Anil U. Mane *(Ph.D)*

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SUMMARY:

- Experienced professional with expertise on R&D of thin film nano-material process development and integration in the semiconductor industry as well as research institutes. Hands-on experience on variety of high volume thin film production ALD, CVD, and PVD 300mm systems as well as R&D tools
- In-depth understanding of numerous nano-materials/nano-devices characterization techniques. Deep knowledge of complete CMOS devices fabrication/integration process flow and failure analysis.
- Innovative engineer with history of initiating and expediting new product development from conception to customer sign-off. Proven track record of highly motivated independent researcher, worked in team with cross-functional engineers, leadership role, strong complex project management, and innovative problem solving skill.

PROFESSIONAL EXPERIENCE:

Process Development Engineer,
Argonne National Laboratory, IL, 60516, USA (06/2009 – Current)

- Research and Development of atomic layer deposition (ALD) of metals, metal nitrides and metal oxides thin film/nano-coating processes for various applications, e.g. Photo-detectors, Spallation targets, Catalysts, Superconducting cavities, Photovoltaic's, etc.

Member of Technical Staff (MTS),
Spansion Inc., Sunnyvale, CA, 94085, USA (08/2008-02/2009)

- Responsible for new contact metallization materials process development (by PVD/ALD/CVD processes) and integration for ≤ 45nm NOR/NAND flash memories
- Lead the project development and integration of Low Resistivity Tungsten (LRW) by ALD/CVD processes for NAND flash memories
- Supported customer related issues on 45nm and 32nm NOR/NAND flash memory devices

Process Development Engineer,
Novellus Systems Inc. San Jose, CA, 95134 USA (01/2006-08/2008)

a) **Project: Tungsten Nitride (W/WN) for contact metallization barrier and metal gate applications in logic and memory devices:**

- Optimized W/WN film properties through extensive DOEs and characterizations on *Novellus DirectFill 300mm ALD/CVD system*, cross-talk optimization through partitioning tests, DOE data analysis by JMP, new hardware implementation,
- Integration scheme for test structures/product lots, electrical test, reliability testing, throughput optimization, CoO comparisons with key competitors

- Thin W-nucleation (flash) layer development for Si-rich surfaces (e.g. Si, SiGe, NiSi, etc), resolved gas phase nucleation issue, improvement of wafer-to-wafer non uniformity(< 4%).
- Process optimization and resolved tungsten delamination issue on various type SiO_2 surfaces (Thermal, BPSG, HDP, TEOS and USG) with integration of remote plasma processes. Boosted CMP performance.
- Optimization of remote plasma processes for surface cleaning/adhesion improvements
- WN byproduct reaction isotherm study by SPOES
- Initiated the F –free Tungsten by organometalic precursor's ALD project.

b) Project: Low Resistivity Tungsten (LRW) process for *contact metallization* in CMOS and memory devices:

- Innovatively developed a process to reduce the tungsten resistivity up to 50% of BKM process on *Novellus ALTUS 300mm ALD/CVD system*, Process DOE and data analysis by JMP, extensive characterizations, process optimization, adhesion improvement, throughput optimization, long term stability
- LRW integrated with different barrier, pre & post plasma treatment for LRW, surface cleaning treatments. Electrical testing on product lots, and BKM documentation
- Resolved the major micro-delamination issue by gas flow DOE and subsequent HW design and implementation *(Patent submitted).*

c) Project: HCM sputtering of Ta/TaN thin films liner/barriers for Cu interconnects:

- Testing of long term reliability of Ta/TaN BKM processes, hardware and software on *Novellus INOVAxT 300mm PVD system*
- Optimization of HCM targets erosion profile with tuning of electromagnetic coil's current setting DOE, data analysis by JMP
- HCM sputtering system ion extractor I-V characteristics testing with pedestal RF power

d) Miscellaneous:

- On-time successfully completed many key customer demos which led to tool orders
- Provided many long term reliable solutions to key customer's R&D requirements and related issues (with Process, HW & SW) which led to follow-up JDPs and tool orders
- Worked in a team and contributed for many hardware's of the ALD, CVD and PVD systems qualification projects

Member of Scientific Staff,
IHP-Microelectronics GmbH, Frankfurt (O) Germany (10/2003/-12/2005)

- Responsible for the characterization and process integration of high-k Praseodymium (Pr)-based (Pr_2O_3, Pr-titanates, Pr-Silicate) gate dielectrics deposited by MBE into CMOS and MIM devices. Epitaxial growth of high-k Pr2O3 on silicon by MBE
- Developed a selective wet etching *(Patent published)* and reactive ion etching (RIE) processes for Pr-based high-k gate dielectrics
- Process development and characterisations of HfO_2 high-k dielectrics by atomic vapour deposition (AVD)
- Surface characterization (sputter XPS, ToF-SIMS) of high-k dielectrics
- Supported the SOI project where the insulator was Pr_2O_3 high-k dielectrics

EDUCATION

06/2003 **Ph.D**. (Materials Science), Indian Institute of Science, Bangalore, India
Dissertation: Atomic Layer Deposition (ALD) and Metal Organic Chemical Vapor Deposition (MOCVD) of metals and metal oxides. (Advisor: S.A. Shivashankar)

06/1997 **M.Sc.** (Physics), Department of Physics, University of Pune, India
Major: Condensed matter physics / Material science
Thesis: Pulsed Laser Deposition (PLD) of strontium ferrites: Thin films growth and magnetic study

06/1995 **B.Sc.** (Physics), Fergusson College, University of Pune, India

AWARDS AND HONORS

- *Alexander von Humboldt postdoctoral research fellowship,* Germany (03-05)
- Council of Scientific and Industrial Research, (CSIR) India research fellowship (1997-02)
- Indian Institute of Science Research Fellowship (1997-02)
- Best Poster award at Materials Research Society of India (2002)
- Selected for *SERC School on the Surfaces, Interfaces and Clusters*, India (2001)

HANDS ON EXPERIENCE / SKILLS:

Fabrication tools:

- Novellus 300mm: Altus, Directfill, and INOVA xT systems
- Applied Materials (AMAT) 300mm Endura system,
- Tokyo Electron (TEL) 300mm Trias system
- Metal organic(MO)-ALD and MOCVD systems
- Aixtron Tricent (AVD) 200/300mm system
- Molecular Beam Epitaxy (MBE) system
- Reactive ion Etching (RIE) and Rapid thermal annealing (RTA) systems

Characterization techniques:

- XRD (Rocking curve, phi-scan analysis), XRR, XRF, Sputter-XPS, ToF-SIMS, RBS, FTIR, UV spectrometry, Ellipsometry, EELS, Cross-section TEM & SEM, AFM, STM,
- Electrical C(V), I(V), transistor characteristics, Low temperature (4.2K) resistivity, magnetic B-H measurement, TG/DTA, RGA, SPOES, mass spectrometry,

WORK EXPERIENCES DURING RESEARCH

Nano-materials research during the Ph.D.

- Atomic layer deposition of Copper, high-k ZrO_2, vanadium oxides (e.g. VO_2, V_2O_5, etc.) using various novel β-diketonate Cu(II) precursors
- Epitaxial Co_3O_4 growth on single crystal MgO, $SrTiO_3$, and $LaAlO_3$ substrates by MOCVD
- MOCVD of polycrystalline Co, Co_3O_4, Fe_2O_3, & nano-composite of Co-CoO (GMR study)

- MOCVD of $Co_xFe_{3-x}O_4$ using bimetallic beta-diketonate precursor
- Invented a novel process to fabricate low weight and high energy density lead-acid batteries *(Patent published)*

Instruments designed and built during research

- Designed and fabricated fully automated "State-of–the-art" 5-channel metal organic atomic layer deposition (MOALD) reactor for metals, metal oxides and multi-layers structures.
- Designed and fabricated ***three*** MOCVD reactors for metals and metal oxides depositions.

COMPUTER SKILLS

- Origin, JMP, MS-Office, Fortran

PUBLICATIONS, PATENTS, TALKS, POSTERS

A) Patents:

1. Ätzverfahren für MOS-Schichtstrukturen mit praseodymoxidhaltigem Dielektrikum
German patent: DE 10 2005 005 229.0
2. A rapid coating process and its applications to the lead-acid battery,
U.S. Patent: 6,889,410
3. Method for depositing thin tungsten film with low resistivity and roust micro-adhesion characteristics
U.S. Patent: US 12/407,541

B) Talk:

1. ALD of Zirconium oxide thin films: study of growth kinetics and dielectric behavior,
Anil U. Mane, A. Chakraborty, M. S. Dharmaprakash, V. Venkataraman and S. A. Shivashankar, The 201st meeting of Electrochemical Society, Philadelphia, USA, 2002.
2. ALD of Zirconia thin films: Electrical properties,
Anil U. Mane, A. Chakraborty, M. P. Singh, M. S. Dharmaprakash, V. Venkataraman and S. A. Shivashankar, The 44th Electronic Materials Conference, Santa Barbara, USA, 2002.
3. The design and fabrication of a 5-channel ALD reactor for thin films of metal and metal oxides,
Anil U. Mane, and S. A. Shivashankar, National Symposium on Instrumentation, IISc, INDIA 2000.

C) Selected papers:

1. A CMOS process compatible wet-etching recipe for the high-k gate dielectrics Pr2O3 and Pr2-xTixO3, Anil. U. Mane, Ch. Wenger, T. Schroeder, P. Zaumseil, G. Lippert, G. Weidner and H.-J. Müssig, Journal of the Electrochemical Society, 152 (6) (2005), C399.
2. Process integration of Pr-based oxide high–k dielectrics,
Anil. U. Mane, Ch. Wenger, G. Lupina T. Schroeder, P. Zaumseil, G. Lippert, G. Weidner and H.-J. Müssig, Microelectronics engineering, 82 (2005) 148.
3. Atomic vapour deposition of HfO2 : Growth kinetics and electrical properties
A. U. Mane, Ch. Wenger, G. Lupina, T. Schroeder, G. Lippert, R. Sorge, P. Zaumseil, G. Weidner, J. Dabrowski and H.-J. Müssig (Unpublish work 2005)

4. Growth of (111)-textured copper thin films by atomic layer deposition
Mane, A.U. and Shivashankar, S.A., Journal of Crystal Growth, 275 (1-2), (2005), 1253
5. Atomic vapour deposition of HfO2 : Growth kinetics and electrical properties
A. U. Mane, Ch. Wenger, G. Lupina, T. Schroeder, G. Lippert, R. Sorge, P. Zaumseil, G. Weidner, J. Dabrowski and H.-J. Müssig (Unpublish work 2005)
6. Atomic layer chemical vapour deposition (ALCVD) of Copper, Anil U. Mane, and S. A.Shivashankar, Materials Science in Semiconductor Processing, 7 (4-6) (2004), 343.
7. MOCVD of cobalt oxide thin films: dependence of growth, microstructure, and optical properties on the source of oxidation. Mane, A.U. and Shivashankar, S.A., Journal of Crystal Growth, 254, (3-4), (2003), 368
8. Strongly oriented thin films of Co3O4 deposited on single crystal MgO(100) by low pressure, low temperature MOCVD, Anil U. Mane, K. Shalini, A. Wohlfart, A. Devi, and S.A. Shivashankar, Journal of Crystal Growth, 240 (1-2) (2002) 157.
9. Atomic layer deposition of ZrO2 thin films: study of growth kinetics and dielectric behavior, Anil U. Mane, Arpan Chakraborty, V. Venkataraman, M, S. Dharmaprakash, and S. A. Shivashankar, Electro. Soc. Proc., PV-11 (2002) 189.
10. Polycrystalline and epitaxial thin films of Co3O4 by low pressure, low temperature MOCVD, Anil U. Mane, K. Shalini, and S. A. Shivashankar, Journal de Physique, IV, 11 (2001) Pr3-637.
11. CVD of thin films of cobalt and copper from different precursor: Growth kinetics and microstructures, Anil U. Mane, K. Shalini, R. Lakshmi, M. S. Dharmaprakash, Anjana Devi, and S.A. Shivashankar, MRS Symposium Proceedings, 615 (2000) G 6.11.1.

D) Contributed publications:

1. High quality layered Pr2Ti2O7/SiO 2 MIM capacitor for mixed-signal applications
Wenger, Ch., Sorge, R., Schroeder, T., Mane, A.U., Knoll, D., Dabrowski, J., Mussig, H.-J. Topical Meeting on Silicon Monolithic Integrated Circuits in RF Systems - Digest 2006, p 241-244
2. Praseodymium silicate films on Si(100) for gate dielectric applications: Physical and electrical Characterization, Lupina, G., Schroeder, T., Dabrowski, J., Wenger, Ch., Mane, A.U., Mussig, H.-J., Hoffmann, P., Schmeisser, D. Journal of Applied Physics, 99, (11), (2006), 14109
3. High-quality Al2O3/Pr2O3/ Al2O3 MIM capacitors for RF applications. Wenger, Ch., Lippert, G. Sorge, R., Schroeder, T., Mane, A., Lupina, G., Dabrowski, J., Zaumseil, P., Fan, X., Oberbeck, L. Schroeder, U., Mussig, H.-J. IEEE Transactions on Electron Devices, 53(8), (2006), 1937
4. Titanium added praseodymium silicate layers on Si(001) for high-k dielectrics application
T. Schroeder, G. Lupina, Ch. Wenger, A. U. Mane, G. Lippert and H.-J. Müssig, Applied Physics letters, (2005) 022902.
5. MIM capacitors using amorphous high-k PrTixOy dielectrics
Ch. Wenger, R. Sorge, T. Schroeder, A.U. Mane, G. Lippert, G. Lupina, J. Dabrowski, P. Zaumseil, and H.-J. Muessig, Microelectronic Engineering, 80 (2005) 313.
6. Praseodymium silicate layers with atomically abrupt interface on Si(100)
G. Lupina, T. Schroeder, J. Dabrowski, Ch. Wenger, A. U. Mane, G. Lippert and H.-J. Müssig, Applied Physics letters S 87, (2005) 092901.
7. Thin films of VO2 on glass by atomic layer deposition: microstructure and electrical properties
P. Dagur, Anil U. Mane and S.A. Shivashankar Journal of Crystal Growth, 275 (1-2) (2005) 1253.
8. Improved lead–acid cells employing tin oxide coated Dynel fibres with positive active-material

B. Hariprakash, Anil. U. Mane, S. K. Martha, S. A. Gaffoor, S. A. Shivashankar, and A. K. Shukla, Journal of Applied Electrochemistry 34 (2004) 1039.
9. A Low-Cost, High Energy-Density Lead/Acid Battery
B. Hariprakash, Anil. U. Mane, S. K. Martha, S. A. Gaffoor, S. A. Shivashankar, and A. K. Shukla, Electrochemical and Solid-State Letters, 7 (3) (2004) A66.
10. Effect of post-metallization hydrogen annealing on C-V characteristic of zirconia grown using ALD, Arpan Chakraborty, Anil U. Mane, S. A. Shivashankar and V. Venkataraman, MRS Symposium Proceedings, 745 (2002) N. 5.2.1.
11. Epitaxial growth of Co3O4 films by low temperature, low pressure CVD
K. Shalini, Anil U. Mane, S.A. Shivashankar, M. Rajeswari and S. Chupoon, Journal of Crystal Growth, 231 (1-2) (2000) 242.
12. CVD of thin films of cobalt grown on different substrates: Study of microstructure
Mandar A. Paranjape, Anil U. Mane, K. Shalini, B. R. Chakravorty, S. A. Shivashankar, and A. K. Raychaudhuri, Thin Slid films, 413 (1-2) (2002) 8.

E) Poster presentations at international conferences:

1. Chemical vapour deposition (CVD) of thin films of cobalt and copper from different precursor: Growth kinetics and microstructures, Anil U. Mane, K. Shalini, R. Lakshmi, M. S. Dharmaprakash, Anjana Devi, and S.A. Shivashankar, Materials Research Society (MRS) Meeting, San Francisco CA, USA (2000)
2. Epitaxial growth of Co3O4 films by low temperature, low pressure chemical vapor deposition. Shalini, K and Mane, A.U. and Lakshmi, R and Shivashankar, SA and Rajeswari, M and Choopun, S., Materials Research Society (MRS), Meeting, San Francisco, CA, USA (2000).
3. Polycrystalline and epitaxial thin films of Co3O4 by low pressure, low temperature MOCVD, Anil U. Mane, K. Shalini, and S. A. Shivashankar, EUROCVD 13 Conference, Glyfada, Athens, Greece (2001)
4. Atomic layer deposition of ZrO2 thin films: study of growth kinetics and dielectric behavior, Anil U. Mane, Arpan Chakraborty, V. Venkataraman, M, S. Dharmaprakash, and S. A. Shivashankar, The 201 meeting of Electrochemical Society, Philadelphia, USA, (2002)
5. Effect of post-metallization hydrogen annealing on C-V characteristic of zirconia grown using ALD, Arpan Chakraborty, Anil U. Mane, S. A. Shivashankar and V. Venkataraman, Materials Research Society (MRS), Meeting, Boston, USA (2002)
6. Atomic layer chemical vapor deposition (ALCVD) of Copper,
Anil U. Mane, and S. A. Shivashankar, E-MRS Spring Meeting, Strasbourg, France (2004)
7. Thin films of VO2 on glass by atomic layer deposition: microstructure and electrical properties
P. Dagur, Anil U. Mane and S.A. Shivashankar, ICCG-14/ICVGE-12 conference, Grenoble, France (2004)
8. Growth of (1 1 1)-textured copper thin films by atomic layer deposition
Anil U. Mane and S.A. Shivashankar, ICCG-14/ICVGE-12 conference, Grenoble, France (2004)
9. Applications of Low Resistivity Tungsten (LRW) at DRAM Production Site for 65nm and 90nm
Anil Mane, Mirko Glass, Lana Chan, Yang Zhuang, Kaihan Ashtiani and Michal Danek
ITC Novellus conference Hawaii (2007)