The removal of photo resist from silicon wafers using a boundary layer controlled ozone/DI-water process

LIFE99 ENV/B/000649

Project description

Background

In semiconductor manufacturing, almost 30% of the processing steps consist of cleaning wafer surfaces. At the moment, Front End of Line (FEOL) wafer cleaning processes have been based on aggressive chemicals such as sulfuric acid (H2SO2/H2O2 mixtures.) These chemicals also require large quantities of de-ionised water (DI) for wafer rinsing. All these chemicals are used in vast quantities, along with a high consumption of de-ionised water, which add to the cost of production. They also produce a negative environmental impact through the emissions and waste deriving from the use of sulphuric acid. Since 1998 IMEC has developed a new concept based on the use of ozone combined with a very small amount of DI water for use in ashed, non-ashed and post-etch photo resist cleans. The boundary layer controlled (or moist ozone gas phase) process appeared to have very promising high organic removal efficiencies, whilst providing improved performance over traditional ozone/DI water processes through enhanced reactive ozone availability near the water surface. The basis of the current project is to develop a full-scale industrial test of the process.

Objectives

The main purpose of the project was to test out the newly developed ozone/DI/water photoresist strip concept for silicon wafers on full industrial scale. The expected environmental benefits from the introduction of this “clean
technology” were the complete elimination of the use of sulphuric acid and its waste and a reduction of the use of de-ionised water by a factor of 10 to 20. This would result in significant cost savings in the production process, thus helping the European microelectronic industry to improve competitiveness. The project would be developed jointly between IMEC and the private company TI (Texas Instruments) and would involve the retrofitting of a standard commercially available strip tool. As the new process was known to emit relatively high concentrations of ozone, representing a potential safety hazard, the abatement of ozone would also be tested. A full cost-benefit and environmental assessment would be carried out. The project would be developed through four key tasks: 1) Implementation of the ozone process at IMEC. 2) Production Implementation at TI. 3) Implementation of ozone abatement system at IMEC 4) Dissemination by IMEC.

Results

The project achieved most of its proposed objectives: The new process was demonstrated on the prototype line at IMEC and proved that it could effectively replace the existing sulphuric acid technique. The new process was initiated on the production line of TI on 6” wafers. However the implementation was not completed due to Company reorganisation introducing the use of 8” wafers. An efficient ozone abatement system was also developed, reducing the exhaust ozone by 90%. An important reduction of the environmental impact was demonstrated, however reliable quantitative data was not available as the process was not terminated. The same applied to the cost evaluation. Several changes were introduced into the process as a result of the fine-tuning procedure, particularly in the initial phases: In the first phase, the existing tubing was removed from the chemical containers, an ozone generator installed and the chemical drain adjusted so as to distinguish between liquid and gas waste. The initial tests with a readily available ozone generator proved unsatisfactory, so a new generator was purchased with gave higher ozone concentrations. An ozone safety monitor was also installed for worker protection and an ozone destruction unit in the waste stream to reduce ozone levels. The DOE process also helped to reveal the key parameters for optimum performance: the ozone flow, rotational speed of the motor, the DI-water temperature and the DI flow. In the second phase, ozone concentrations were improved through the installation of a separate well-water system, enabling process strip rates of more than 200nm/min. Another improvement was the integration of the system within the general computer system of the factory. In the third phase, the original ozone abatement system tried was a very efficient catalytic unit, however the unit had the disadvantage of producing clogging through the reaction with water. As a result, the unit was replaced with a thermal unit which decomposed the ozone simply by heating it, which gave a 90% removal efficiency, but was resistant to water and clogging. Although the full economic and environmental evaluation could not be carried out, the evaluations carried out by IMEC on the prototype indicated significant benefits: The use of sulphuric acid was indeed eliminated whilst the consumption of DI water was reduced by 90%. This means a reduction of 500,000 litres a week and 22,000 litres of sulphuric acid for an average factory. This implies a significant economic saving on production costs, which should ensure the attractiveness of the option to the industry and its sustainability. The new system has the advantage of not requiring additional
investment as the necessary “hardware” tools can be integrated into the conventional machines by retrofitting. As it appears that the IC manufacturing plants are likely to increase at a European level, the new process has a significant role to play in reducing the environmental impact of the industry and its transfer actively encouraged. According to a report on the project featured in the LIFE Focus publication, "Industrial pollution, European solutions: clean technologies" (2004, although the project could not be completed within the LIFE framework, because of technical restructuring at development partner, the German arm of Texas Instruments, its results were nevertheless more than promising. The new process was considered attractive and transferable, with a promising future in Europe’s integrated circuit industry.

Environmental issues addressed:

Themes

Environmental management - Cleaner technologies
Industry-Production - Electric - Electronics - Optical

Keywords

cost-benefit analysis, clean technology, emission reduction, exhaust gas, environmental assessment, electronic material

Target EU Legislation

- Waste
- Air
- Directive 84/360 - Combating of air pollution from industrial plants (28.06.1984)
- Directive 2001/81- National emissions ceilings for certain atmospheric pollutants (23.10.2001)

Natura 2000 sites

Not applicable
Beneficiaries:

**Coordinator**
IMEC

**Type of organisation**
Research institution

**Description**
The Interuniversity Microelectronics Center (IMEC) was set up in 1984 by the Flanders Government as a non-profitmaking independent body. It has now become one of the largest independent research centers in the world in the field of microelectronics. The centre employs around 1000 people on different aspects of the production of chips. All research is done in close cooperation with the industry and with Flemish and other Universities. thus aiding cost sharing but leaving the center free to work from an independent base. The ASTEG division is responsible for this project, and is specialised in the cleaning and drying of wafers, the deposition of specific layers on these wafers and the search for environmentally benign solutions in these processes.

**Partners**
Texas Instruments Deutschland, GmbH

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Administrative data:

**Project reference**
LIFE99 ENV/B/000649

**Duration**
01-FEB-1999 to 01-FEB -2001

**Total budget**
1,571,753.03 €

**EU contribution**
675,509.11 €

**Project location**
Vlaams Gewest(België - Belgique)

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**Poster**
Title: Photo

**Publication: Article-Paper**
Title: A novel resist and post-etch residue removal process using ozonated chemistry. Ultra Clean Processing of Silicon Surfaces. Author: De Gendt S; Snee P; Cornelissen L et al. Year: 1999 Editor: Scitec Publications. pp 165/168 No of pages: 3
Publication: Article-Paper
Title: Determination of photoresist degradation products in O3/DI water processes by ion chromatography. Author: Vankerckhoven, H; Vinckier, C; De Smedt, F; De Gendt Year: 2000
Editor: UCPSS2000

Publication: Article-Paper
Title: Evaluation of ozonated water spray for resist cleaning applications. 196th Meeting of the Electrochemical Society.: 6th International Symposium on Cleaning Technology in Semiconductor Device Manufacturing. Author: De Gendt, S; Lux M; Claes M et al. Year: 1999

Publication: Article-Paper
Title: Materials compatibility and organic build-up during ozone-based cleanings for semiconductor devices. Author: De Smidt, F; De Gendt, S; Heyns, M; and Vinckier, C Year: 2000
Editor: UCPSS2000

Publication: Layman report
Title: Laymans Report Author: IMEC Year: 2001
Editor: Nausikaa Van Hoornick No of pages: 7