

Photoresist, Extensions & Ancillary Materials Technology, Market & Supply Chain

for Semiconductor Device Processing

A TECHCET Critical Materials Report™

By Ed Korczynski

Reviewed & Edited by L. Shon-Roy

TECHCET CALLC

June 2016

www.Techcet.com info@Techcet.com

COMPANY PRIVATE -

Confidential Information

The information contained in this presentation is for the use of TECHCET's representatives and customers or prospective customers. It is considered confidential in nature and should not be shared with others outside of the aforementioned parties. Your cooperation is much appreciated.

Note to Readers

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



RESEARCH METHODOLOGY

TECHCET employs subject matter experts having first-hand experience within the industries, which they analyze. Most of TECHCET's analysts have over 25 years of direct and relevant experience in their field. Our analysts survey the commercial and technical staff of IC manufacturers and their suppliers, and conduct extensive research of literature and commerce statistics to ascertain the current and future market environment and global supply risks. Combining this data with TECHCET's proprietary, quantitative wafer forecast results in a viable long-term market forecast for a variety of process materials.



REPORT SCOPE

This TECHCET Critical Materials Report provides information and market assessment of the business and technology trends associated with the Photoresist, Extension & Ancillary Materials used for semiconductor device manufacturing. Supply chain activity and dynamics, as well as supplier profiles are provided. Market drivers forcing change in the industry are looked at from a macro as well as micro viewpoint as it relates to the semiconductor industry. This report includes market statistics (market shares and revenue history and growth), business and technology drivers and challenges.



Topic	Page
i. Report Scope	4
ii. Acronyms and Definitions and Keywords	14
1. Executive Summary	21
2. Market for Photoresists & Extensions & Ancillaries	30
2.1 Industry Roadmaps	31
2.1.1 Industry Roadmaps 2.1.2 Litho Roadmaps	32 33
2.2 Market Dynamics	35
2.2.1 PR Thickness Reduction 2.2.2 ArFi Integration Requires Additional Layers and \$ 2.2.3 MP vs. SE Litho 2.2.4 MP Variations fro 1D vs. 2D 2.2.5 MP Overlay Requirements 2.2.6 EUVL Lower Cost & Better Pattern Fidelity 2.2.7 "7nm-node" Litho Can Be Done by ArFi MP 2.2.8 MP Overlay Spec Challenging 2.2.9 Advanced Nodes Push Litho Resolution – EXT Vital	35 36 37 38 39 40 41 42 42



Topic	Page
2.3 Extensions of Resolution with Materials	44
2.3.1 Shrinks 2.3.2 Spin-On Trim 2.3.3 Tri-Layer Resist (TLR) 2.3.3.1 TLR Seminal Patent 2.3.3.2 TLR Resolution 2.3.3.3 TLR Si Hard Mask (Si-HM) 2.3.3.4 TLR up to 5 Layers	45 46 47 48 49 50 52
2.3.4 Spin-On Metal Hard Mask (SOMHM)	53
2.4 Negative Tone Materials2.4.1 Tone-Reversal Mechanism2.4.2 Improved LWR with NTD for LELELE MP	54 55 57
3. Market Trends & Statistics: PR & EXT & ANC	58
3.1 IC Fab Industry	59
3.1.1 Intel 3.1.2 Samsung 3.1.3 TSMC	60 61 62



Topic	Page
3.1.4 IC Industry Mature Revenue Growth 3.1.5 Wafer Area Growth Forecast by TECHCET 3.1.6 IC Process Materials Market 3.1.7 Exchange Rate	63 65 66 67
3.2 Litho Materials Supply Chain Trends	68
3.2.1 Single versus Multiple Sources 3.2.2 IC Litho Materials Market Dynamics 3.2.3 KrF Litho Growth for 3D NAND 3.2.4 Pricing Trends 3.2.5 Market Forecast Inputs 3.2.6 Photoresist Market Shares 3.2.7 PR + EXT Market Share Analysis 3.2.8 WW Photoresist Revenue History and Forecast	69 70 71 72 73 75 76 77
3.2.9 WW Litho EXT Revenue History & Forecast	78
3.2.10 Ancillaries Materials & Applications 3.2.11 Ancillaries Revenue History and Forecast 3.2.12 Total WW PR + FXT + ANC Revenue History & Forecast	79 80 81
3.2.12 Total WW PR + EXT + ANC Revenue History & Forecast	81



	Topic	Page
4.	Next Generation Lithography (NGL)	82
	4.1 Extreme Ultra-Violet (EUV)	84
	4.1.1 Expensive but Lower Cost than ArFi MP for "7nm node" 4.1.2 EUVL Least Expensive Option for "10nm node" M1 Patterning 4.1.3 EUVL Developer Must be Tuned to PR Chemistry	85 86 87
	4.2 Nano-Imprint Lithography (NIL)	88
	4.2.1 NIL for Memory ICs	89
	4.3 Direct Self-Assembly (DSA)	90
	4.3.1 DSA delayed	91
	4.4 E-Beam Direct Write (EBDW)	92
5.	Environmental and Regulatory issues	93
	5.1 REACH and PFOS/PFOA related chemistries	94
	5.2 Alternative Developers including TBAH	96
	5.3 Alternative Solvents	98



Table of Contents - 5

Topic	Page
6. Litho Materials Supplier Profiles and News	100
6.1 Avatar (J.T.Baker)	101
6.2 Brewer Science / Nissan Chemical	102
6.3 Dow (Rohm and Haas)	105
6.4 Fuji Film (Hunt)	108
6.5 Japan Silicon Rubber	112
6.6 Kempur	116
6.7 Merck (AZ)	117
6.8 SACHEM	118
6.9 Shin-Etsu	119
6.10 Sumitomo	121
6.11 Tokyo Ohka Kogyo	125
7.0 Figure Sources / Website References	127



TECHCET CA LLC Copyright 2016

All rights Reserved.

Figures - 1

Topic	Page
1. Last (2012) ITRS Litho Chart	32
2. ASML (default industry) Litho Roadmap	33
3. 193nm Immersion (193i) Litho Stage Cross-section	36
4. Multi-Patterning (MP) options LELE and SADP	38
5. MP Overlay specifications by node	39
8. EUVL reduces Overlay and Metrology in the future	40
7. "7nm-node" logic pitch specifications by layer	41
8. Mix-and-Match Litho needs by node	42
9. Resolution Limits of 193i and EUVL	43
10. SLR Triangle	44
11. Spin-On Trim EXT material and benefits	46
12. Tri-Layer Resist (TLR) process schematic	47



Figures - 2

Topic	Page
13. SEM showing TLR Line Collapse at Minimum Half-pitch	51
14. Five Layer Resist stack for 3D-NAND etching	52
15. Positive-Tone Resist Optimized Using NT Developer	55
16. SEMs showing Reduced LWR with NTD	57
17. IC Industry Revenues and Growth	63
18. TECHCET's WW Annual Wafer Forecast (200mm equivalents)	65
19. \$ to ¥ Exchange Rates 2006-2016	67
20. 3D NAND Staircase Structure and Complexity	71
21. Photoresist Suppliers Market Shares	75
22. Worldwide IC Photoresist Forecast 2020	77
23. Worldwide IC PR Extension Materials Forecast 2020	78
24. Worldwide IC PR Ancillary Materials Forecast 2020	80



Figures - 3

Topic	Page
25. Worldwide IC PR+EXT+ANC Materials forecast 2020	81
26. EUVL vs. ArFi mask counts for advanced nodes	85
27. EUVL vs. ArFi for "10nm-node" M1 patterning	86
28. EUVL Developer Options shown in SEMs	87
29. Nissan Chemical Sales and Net Income History & Forecast	104
30. DowEM Litho Materials functions in schematics	106
31. Fujifilm Sales and Net Income History & Forecast	111
32. JSR Sales History & Forecast of Litho Products	112
33. JSR Sales and Net Income History & Forecast	115
34. SACHEM TMAH Recycle Flow Diagram	118
35. ShinEtsu Sales and Net Income History & Forecast	120
36. Sumitomo PT Product Line up	122
37. Sumitomo KrF PR & EXT Product FT vs. CD	123
38. Sumitomo i-Line PR Product Line Resolution vs. Sensitivity	124
39. TOK Sales and Net Income History & Forecast	126

