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Final CRADA Report
for
CRADA Number Y-1296-0427

ENERGETIC NEUTRAL BEAM CLEANING

MASTER

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Abstract

The purpose of this project is to evaluate the feasibility of cleaning silicon wafers with an energetic (1 to 100 eV) neutral particle beam and to develop a viable neutral beam source. A microwave plasma source on an existing test stand was modified to produce a 2-cm diameter neutral beam for cleaning the wafers. Significant results regarding neutral beam wafer cleaning are reported.

Statement of the objectives of the CRADA

The objectives of this CRADA project is to develop a neutral beam source and evaluate the feasibility of energetic neutral beam cleaning techniques for wafers.

Discussions of the objectives that were met

1. Under this CRADA, a neutral beam source has been designed and developed.
2. Several cleaning conditions have been tested for wafer cleaning evaluation. Preliminary results of neutral beam cleaning of wafers are encouraging.

Benefits to DOE programs

This project has provided the Contractor with opportunities to (1) better understand manufacturing requirements for neutral beam equipment and (2) gain experience in developing novel neutral beam cleaning techniques. Neutral beam equipment and cleaning processes developed under this project could be applied to cleaning delicate surfaces of special components for Y-12 DP programs.

Work Accomplished (Appendix 1)

Following the project approval and a kickoff meeting in June 1996, a facility with a neutral beam source was prepared by September. The neutral beam source was operated for cleaning wafers in October and November. The feasibility of the neutral beam cleaning was confirmed in November 1996.

Inventions

No inventions have resulted from this work.

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Assessment of commercialization possibility

It is possible to develop viable neutral beam cleaning devices for manufacturing wafers. However, further development efforts are required before this process is ready for commercialization.

Any plans for future collaboration

Both the Contractor and the participant are actively pursuing further collaborations on new projects for neutral beam processing of large size wafers for manufacturing semiconductors. In-situ diagnostics for measuring the concentration of energetic neutrals and cleaning rate will be implemented in future projects.

Conclusions

This project offered a good opportunity for both the Contractor and the participant to work together on developing a novel processing technique for manufacturing next-generation microelectronics. Results look promising, but further efforts are required to understand and optimize the cleaning processes.

Appendix 1

Accomplishments of Neutral Beam Cleaning CRADA Project

1. Kickoff Meeting

After being approved, a kickoff meeting was held in Building 9201-2 on June 19-20, 1996. The meeting was attended by Charles Boitnott, Stan Milora, Don Schechter, and Jim Tsai. Project R&D activities, including planning and scheduling, were discussed.

2. Facility Preparation

Following the Kickoff Meeting, modifications of an existing microwave plasma source for producing neutral beams with energies up to 100 eV were pursued. The neutral beam source was designed, fabricated and installed in the existing plasma source facility in Building 9201-2. The facility was commissioned and ready for operation in September 1996.

3. Source Development

The neutral beam cleaning device was designed with a microwave electron cyclotron resonance (ECR) plasma source, an anodized aluminum grid, a plasma neutralizer, a deflection magnet, and a sample holder. In the plasma source, the microwave ECR discharge is used to produce plasma in a mirror magnetic field that is produced by two identical solenoid coils. In the plasma neutralizer, a microwave ECR discharge is established in a solenoid magnetic field. The ions in the source plasma are accelerated to the bias grid and converted to energetic neutrals in the biased neutralizer gas cell. Residual ions at the gas cell exit are removed by a movable deflection magnet. This device is capable of providing energetic neutrals for cleaning 2.5-cm wafers.

The plasma chamber is 25-cm diam. by 18-cm height. On the outside walls, 12 permanent magnet columns with alternating polarity form multiple-line cusp magnetic fields for confining plasma particles. This source uses two solenoid coils to produce mirror magnetic fields for establishing the two ECR zones. For microwave energy at a frequency of 2.45 GHz, a magnetic field of 875 gauss is required in the primary ECR zones, and ~438 gauss is required in the second harmonic ECR zone. When the microwave energy was applied, electric fields in the ECR zones accelerate and produce hot electrons for initiating ECR discharges and producing plasmas.

The base pressure of $\sim 3 \times 10^{-6}$ torr is maintained by a turbomolecular pump. The working gas, which is either nitrogen or oxygen, is fed continuously through a needle valve. The gas pressure in the source can be controlled by manual adjustment of the needle valve in the gas feedline. The magnetic field is induced by passing a current through the solenoid coils. When the impulse microwave power (~ 550 W) is applied, a microwave discharge can be established. Reliable source operation is established at pressures above 5×10^{-4} torr. The typical operating pressure of the source is set at 1 mtorr.

With the grid biased at -40 V, the energies of neutrals produced from low energy ions are variable up to 40 eV. The neutralized particles formed from ions impinging on the grid walls have a minimum energy of about 20 eV. The neutral energy is increased by biasing the neutralizer gas cell at -200 V. The neutrals can have an energy up to 100 eV.

4. Cleaning Results

Under this SBIR CRADA project, many wafers were cleaned and processed by energetic neutral beams of oxygen. The operating conditions could be varied as a function of different parameters, such as microwave power, gas pressure, magnetic field, grid bias potential, and gas cell bias potential. To produce neutrals at the highest energy achievable under the experimental setup, the grid and the gas cell were biased at -40 V and -200 V, respectively. Usually, the neutral beam cleaning was conducted by applying 400 to 500 W of microwave power at a source pressure of 1 mtorr. Thirty to forty wafers (2.5-cm diam.) were tested for beam particle cleaning under the above mentioned conditions in October and November. The original wafers were prepared and provided by GaSonics. After being cleaned by beam particles, the processed wafers were sent back to GaSonics for surface analysis.

The initial results of this work are encouraging, as some processed wafers have been properly cleaned; i.e., material was removed and there was no observable thermal degradation of the resist.

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