EHD for Particle Removal Applications

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Abstract

We present an innovative process for removing nanoscale particles from high value surfaces using electrohydrodynamics (EHD). By placing an electrical charge on a liquid cleaning solution, a unique spray mode can be used to generate and accelerate nanoscale droplets toward the surface to be cleaned. Able to create uniquely small nanodroplets, this technology is used to address advanced node (≤32nm) semiconductor manufacturing. More efficient momentum transfer from the inbound nanodroplet to the particle to be removed is obtained through the use of EHD, and this physical removal may be assisted by chemistry and charge.

Electrohydrodynamic Fundamentals

To generate nanodroplets using EHD, a pressurized reservoir of liquid is used. The liquid is then charged through a conducting wire or contact. One end of a capillary tube is placed in the reservoir, and the other end of the capillary is used as the EHD nozzle. An electric field is created at the nozzle end of the capillary, which breaks up the meniscus of the charged fluid and creates a stream charged nanodroplets. Electric fields further accelerate the nanodroplets and direct them toward the surface for particle removal. Figure 1 shows a typical EHD system.

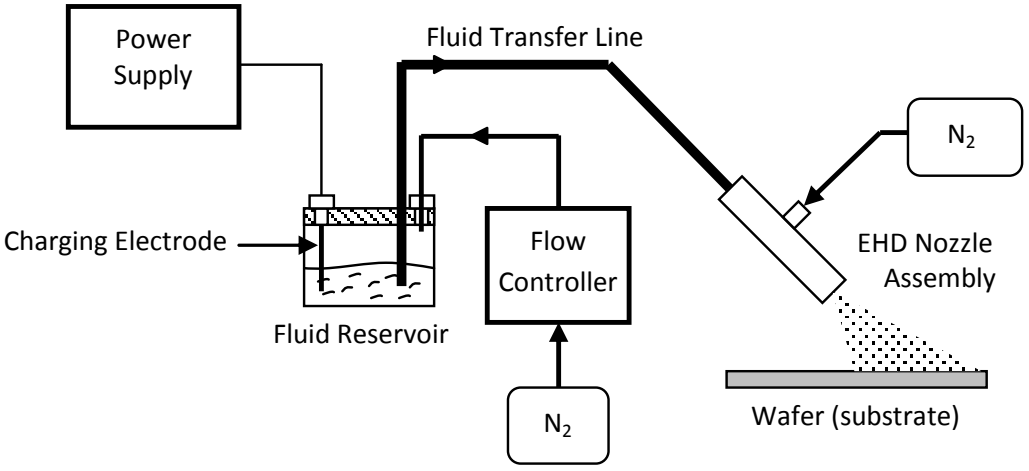

Figure 1 EHD Particle Removal System

EHD Processing Chambers

For demonstration purposes, multiple EHD processing chambers have been designed and installed in the company's cleanroom in Duarte, California. One typical EHD chamber is shown in Figure 2. This chamber is used for 200mm and 300mm silicon wafers. Figure 3 shows a close-up of a typical EHD nozzle assembly. This nozzle configuration also includes a gas sheath around the EHD nozzle to provide a velocity assist to the nanodroplets emitted from the EHD nozzle.

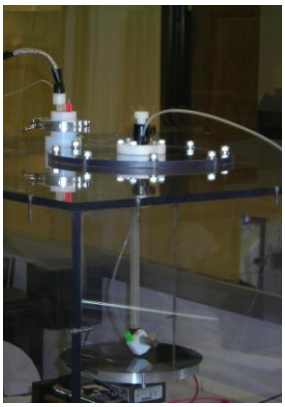

Figure 2 EHD Chamber

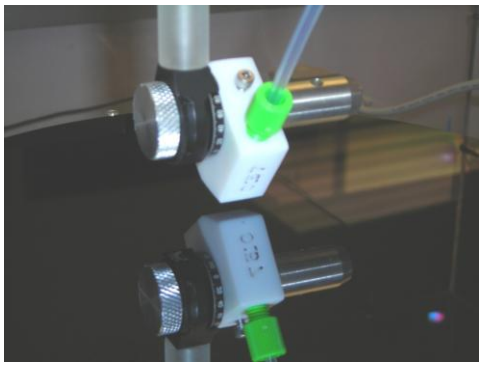

Figure 3 Close-up of EHD Nozzle Assembly

Typical Results

EHD demonstrations have been performed on a wide variety of samples. Figure 4 shows a scratch made on a bare silicon wafer. The SEM image on the right is the same area of the wafer after exposure to an EHD nanodroplet beam.

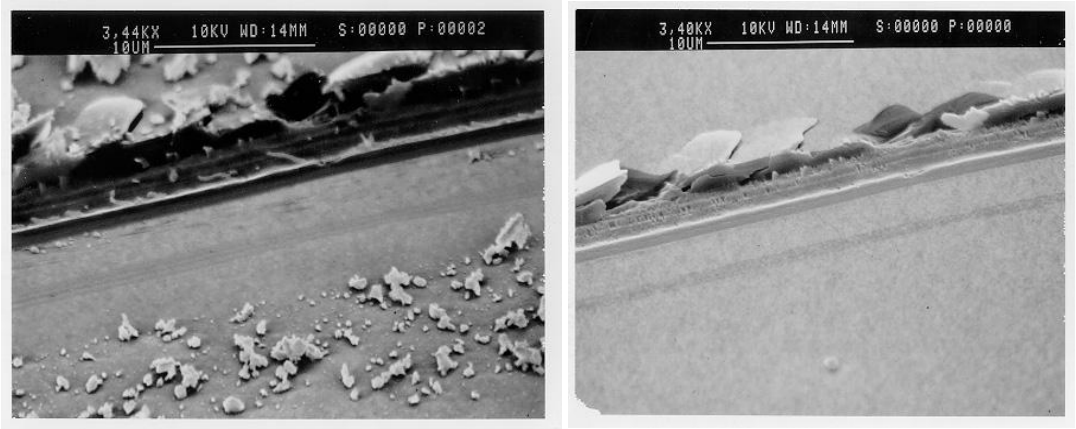

Figure 4 Silicon Debris Removal with EHD

In other demonstrations, 200mm bare silicon wafers are coated with a dilute slurry of <50nm silicon nitride particles. A KLA-Tencor defect mapping system is then used to create defect maps before and after EHD particle removal. Figures 5 and 6 show defect maps before and after EHD particle removal processing. Demonstrated Particle Removal Efficiency (PRE) is 95%.

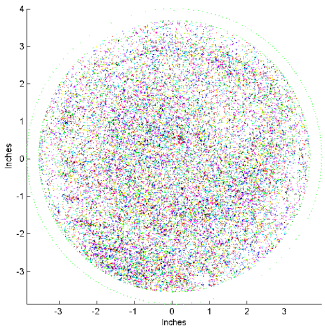

Figure 5 Silicon Nitride Particles
Before EHD Processing
Count = 28,408

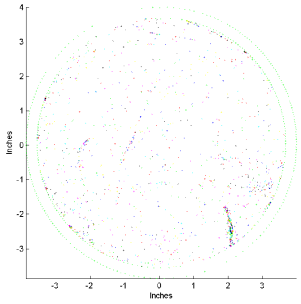

Figure 6 Silicon Nitride Particles
After EHD Processing
Count = 1,460

References

[1] U.S. Patent #5,796,111 (18 Aug. 1998) and U.S. Patent #6,033,484 (7 Mar. 2000).

[2] J. Perel, et al., in *Particles on Surfaces 8: Detection, Adhesion and Removal*, K.L. Mittal (Ed.), pp. 345-352, VSP, Utrecht, The Netherlands (2003).

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[4] K. Finster, Advances in EHD Cleaning Process, Sematech Surface Preparation and Cleaning Conference, 4-May-2006