production and processing of na osized ceramic materials

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1. Introduction

Ceramic powders with particle sizes below 100 nm have gained an increasing interest during the last few years because ceramics with improved and/or new properties are expected from these powders. One of the most interesting features of these so-called nanosized powders is their high sintering activity which should lead to much lower sintering temperatures than conventional submicron powders. This has been demonstrated already for a 15 nm rutile powder which could be densified to 94 % of the theoretical density well below 1000 °C [1]. On the other hand, due to this high sintering activity, a separation of densification from grain growth during sintering can be envisaged giving rise for an unique opportunity for tailoring ceramic microstructures and, as a consequence, material properties.

Another point of interest is the possibility of reducing the flaw size in ceramic parts and, in combination with defect-free processing technique, of improving the reliability of ceramic materials. However in order to use these potentials, economic synthesis methods for high quality powders as well as size-adapted processing and forming techniques have to be developed.

2. Powder Synthesis

Chemical synthesis routes from solution are one of the most attractive techniques for the development of economic production lines of nanosized ceramic oxide powders. Starting from aqueous or nonaqueous precursor solutions, nano-sized particles are generated by chemical reactions. These particles spontaneously agglomerate and, due to their high surface reactivity caused by hydroxy groups, tend to form strong agglomerates either in solution or during drying and calcination. These agglomerates cannot be destroyed in further processing steps. From this point of view, it is obvious that wet chemical synthesis of nanosized powders requires a proper control of the particle surface in order to prevent the formation of hard agglomerates. Agglomeration can be suppressed in solution by surface modification of the originated particles with small organic molecules (e. g. carboxylic acid, ß-diketones) or by the adsorption of organic polymers [2 - 4]. This technique is limited to single component systems and the avoidance of strong agglomerates during calcination is still an unsolved problem.

Another technique is the so-called water-in-oil-(w/o) microemulsion technique [5, 6]. This method has the advantage that a wide variety of compositions (single- and multicomponent systems) can be prepared and that the formation of hard agglomerates in a subsequent calcination step can be avoided. The principle of this technique is that nanoscaled microreactors are generated by emulsifying an aqueous precursor solution in a hydrocarbon in the presence of emulsifiers and that precipitation reactions are carried out inside these aqueous droplets by changing the pH [5]. After the removal of all liquid phases, nanosized particles coated with emulsifier molecules are obtained which can be transferred to a softly agglomerated powder by calcination if the thermal stability of the organic coating is high enough to act as a surfactant until all surface groups of the particles have been desactivated.

Going this way, a variety of nanosized ceramic powders with particle sizes down to 2 nm have been synthesized. This includes Al_2O_3, ZrO_2, Y_2O_3/ZrO_2, PZT and others.

3. Processing

The major problem of processing nanosized particles is the achievement of deagglomerated slurries or pastes with solid contents high enough so that ceramic forming techniques can be used [7]. In this case, the conventional stabilization methods, which are applied in submicron powder processing, as the electrostatic stabilization or the steric stabilization by adsorption of macromolecules cannot be transferred to nanoparticle systems due to the large exclusive volume of the stabilizing layer [6]. For that reason, other ways must be found to provide slips with a sufficient solid loading for industrial applications of nanotechnologies. A solution to that problem could be the surface modification of nano particles by chemical bonding of short chained molecules to the particle surface, which reduces the thickness of the stabilizing layer. This results in higher solid contents of slips by improved stability. First successful experiments confirming the feasibility of this route have been carried out already with 15 nm boehmite powders which were surface-modified with proprionic acid. Due to the surface modification extrusion pasts with 45 Vol.-% solid content could be developed. These pastes could be processed by extrusion to tubes and rods. After drying a green density of 60 - 65 % of the theory was achieved [8].

4. Conclusion

The key for the successful development of chemical synthesis routes for nanosized ceramic powders as well as the corresponding processing and forming techniques is the control of the particle surface by surface modification. In the case of powder synthesis, the surface modification should protect the particle against interparticle condensation reactions until the desactivation of the surface by thermal heat treatment has taken place. On the other hand, for processing and forming, the surface modification should provide small hydrodynamic radii leading to processable slips with high solid contents.

5. Literature

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