ULTRASONIC SYSTEMS, INC.

ULTRA-SPRAY WHITE PAPER

Title: **Photoresist Application with "Nozzle-Less" Ultrasonic Coating Technology**

Significant improvements in coating deposition control can be achieved with advanced ultrasonic coating technology that provides precise control of film thickness for the application of Photoresist to wafers.

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Introduction

There are numerous cases in which "non-standard" semiconductor wafers need to be coated with Photoresist. Such cases include wafers with many micro vias and wafers with non-circular shapes. The traditional spin coating method has proven ineffective in applying a thin, uniform coating of Photoresist to these wafers. The spin coating technique tends to clog the micro vias and has difficulty achieving a uniform coating application to non-circular wafers. Additionally, spin coating generates significant waste of Photoresist.

Spray coating for the application of Photoresist to wafers has proven to be a viable alternative to spin coating. Various spray generation methods are available including air-atomized spray valves, ultrasonic nozzles and "nozzle-less" ultrasonic spray heads. Air atomizing spray valves produce excessive overspray, have a tendency to clog easily, produce a non-uniform spray pattern and have difficulty maintaining accurate control of the liquid flow rate. Ultrasonic spray nozzles produce a softer, more efficient spray but produce non-uniform coating layers due to difficulties with control of the spray pattern shape and inability to precisely start and stop the liquid spray.

An automated method for the precise application of Photoresists has been developed that utilizes a "nozzle-less" ultrasonic spray head and a high performance X-Y-Z motion control platform with advanced material handling capabilities. The ultrasonic spray head uses ultrasonic energy to break the liquid into small drops to form the spray; however the liquid does not pass through the device. Liquid is applied externally to a solid surface, which is vibrating at an ultrasonic frequency (>20kHz). Directed air streams are used to expand or focus the ultrasonically produced spray, providing a

rectangular, uniform spray pattern. The liquid flow and airflow to the spray head are electronically controlled, providing complete control of the spray pattern shape and velocity. The coating system incorporates an advanced liquid delivery system to ensure that the coating flow is precisely metered to the ultrasonic spray head. The "nozzle-less" ultrasonic spray technology is widely used for applying various coatings across multiple industrial markets.

This paper considers a particular advancement in thin film application of Photoresists using the "nozzle-less" ultrasonic spray head known as *Ultra-Spray* technology with the integrated fluid delivery applicator and X-Y-Z motion control platform.

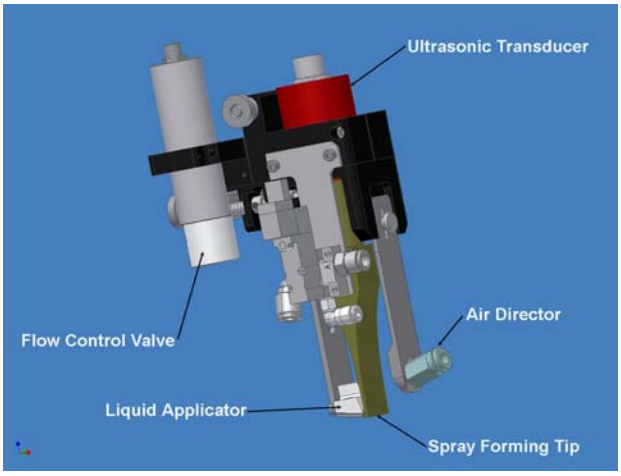
Ultra-Spray Head with Integrated Fluid Delivery System

The Ultra-Spray head with integrated fluid delivery system (IFDS) consists of an ultrasonic transducer with a spray forming tip, an ultrasonic generator, an external liquid applicator, a precision liquid delivery system and air directors.

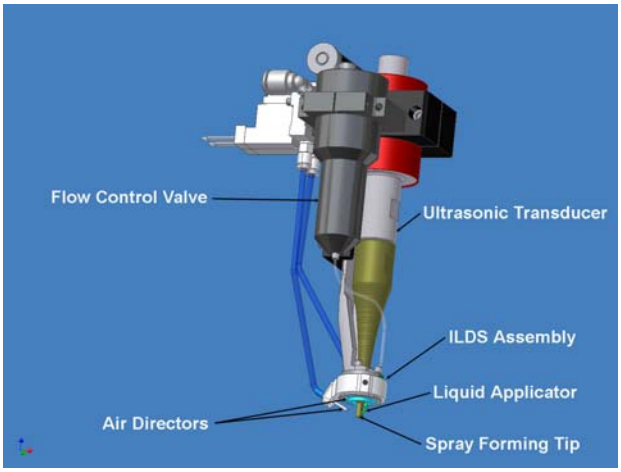
The ultrasonic transducer contains a spray-forming tip that vibrates at an ultrasonic frequency (> 20 kHz). The ultrasonic transducer is resonant at a particular ultrasonic frequency of 35 kHz, 45 kHz, or 60 kHz and is driven by an ultrasonic generator with a corresponding frequency. The particular ultrasonic frequency is selected based upon the material to be sprayed and the coating application requirements. In general a lower frequency ultrasonic transducer is capable of spraying a higher viscosity liquid and producing higher flow rates. The amplitude of vibration of the spray-forming tip is also set with the ultrasonic generator.

The Photoresist is delivered to the spray-forming tip on the ultrasonic transducer with an external liquid applicator. The liquid is stored in a reservoir and fed to the liquid applicator with a precision liquid delivery system. The ultrasonic vibrations of the spray-forming tip break up the liquid into small drops and propel them from the tip in the form of a spray. The spray produced with ultrasonic energy alone is a very low velocity "sheet-like" pattern. The width of the spray pattern produced is equal to the width of the spray-forming tip (2 mm to 20 mm).

Air directors are used to produce air streams to shape and accelerate the ultrasonically produced spray. The air director impinges a jet of air on tip of the spray head opposite the liquid feed side. The resulting airflow entrains and expands the ultrasonically produced spray to produce a flat (rectilinear) pattern up to 5 times the width of the pattern produced by the ultrasonic energy alone. The width of the spray pattern is proportional to the distance between the spray head tip and the substrate.



CAT ILDS Head



CAT Blade Head

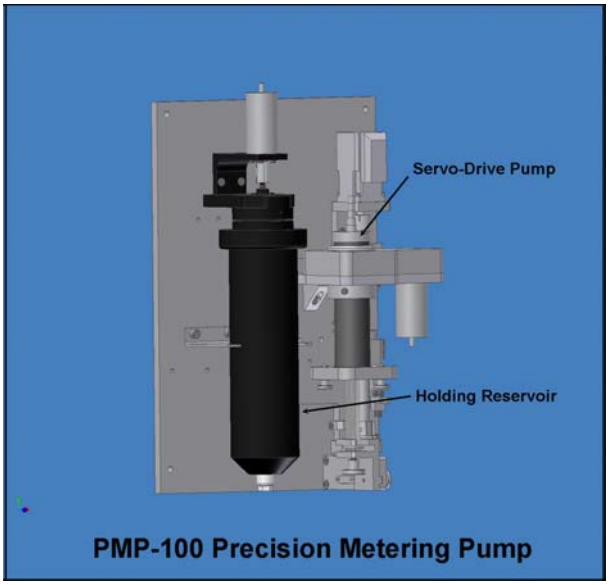
Two spray head types are available: the CAT ILDS Head and the CAT Blade Head. The ILDS head produces a spray pattern width in the range of 3 mm to 25 mm while the Blade head produces a spray pattern width up to 100 mm. The ILDS head is used for smaller wafers and the blade head is used for larger wafers or substrates.

Since the spray is produced with ultrasonic energy rather than pressure and because a low velocity air stream is used only to shape the spray, the transfer efficiency is in the range of 97 to 99%. In other words, very little coating is wasted due to overspray.

All process parameters for the *Ultra-Spray* Head are set electronically including liquid flow rate, air pressure, head height, and head speed.

Liquid Delivery and Material Handling Systems

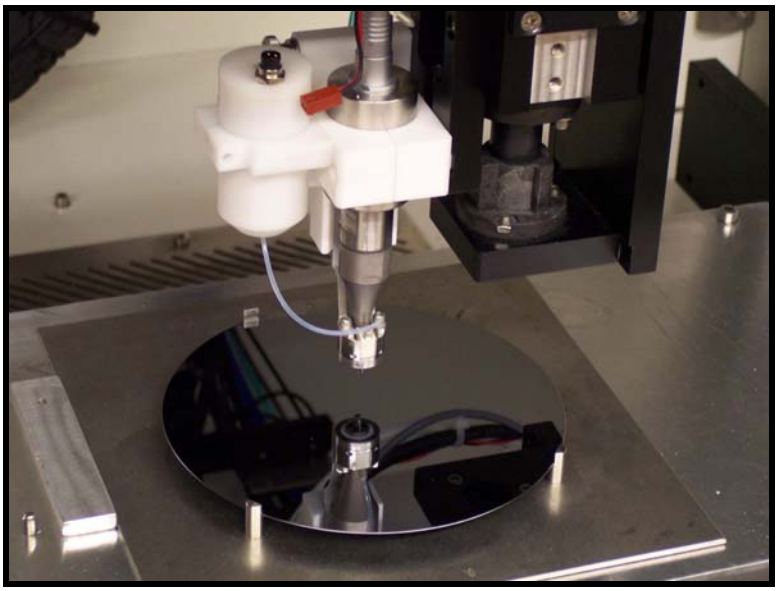
The method used to deliver the coating liquid to the liquid applicator on the ultrasonic spray head is critical to achieving the desired coating thickness and uniformity. A Precision Metering Pump is used to meter the coating flow to the ultrasonic spray head. The pump consists of a 100 ml capacity cylinder and a servomotor driven piston to deliver the liquid at the required flow rate. The pump automatically refills from a sealed holding reservoir. A graphical user interface (GUI) is used to set all set up and operating parameters of the Precision Metering Pump.



Motion and Positioning Platform

One or two Ultra-Spray heads are mounted to a high performance X-Y-Z motion and positioning system. The system is controlled with a Windows XP based operating system utilizing an integrated PCI motion controller. A graphical user interface (GUI) is used to set all operating parameters and create process programs. The GUI employs a graphical image of the entire coating system platform with "hot spots" for each subsystem. The system operator uses a trackball to highlight each hot spot and bring up a window to setup or configure each subsystem. Hot spot windows include the X-Y-Z gantry system, the coating head setup, the system conveyor and coating program recipe.

The X-Y-Z gantry system window allows the head(s) to be moved manually with the trackball anywhere throughout the range of motion within the system.



CAT ILDS Head Coating a 150 mm Wafer

Example of Photoresist Coating Results

The following are typical results for the application of Photoresist to semiconductor wafers with *Ultra-Spray* technology:

Results

- *Deposition:* dry coating thickness sub micron and up.
- *Deposition Uniformity:* Better than ± 3%
- *Surface Appearance*: Defect free coating with no edge bead effect
- *Transfer efficiency*: A transfer efficiency of 97 to 99% is verified by the weight of dry coating on the substrate when compared with the amount metered through the spray head.

Conclusion

There are numerous requirements to apply Photoresist to non-standard semiconductor wafers and other substrates with a thin, uniform coating of Photoresist. The combination of the nozzle-free Ultra-Spray head and a precision, liquid handling and delivery system and a sophisticated X-Y-Z head motion and positioning platform is a significant improvement over conventional spin coating and spray nozzle application techniques.

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