

Advanced Dielectrics for Interconnects

2007

A Semiconductor Critical Materials Report

Prepared for ISMI

by S. Holland, Ph.D. and K. Holland, Ph.D.

Techcet Group, LLC*

March 2007

775-783-8180

* www.techcet.com

TABLE OF CONTENTS

| | PAGE # |
|---|--------|
| 1 EXECUTIVE SUMMARY | 4 |
| 2 TECHNOLOGY OVERVIEW | 5 |
| 2.1 Interconnect Trends | 8 |
| 2.2 Roadmap Implications | 9 |
| 2.3 Low κ Spin-On Dielectrics (SOD) | 17 |
| 2.4 CVD Low κ Dielectrics | 18 |
| 2.5 Spin-On Dielectrics for RAM Applications | 19 |
| 3 DIELECTRIC TECHNOLOGIES | 20 |
| 3.1 CVD Precursors | 24 |
| 4 ADVANCED DIELECTRICS MARKET UPDATE | 28 |
| 4.1 Spin-on Inorganic Materials: New Application for STI and PMD | 30 |
| 4.2 Spin-On Organic and OSG for Low κ Dielectrics | 33 |
| 4.3 The Dow Chemical SiLK Story | 34 |
| 5 MARKET | 34 |
| 5.1 Fluorine in Dielectrics | 36 |
| 6 COMPETITIVE POSITION | 36 |
| 6.1 Material Suppliers Participating in the Low κ Precursor or Low κ Spin-On Market | 37 |
| APPENDIX A | 43 |
| Metal Cross Sections | 43 |
| Interconnect Processes | 46 |

PAGE #

List of Figures

| | |
|---|----|
| Figure 1: Percentage of Wafers by Technology with Cu Interconnects by Technology Node and Product Type | 6 |
| Figure 2: κ_{eff} Roadmap Delay as Explained in the 2003 ITRS | 14 |
| Figure 3: 65 nm Potential Integration Schemes | 15 |
| Figure 4: CVD Precursors by Technology Node from ITRS | 25 |
| Figure 5: AMAT Proposed Transition for CVD Low κ Dielectrics | 28 |
| Figure 6: Estimate of CVD Dielectric Precursor Revenues | 29 |
| Figure 7: Estimate of Spin On Glass ($\kappa \geq 3.0$) Market Shares by Region for 2006. | 32 |
| Figure 8: Interconnect Dielectric Revenue Distribution 2006, (A) for All Parts and (B) 90 nm Node and Below. | 35 |
| Figure 9: Circuit Delay as a Function of Feature Size | 44 |

| | |
|--|----|
| Figure 10: RC Delay, Cu, & Low κ | 44 |
| Figure 11: Older 2 Level Metal Technology (Prior to 0.5 μm Node) | 46 |
| Figure 12: Cu Dual Damascene with Oxide Dielectric | 47 |
| Figure 13: Process Sequence for a Cu Dual Damascene | 48 |
| Figure 14: Cu Interconnect with Polymer Dielectric..... | 48 |
| Figure 15: Cross-Section of MPU Device Hierarchical Scaling - from 2005 ITRS Interconnect | 49 |

List of Tables

| | |
|---|----|
| Table 1: Materials & Processes, 2006 & 2009 | 8 |
| Table 2: 2006 ITRS for MPUs (Near-Term Years)..... | 10 |
| Table 3: 2006 ITRS for DRAMs (Near-Term Years)..... | 13 |
| Table 4: The 2006 ITRS, Interconnect Difficult Challenges as Related to Advanced Dielectrics | 16 |
| Table 5: Dielectrics & Suppliers..... | 21 |
| Table 6: Typical Properties of JSR’s Customizable Spin-On Low κ Materials | 23 |
| Table 7: Precursors and Their Chemistry | 25 |
| Table 8: Precursors and Their Suppliers..... | 26 |
| Table 9: Precursors and Their OEMs..... | 26 |
| Table 10: Spin-On Inorganics for PMD or STI | 33 |

Readers note: this report represents the interpretation and analysis of information generally available to the public or released by responsible agencies or individuals. Data was obtained from sources considered reliable. However, accuracy or completeness is not guaranteed.