Synthesis and Characterization of Aluminum Nanoparticles with Customized Coatings Manufactured via the Flow-Levitation Method

Abstract
This is a detailed study and characterization of Aluminum nanoparticles that have been coated with customized inorganic, organic and element-organic materials in order to prevent undesirable agglomeration and surface activity between particles. The synthesis of the Al nanoparticles and the deposition of nano-sized customized coatings on their surface were accomplished using the Guen-Miller Flow-Levitation (FL) technique. This study focuses specifically on Al nanoparticles coated with oxide, (oxy)nitride, organic, silicon- and fluorine-organic coatings, and aluminum oxide particles.

Method: Synthesis and in-situ Coating
Synthesis of Al nanoparticles and deposition of nano-sized customized coatings is accomplished using the Guen-Miller Flow-Levitation (FL) method, a technique invented in Russia, unknown in the US and perfected at the Talrose Institute for Energy Problems of Chemical Physics of the Russian Academy of Science, Moscow, Russian Federation.

Key parameters for proper coating deposition:
1) Distance L must be carefully selected to ensure the proper chemical reaction and achieve the required properties of the coating.
2) Proper concentration of reactive gas is needed so that the reaction is fast enough to form coating before the collisions that eventually occur among the forming nanoparticles.

Conclusions
- The Guen-Miller FL-method in conjunction with nano-sized surface chemical modification of nascent nanoparticles constitute a powerful and versatile method to control physico-chemical properties of metal particles.
- The characteristic high reactivity and undesirable agglomeration of aluminum nanoparticles can be controlled by the deposition of nano-sized organic and/or inorganic coatings on the surface of the particles.
- Coating uniformity and thickness depend on proper concentration of reactant gas and its injection distance downstream the nascent nanoparticles during synthesis.
- Coating deposition is highly sensitive to the temperature of reaction which in turn is dependent on the operation regime of the manufacturing apparatus, i.e.: inert gas flow rate and pressure, metal evaporation rate, type of carrier gas and heat of reaction.
- Coated particles present a wide variety of morphologies depending on the coating process and material. Shapes observed vary from perfectly spherical to “pea-like” shapes, to corrugated “nano-scaled” shapes.
- Aluminum particles with organic and silicon-organic coatings possess strong hydrophobic properties.

References
- A.N. Ilyushin, I.A. Berezkina, N.G. Zhigach, Alex, PhD. Berezkina, Nadezda, PhD.

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Sample Results - Organic nano-scaled coatings

Sample Results - Inorganic nano-scaled coatings

Background
The high reactivity and explosiveness of aluminum nanoparticles are attractive characteristics for energetic technologic applications that can fulfill civilian and/or military needs. However, the extremely high chemical surface activity in conjunction with agglomeration susceptibility present a serious manufacturing challenge during synthesis of aluminum nanoparticles which lead to undesirable pyrophoric effects and adsorption of environmental species. This technical issue can be resolved by applying customized chemical coatings on the surface of the nascent aluminum nanoparticles before metal-to-metal bonds are formed.

Method: Characterization and Results
Transmission (TEM) and scanning (SEM) electron microscopy, electron diffraction analysis (EDA), energy-dispersion spectroscopy (EDS), X-Ray photoelectron spectroscopy (XPS) and X-Ray diffraction analysis (XRD). Specific surface areas were measured using the BET technique by nitrogen adsorption. Composition of volatile layers on the particles was studied using temperature-programmed desorption method with mass-spectral desorption products analysis (TPD).