Introduction to the

TDMR Special Issue on Parts per Trillion (ppt) Contamination

I. **Introduction** – Rapid introduction of new materials for nm chips such as immersion resists, low and high k dielectrics, CMP, CVD/SiGe/SOI type precursors are challenging the capabilities of measuring techniques for characterization, screening and control of contaminants. It is recognized that current metrologies and techniques for sample preparation for ultra trace contaminants will not meet the requirements of the International Technology Roadmap for Semiconductors (ITRS) even in the near term, 2003-2009. This is particularly true for measuring small particles (<30 nm) and trace metals (<0.5 ppt for ultra pure water and <150 ppt for cleaning chemicals). A further challenge is the need to develop robust in-line monitoring of contaminants, for processes smaller than 65nm, that is both sensitive and cost effective. Recognizing these issues, TDMR has, in this current special issue, compiled four key papers addressing solution paths to some of these challenges. It is likely, given the importance of the topic, that there will be other special editions focused on contamination control as new breakthroughs dictate.

II. **Special Issue on ppt Contamination** – This special issue contains four papers each addressing different aspects of contamination control. The first paper is a broad overview of metrologies (Tseng et al) followed by a second paper (Pathangey et al) that provides a practical look at adjusting contaminant disposition limits in sub 100 nm manufacturing processes. Two other papers address optimization of specific metrologies i.e.Total Reflection X-ray Fluorescence (TXRF, Hellin et al) and On-line Pyrolysis Mass Spectrometry (MS) for organic contamination on wafers (Ketola et al).

The lead paper, Characterization and Control of Micro-Contamination for Advanced Technology Nodes & 300mm Wafer Processing; Overview & Challenges, is authored by Berry Tseng, M.D. You and S.C. Hsin of TSMC. The authors use a novel microwave assisted High Resolution Inductively Coupled Mass Spectrometric technique (MA-HR-ICP-MS) to achieve 10 ppt detection of metals after diffusion cleans i.e. concentrated acids. They also discuss a Vapor Phase Decomposition Inductively Coupled Mass Spectrometric (VPD-ICP-MS) technique to evaluate cross contamination of high k and metal gate elements. TXRF limitations for in-line monitoring of Na and Al are discussed as is thermal desorption gas chromatographic mass spectrophotometry (TD-GC-MS) for analyzing airborne organic contaminants from wafer outgassing. Tseng et al also address lithographic contamination control in immersion fluids and wet scanner systems. Finally, the author's summary of test methodologies and detection limits for various target contaminants is a useful, practical guide.

The second paper, The Effect of Metal Contaminants in Pre-Gate Oxide Cleans for Sub 100 nm Devices, is authored by Balu Pathangey, Laura McCarthy and Dave Skilbred of Intel Corporation. These authors used pre-gate oxide sub 100 nm manufacturing lots and exposed them to clean contaminants from a 35 multi-element NIST standard. They then used EOL e-test and Sort to establish device functional failure as a direct result of the metal spiked cleans. Subsequent to that, they performed surface analysis using TXRF, Direct Surface Extraction Inductively Coupled Mass Spectrometry (DSE-ICP-MS) and Time of Flight Mass Spectrometry (TOF-SIMS). Using these techniques, they characterized wafer surfaces with respect to alkali, transition and noble metals. One key result was dramatic, deleterious results of Pt on gate oxide integrity. The other key result was a surprising lack of impact to gate oxide integrity for 200 ppb Cu. This result enabled a change to the chemical contamination disposition limits, resulting in significant cost savings.

The third paper, Total Reflection X-Ray Fluorescence Spectrometry for Introduction of Novel Materials in Clean Room Production Environments, is authored by D. Hellin, S. DeGendt, J. Rip, and C. Vinckier of IMEC and KUL Department of Chemistry. This paper presents a number of practical case studies using TXRF as the metrology of choice. The investigated materials include Si and Ge substrates, high k dielectric contaminants and Si wafers contaminated with elements from metal gates and Cu interconnects. The paper focuses on pre-concentration techniques such as Vapor Decomposition Droplet Collection (VPD-DC) and numerous techniques to optimize the detection limits of TXRF.

The final paper, Simultaneous Qualitative Analysis of Volatile and Non-Volatile Organic Contamination on Silicon Wafers by On-Line Pyrolysis Mass Spectrometry is authored by Raimo A. Ketola, Jari Kiuri, Virpi Tarkiainen, Arto Kiviranta, Jaakko Rasanen, Heini Ritala, Simo Eranen of VTT Processes in Finland. These authors address development of a new analytical set-up to qualitatively analyze both volatile and non-volatile organic contaminants simultaneously from a given silicon wafer. The aim of the study was development of quality control for manufacturing processes. The instrumental set-up included a sample compartment that could be heated and an on-line mass spectrometer. The volatile organics were thermally desorbed from the wafer and the non-volatile organics were pyrolyzed at higher temperatures and then desorbed. An on-line mass spectrophotometer provided the qualitative identification of the desorbed organic contaminants.

In conclusion, while the papers presented in this issue deal effectively with improved techniques for taking existing metrologies and optimizing resolution and sensitivity, it is clear that there is even greater need to develop new approaches to contamination control. Subsequent issues will address these breakthrough techniques as they become available.

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