

DISTRIBUTION OF CHEMICAL ELEMENTS IN POLYDISPERSED DUST-GAS MIXTURES

Skitina V. V.¹⁾, Akimov V. V.²⁾, Tauson V. L.²⁾, and Chernykh A. E.³⁾

¹⁾SUAL-Powder Metallurgy, Shelekhov; Russia; ²⁾Institute of Geochemistry, Siberian Branch Russian Academy of Sciences, Irkutsk; Russia; ³⁾SibVAMI, Irkutsk, Russia

Key words: *Differentiation of elements, dust-gas mixture, powder aluminum production*

Chemical differentiation of matter in a dust-vapor mixture is considered both in analysis of the production of powder materials by gas atomization of molten metal and in theories of the origin of the planets of the solar system. A number of hypotheses assume that the planets formed from "a chemically and physically uniform protoplanetary cloud" [1]. It is as yet unclear whether the earliest evolution of such a cloud could involve chemical differentiation leading to separation of elements and, ultimately, to differences in the chemical composition between the planets of the solar system. And although both the scales and the complexities of industrial and space systems are incomparable, some physicochemical mechanisms of processes in such systems can be common.

In this paper, we consider our discovered unusual example of chemical differentiation in aluminum powders. Powders were obtained on an industrial plant for production of dispersed aluminum by atomization of molten metal by a heated unreactive gas (nitrogen) fed under pressure.

An aluminum powder production experiment was carried out on standard equipment of SUAL powder metallurgy works in Shelekhov. Samples of material were taken from different apparatuses of the production line. Fresh samples were separated into fractions by sedimentation and sieving. Sedimentation was performed in 96% ethanol. Three fractions with particle size distribution maxima at 4, 7, and 20 micron were isolated. The particle size distribution was analyzed with a Micro Sizer 201 ultrasonic laser analyzer (VA Instruments). All the isolated fractions were examined in detail with a JEOL JCSA-733 electron probe micro analyzer operating as a scanning electron microscope; structural and morphological features of the particle surface were studied with an SMM-2000 atomic force/scanning tunneling microscope using a standard program for morphological surface analysis. Elemental analysis of each of the fractions of each of the three samples was performed by the inductively coupled plasma mass spectrometry method. A Plasma Quad PQ2@+ quadrupole mass spectrometer (VG Instruments, Thermo Elemental) was used under conditions that are standard for this instrument. The concentration calculation accuracy was 10-50%, depending on an element and its content in a sample.

The first thing that attracts attention when analyzing the data obtained is the nonuniformity of the distribution of impurity elements over fractions, which manifests itself against the background of differences determined by the apparatus from which a given sample was taken. In other words, substantial differences also take place both in the distribution of individual elements over fractions and in their distribution over samples that contain particles of close size but were taken from different apparatuses. The curves of impurity distribution over fractions have different shapes for different samples. An interesting feature is the fact that some sets of elements behave similarly in the fractions of particles of the same size in different samples. Enrichment by certain elements is sometimes very high (3 to 130 times).

All the above features are indicative of the nonuniformity of the distribution of impurity elements over fractions and samples, which is quite unexpected. It is usually believed that the chemical properties of atomized metals and alloys are independent of the particle size in inert systems and all particles give identical analysis results, regardless of the size [2]. The nature of the observed phenomenon is most likely to be determined by the surface properties of particles. Many impurities undergo high surface enrichment [3], which can affect the composition and structure of the film forming on particles. Sites of accumulation of active impurities act as catalytic sites (in particular, catalytic sites of electrochemical nature) and give rise to oxide or nitride surface formations, on which both the adhesion of particles and their behavior in a gas flow depend. Fluctuations of parameters in nonequilibrium atomization process are considerable; drops of close size form under not quite identical conditions and, therefore, also differ in the chemical composition. The nonuniformity of the composition can also be characteristic of the initial melt, if this melt is insufficiently superheated or insufficiently homogenized. As drops crystallize, impurities rise to the surface and actively participate there in the formation of particle shells. According to their chemical nature, elements differently affect

this process and, ultimately, the physicochemical properties of powder particles. For example, small particles with increased contents of impurities either have an uneven surface because of the multiplicity of nuclei on it or are more highly aggregated. Therefore, these particles, albeit close in size, reach different apparatuses along the process line. Apparently, the system under consideration is macroscopically uniform (quasi-uniform) and consists of many subsystems, each differently nonuniform.

Returning to the problem of chemical differentiation in the protoplanetary cloud, note an important conclusion that directly follows from the results obtained. Models of the evolution of the vapor--dust mixture must take into account the surface properties of particles and their possible changes during (homogeneous or heterogeneous) accretion, rather than only appeal to Stokes' law and different densities and sizes of particles. Our data show that certain sets of chemical elements can be concentrated in fractions of particles of different size of even the same substance. The interaction in subsystems of particles with different surface properties can prove to be a decisive factor of separation of chemical elements.

References

1. Rudnik V.A. and Sobotovich E.V. Early History of the Earth // Moscow: Nedra, 1984.
2. Gummeson P.U. // Powder Metal. 1972. V.15, N29. P.67-94.
3. Akimov V.V., Tauson V.L., Belozeroва O.Yu. et al. // Electrometallurgy of Light Metals. Irkutsk: IrkAZ - SibVAMI. 2002. P.74-88.

Electronic Scientific Information Journal "Herald of the Department of Earth Sciences RAS" № 1(21) 2003
Informational Bulletin of the Annual Seminar of Experimental Mineralogy, Petrology and Geochemistry – 2003
 URL: http://www.scgis.ru/russian/cp1251/h_dggms/1-2003/informbul-1_2003/planet-15e.pdf
 Published on July 15, 2003

© Department of the Earth Sciences RAS, 1997-2003
 All rights reserved