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MORPHOLOGY OF CERAMIC PARTICLES PRODUCTED BY PLASMA-CHEMICAL SYNTHESIS[1]

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The use of fine powders of metal oxides in the preparation of ceramic composite materials enables to ynthesize products for various purposes with unique mechanical properties, create metal-substituting con-truction materials and protective coatings, as well as filters, membranes, and thermoinsulating and catalyst tructures with a specified pore size. One of the most promising technologies for producing ceramic pow-lers with controlled parameters is plasma-chemical synthesis, including the thermochemical decomposition f liquid-drop reagents (precursors) in a flow of high-temperature gaseous heat carrier. This technology is nown as "spray pyrolysis". Depending on the chemical composition of the precursor, a wide range of metal xide powders can be obtained: Al_2O_3 from an aluminum nitrate $Al(NO_3)_3$ solution, zirconium oxide ZrO_2 rom a zirconium nitrate $Zr(NO_3)_3$ (or zirconium chloride $ZrOCl_2$) solution, as well as mixed oxides, such as $rO_2 + MgO$, $ZrO_2 + Y_2O_3$, $ZrO_2 + CaO$, $ZrO_2 + Y_2O_3 + Al_2O_3$, etc.

Electron microscopic studies of powder particles prepared by the plasma-chemical method revealed that heir morphology may vary, featuring solid spherical single-crystal formations, hollow spheres and their ragments, films, and porous or foamed particles. The internal structure of ceramic particles is the most mportant parameter that determines the quality of the product. While the production of construction eramics requires fine spherical solid particles, the manufacture of heat-shielding materials and catalysts referably uses porous and hollow particles.

Clearly, the particle morphology is defined by both the precursor characteristics (dispersion of drops, olution concentration) and thermochemical process parameters (speed of drops, time of their residence in he reactor, temperature regime, aerodynamic pattern of the two-phase flow in the reactor, thermophysical roperties of the reagents, etc.). To ensure a controllable mode of operation of the plasma-chemical reactor n order to produce particles with desired characteristics, it is necessary to develop mathematical models of he processes occurring in it. The development of such a mathematical apparatus involves multivariate nalysis of the problem of calculating the parameters of a multicomponent two-phase chemically reacting nedium with a detailed description of heat and mass transfer in the individual spray drops and between the lrops and the gaseous heat carrier. However, the available studies are based on mathematical models nvolving a number of serious simplifications in describing the processes within the solution drops, an pproach that significantly reduces the possibility of predicting the characteristics of the synthesized owders of metal oxides, in particular, their morphology(internal structure)..

In this report, we developed a mathematical model of heat and diffusion processes in a drop of slightly oncentrated solution of a metal salt as it is heated in a plasma-chemical reactor. This model is designed to redict the morphology of the particles of ceramic powders depending on the characteristics of the solution nd gaseous heat carrier.

Analysis of the results of numerical calculations within the framework of this model showed that the only imensionless parameter that determines the structure (morphology) of the particle formed is the ratio of the haracteristic times of diffusion t_1 and evaporation t_2: $K = t_1/t_2$. At $K < K_{cr}$, diffusion is faster than vaporation, and therefore, solid particles are formed; at $K > K_{cr}$, hollow spherical particles are formed.

In the case of the formation of hollow particles, the process of salt crystallization occurs in two stages: ie primary precipitation to form a layer of thickness h_1 followed by the deposition of the remaining salt nto the inner surface of the particles to form a layer of thickness h_2. The ratio between h_1 and h_2 is etermined by the value of K.

In producing ceramic powders with a given morphology, the main parameters of the controlled plasma-hemical synthesis are the initial concentration of the precursor salt (salt solubility), temperature difference etween the gaseous heat carrier and the precursor, as well as the difference between the critical upersaturation concentration C_{cr} and equilibrium saturation concentration C_0.

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