Ultrasonic spray coating of nanoparticles

Joseph Riemer, PhD, Sono-Tek Corporation

Ultrasonic atomization is a proven spray coating technology of unmatched functional and economic performance, especially for applications where expensive chemical solutions and suspensions are accurately and uniformly deposited on substrates.

Ultrasonic atomization technology's unique advantage is based on two features: its ability to generate very small droplets of an extremely narrow range diameter size, and its ability to apply these droplets gently on the substrate with minimum "bounce back" from the target surface. These features enable superior transfer coefficients when compared with conventional coating technologies, providing high-quality functional coatings at significantly lower cost of goods sold (COGs).

Sono-Tek Corporation has developed and patented commercial ultrasonic atomization systems for challenging applications in various industries. This article describes Sono-Tek's most recent technology releases for dispensing and coating of nanoparticles.

Ultrasonic atomization nozzle operating principle

Ultrasonic nozzles operate by converting a high frequency electrical signal, fed into two electrodes sandwiched between two piezoelectric transducers, resulting in mechanical expansion and contraction of the transducers. This causes vibrations to be sent down the nozzle's titanium horn, ultrasonically vibrating at the nozzle's atomizing tip. Liquid traveling down the center of the nozzle forms capillary waves as a result of this vibrational energy. As the liquid emerges onto the atomizing surface, it reaches a critical wave amplitude and is broken into a spray of tiny drops by the ultrasonic energy concentrated there. This ultrasonic nozzle design provides an easily controllable atomized spray that does not clog because of the large liquid feed orifice and the self-cleaning ultrasonic vibration.

Droplet sizes

In an ultrasonically produced spray, drop size is governed by the frequency at which

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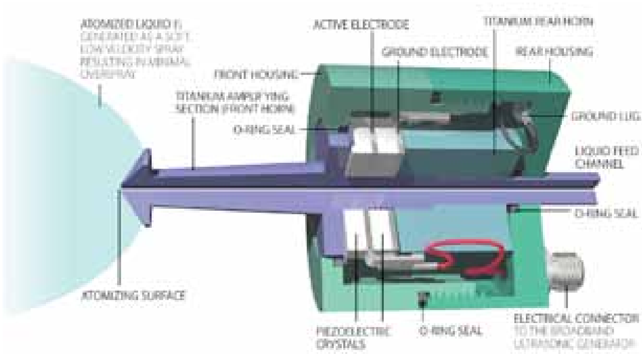

Figure 1. Ultrasonic atomization nozzle.

Keywords: Ultrasonic Spray Coating, Nanoparticles, Solar Cell Manufacturing, Active Layer Coatings

the nozzle vibrates, and by the surface tension and density of the liquid being atomized. Frequency is the predominant factor. The higher the frequency, the smaller the median drop size.

Unique advantages of ultrasonic coating for nanoparticles

When conventional mixing devices and pumps are used for dispensing nanoparticles, the particles tend to agglomerate and separate from the liquid suspension. Sono-Tek developed custom solutions to liquid delivery of nano suspensions: SonicSyringe, CSP Flow and SonoFlow CSP. These liquid delivery systems employ disc-shaped piezoelectric transducers located inside a syringe plunger to convert high-frequency electrical energy into mechanical energy, which is transferred into the liquid suspension. A control module provides the high-frequency electrical input controlling power intensity and duration, depending on the liquid suspension characteristics. The resulting high-frequency and high-reflection vibrations created inside the syringe barrel effectively mix most slurries, dispersions, and suspensions to near-perfect homogenous blends within a few seconds. Further electrical impulses triggered automatically from the control module generate continuous vibrations, holding nanoparticles evenly dispersed in the suspension for several hours.

When conventional coating technologies (e.g. pressure spray coating, spinning disc coating and web printing technologies) are used to coat nanoparticles on substrates, their uniformity control is limited, and the amount of nano material that must be used is excessive and costly. Sono-Tek ultrasonic spray nozzles uniformly and accurately coat very thin layer of nanoparticles on substrates of different shapes, forms and sizes. The ultrasonic spray nozzle continuously generates micronic droplets which carry within them identical concentration of nanoparticles. The nozzle imparts ultrasonic vibration into the liquid suspension, providing an agglomerate free system. By the time the liquid reaches the target, it evaporates and gently positions the nanoparticles with a transfer coefficient higher than 95% and practically no "bounce-back" associated with conventional coating technologies.

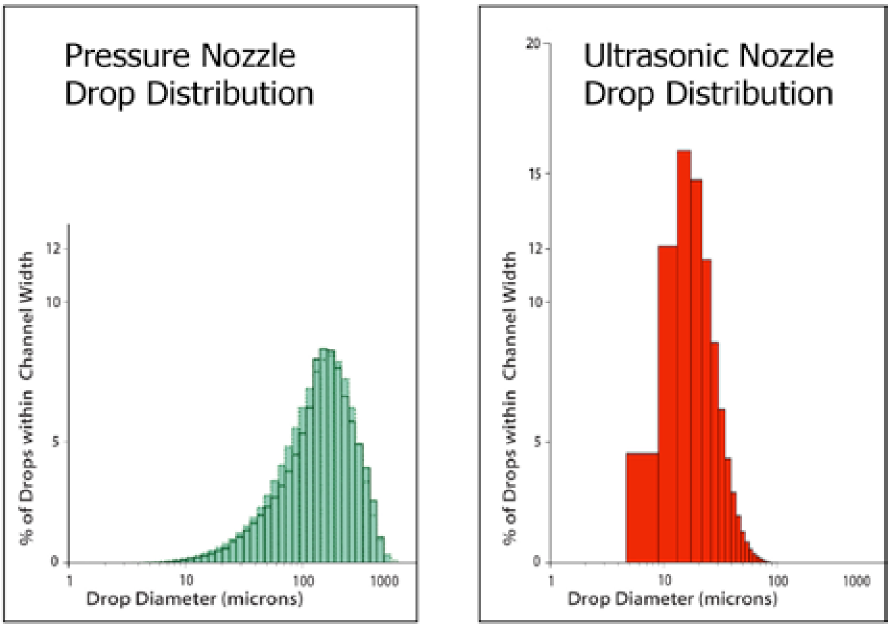

Figure 2. Ultrasonic droplet diameter sizes.

Ultrasonic spray coating for advanced energy applications

Using high-frequency sound waves to atomize liquids, Sono-Tek ultrasonic nozzle systems are well suited to the deposition of nanoparticles in suspension for a number of reasons. The ultrasonic nozzles' large orifice and ultrasonic vibration make it possible to atomize high solids materials without clogging. The technology is ideally suited for suspended solids that tend to agglomerate, as agglomerations are broken

Figure 3. SonoFlow CSP.

Figure 4. Sono-Tek ExactaCoat for coating of fuel cell catalyst.

up during liquid delivery by the same ultrasonic vibrations causing atomization. Therefore, the dispersion of particles in solution is highly uniform throughout the entire coating process, providing the most homogenous coatings possible. Often in the case of advanced energy applications such as carbon catalyst coatings onto fuel cells and electrochemically active coatings onto solar cells, the greater the homogeneity and uniformity of the coating, the higher the cell efficiency and conductivity of the substrate. An added major benefit is the decreased waste and overspray of raw materials in the form of expensive metal solutions due to the non-clogging nature of the atomized spray.

Fuel Cell coating applications

Fuel cell carbon catalyst ink films created with ultrasonic nozzles exhibit several key advantages when compared to conventional coating techniques: Maximum surface area exposure of Platinum with particles uniformly dispersed, maximum uniformity of film thickness and Pt web density to create the largest amount of Platinum available to the flow of gas without inconsistent hot spots or areas of low catalyst density, and maximum repeatability of film characteristics without process degradation. Platinum films deposited with Sono-Tek ultrasonic spray methods have coating efficiency optimized above 90% efficient with repeatability at ±1 percent.

Solar cell coating applications

In the application of solar cell manufacturing, ultrasonic nozzles offer similar benefits to those described for fuel cell production in the deposition of active layer coatings such as CIG(s), CDTe, and CZTS onto thin film solar cells. Transfer efficiencies as high as 95%, reduce consumption of expensive raw materials, translating to lower cost per watt production. The advantages of Sono-Tek's unique ultrasonic atomizing systems has provided a strong and growing niche for supplying equipment to manufacturers looking to maximize efficiencies in the deposition of very thin micron layers of nanomaterials.

Figure 5. Sono-Tek FlexiCoat for inline coating of PV solar panels.

Conclusion

Sono-Tek ultrasonic atomization technology is a proven enabler for dispensing and coating an ever-growing array of new nanomaterials, accurately and uniformly. The systems provide significant COGs reduction and excellent ROI. Confidential programs are carried out jointly with customers, who benefit from Sono-Tek's extensive IP, experience and global leading reputation in the field of ultrasonic spray coating of nanoparticles.