Institute of High Current Electronics SB RAS
Tomsk Scientific Center SB RAS
National Research Tomsk Polytechnic University
Chongqing University of Arts and Sciences

7th International Congress on Energy Fluxes and Radiation Effects (EFRE-2020 online)

Abstracts

September 14–25, 2020
Tomsk, Russia

Tomsk
Publishing House of IAO SB RAS
2020

ISBN 978-5-94458-182-2

MATHEMATICAL SIMULATION OF THE PROCESS OF CREATING THE SILICA PARTICLES MORPHOLOGY IN PLASMA FLOW

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Today the progress in thermal processing of multicomponent powder materials for production of small hollow spheres (with the diameter of tens microns) remains a topical problem because those particles have many applications in different industries [1]. A promising approach for powder treatment is the heating with plasma flow. It has a high energy density and the working temperatures in the range (3000–10000)°C. The plasma technologies are available for production of hollow ceramic microspheres made from zirconium dioxide powder, silicon dioxide and other materials, as well as spray pyrolysis technology for synthesis of metal oxide powders from precursor solutions [1–5].

The presented report is focused on mathematical simulation of the process of plasma-aid production of hollow silica microparticles. The first part of this study deals with dynamics, heating, and melting of primary powder in the plasma flow as a function of diameter and porosity of initial particles. The second part of the research deals with processes of creating the hollow particle morphology in the plasma flow.

In contrast to the known models [1–5], the proposed physical and mathematical model of the formation of hollow microspheres at heating and melting the porous silica particles (precursor) in the flow of low-temperature plasma takes into account the partial encapsulation of the gas during the formation of the shell from the molten metal.

The solid particles of SiO_2 (with air in pores) are fed to the high-temperature zone (plasma flow). We take the following assumptions in the simulation problem:

– gas flow (a turbulent nonisothermal submerged jet) is uniform and steady;

– the temperature and velocity of gas over the plasma jet length are known;

– gas pressure is constant over the jet length and equals the atmospheric pressure: $p_g = p_{atm} = \text{const}$;

– SiO_2 porous particles are almost spherical; we know the diameter D, volumetric porosity P_{po}, initial temperature T_{po}, and the velocity u_{po} of injected particles;

– pores in the particles are filled with air with the parameters corresponding to initial conditions $T_g = 293$ K, $p_g = p_{atm}$;

– volumetric concentration of particles $C_V < 0.02$;

– after the particles enter the high temperature gas flow, they evolve during the four stages. The first stage is particle heating from the initial temperature T_{po} to the melting temperature T_{melt}; meanwhile, all air captured in the pores undergoes thermal expansion and it releases through the open pores. The second stage is the formation of the primary coating. When a porous particle is heated to the melting temperature, a liquid coating of molten particulates is produced. This liquid coating captures a certain amount of air. The remained air coalescences into a single spherical cavity. The third stage is the formation of the final coating. During the fourth stage, liquid coating undergoes amorphous solidification (after the particle exits the high temperature zone).

REFERENCES

[1] I.P. Gulyaev, O.P. Solonenko, "Modeling of the behavior of hollow ZrO_2 particles in plasma jet with regard to their thermal expansion", Thermophysics and Aeromechanics, vol. 20, no. 6, pp. 769–782, 2013.

[2] I.P. Gulyaev, "Peculiarities of production and treatment of hollow particles of zirconium dioxide in plasma flow", Vestnik Yugorskogo Universiteta, vol. 13, no. 2, pp. 10–22, 2009.

[3] V.A. Arkhipov, S.S. Bondarchuk, V.V. Shekhovtsov, O.G. Volokitin, A.S. Anshakov, V.I. Kuzmin, "Simulation of production of hollow silica particles in a plasma flow. Part 1. Dynamics of motion and heating of porous particles", Thermophysics and Aeromechanics, vol. 26, no. 1, 2019.

[4] V.A. Arkhipov, O.G. Volokotin, A.I. Konovalenko, A.S. Usanina, V.V. Shekhovtsov, "Formation of hollow ceramic particles in plasma flow", Proc. 6th Int. Cong. on Energy Fluxes and Radiation Effects (EFRE), Tomsk, Russia, p. 298, 2018.

[5] V.A. Vlasov, O.G. Volokitin, G.G. Volokitin, N.K. Skripnikova, V.V. Shekhovtsov, "Calculation of the melting process of a quartz particle under low-temperature plasma conditions", J. Eng. Phys. Thermophys, vol. 89, no. 1, pp. 152–156, 2016.