UNIVERSITY of NORTH TEXAS


## Professor Oliver Chyan

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### *Biographical Sketch*

Professor Chyan's research program has an international reputation of successfully exploring critical underlying fundamental science to greatly facilitate microelectronic fabrication and functional nanostructure design development. Professor Chyan received his Ph.D. degree in materials chemistry from MIT. Since 1992, Chyan established *the Interfacial Electrochemistry and Materials Research laboratory* where he leads an interdisciplinary research team to investigate multitude of fundamental and applied research projects relevant to semiconductor processing and advanced microelectronic fabrication. For front end processing, detection and monitoring of metal and organic contamination in various wet clean solutions were carried out to achieve ultraclean silicon surface. Relating to the back end processing, Dr. Chyan invented an ultra-thin, directly-plate-able Ru-based Cu diffusion barrier/liner for advanced interconnect application. Important interfacial phenomena including Cu ECD back fill, Cu diffusion, Cu post CMP clean and Cu/Ru bimetallic corrosion were actively investigated. Novel spectroscopic metrology was developed to characterize trace post-etch residues on patterned ultra-low k nanostructure. New insights obtained on the chemical, structural and bonding modification across ULK ILD interfaces has facilitated development of plasma etching and post etch cleaning techniques that minimize low-k dielectric damage. In IC packaging area, our work brings new insights on fundamental corrosion mechanism that causes failures of Cu wire Bonded on Al pad. Effective corrosion inhibition was demonstrated by strategically modifying the surface chemistry of Cu wires and/or Al pads. Dr. Chyan's research program was supported by Semiconductor Research Corporation and industrial partners including Intel, TI, Freescale, L-3 Communications, Lam Research, TEL, NXP, Freescale and ATMI.

### *Highlights of Industrial Collaboration Research Activities:*

- Identify/solve Fluoride-induced microscopic corrosion in TI's DLP dynamic mirror structure (**TI**).
- Invent Si-based impurities senor (U.S. Patent 6,145,372) to aid FEOL chemical processing control (**TI**).
- Invent Ru-based liner/barrier (U.S. Patent 7,247,554) that is directly plate-able with ECD Cu (**TI, SRC**).
- Develop rapid corrosion screening metrology relevant to advanced Cu interconnect fabrication processing, identify new corrosion inhibitors tailored to each chemical formulation (**SRC; ATMI**).

## *Highlights of Industrial Collaboration Research Activities: (continued)*

- Explore a better understanding of fundamental corrosion mechanism of Cu wire bonded Al bond pad to aid the practical packaging process designs for improved reliability (**NXP, Freescale, TI , SRC**).
- Developed a highly sensitive (<1-2 nm) Infrared spectroscopic metrology (US patent pending) to aid RIE-patterned ultra-low *k* nanostructure with minimum dielectric damages. (**Intel, SRC**)
- Identify key Chemical equilibria that enable precise control on the Cu etching rate for high density interconnects fabrication in advanced IC packaging application. (**Intel**)

## *Invention and Technology Transfer from Professor Chyan's Group*

Three United States Patents (*US Patent*# 6145372, 7247554 and 9366601) were awarded to professor Chyan's invention. Two US Provisional Patents #62/432115 and 62/511863 were filed in 2016 and 2017.

- ***US Patent* # 6145372 (Detection of Trace Contamination on Silicon wafer)** has attracted >$523,000 external funding. The original invention results in 9 publications, 14 professional presentation and 15 invited talks.

- ***US Patent* # 7247554 (New Ru-based Cu Diffusion Barrier and Cu/Ru Bimetallic Corrosion)** has attracted >$1,340,000 external funding. The original invention contributed to 14 publications, 40 professional presentation and 12 invited talks.

- ***US Patent* # 9366601 (Novel Chemical Bonding Transformation Mapping Probe based on MIR-IR)** has received >$839,000 external funding. The original invention results in 15 publications, 11 professional presentation and 15 invited talks. A major microelectronic company has formally initiated technical transfer negotiation and licensing request to UNT on Dec. 2016.

- ***US Provisional Patent #* 62/432,115 (New Monitoring Metrology for Precise Cu Etching Control).** Funding request of $375,000/3 years was under reviews by microelectronic industry. CHEMCUT Inc. has expressed interested in technical transfer negotiation and licensing request to UNT on Jan. 2017. Report in 1 publication and 3 presentation.

- ***US Provisional Patent #* 62/511,863 (Mechanistic Investigation and Prevention of Al Bonded Pad Corrosion in Cu Wire-Bonded Device Assembly)** has attracted >$250,000 external funding. The original invention contributed to 3 publications, 3 professional presentation and 5 invited talks.

# *Recent Selected Publications with Collaborating Industrial Partners*

1. "Mechanistic Investigation and Prevention of Al Bond Pad Corrosion in Cu Wire-bonded Device Assembly" Chyan, O.; Ross, N,; Lambert, A.; Asokan, M.; Berhe, S.; Chowdhury, M.; , S. O. Connor, S.O. ; Nguyen, L., *IEEE Electronic Components and Technology Conference Proceeding*, 2017. **(SRC, TI)**

2. "Characterization of Chemical Equilibria of Cupric Chloride Copper Etching Baths via Thin-Film UV-Vis Spectroscopy" Lambert, A.; Goutham, I.; Asokan, M.; Chyan, O.; Ojeda, O.; Jeremy Ecton, J.; Roy, A.; Hsin-Wei Wang, H.; Arana, L. , *Industrial and Engineering Chemistry Research (ACS Journal) ,* 2017, submitted. **(Intel)**

3. "Thin-Film UV-Vis Spectroscopy as a Chemically-Sensitive Monitoring Tool for Copper Etching Bath" Lambert, A.; Asokan, M.; Goutham, I.; Love, C.; Chyan, O., *Journal of Industrial and Engineering Chemistry*, 2017, *51*, 44–48. **(Intel)**

4. " Micro-pattern Corrosion Screening on Bimetallic Corrosion for Microelectronic Application" Yu, K.; Rimal, S,; Asokan, M.; Nalla, P.; Koskey, S.; Pillai, K.; Chyan, O.; Singh, K.J.; Suri, S.; *Electrochemica Acta*, 2016, *210*, 512-519. **(Intel, SRC)**

5. *"Exploration of Chemical Bonding Transformation Mapping to Assist Low-k Dielectric Nanostructure Fabrication"* Rimal, S.; Mukherjee, T.; Goswami, A.; Ross, N.; Chyan, O.; *ECS Transactions*, 2015, *66*, 1-13. **(Intel, TEL)**

6. *"UV-assisted Modification and Removal Mechanism of a Fluorocarbon Polymer Film on Low-k Dielectric Trench Structure"* Mukherjee, T.; Berhe, S.A.; Goswami, A.; Chyan, O.; Singh, K. J.; Brown, I., *ACS Appl. Mater. Interfaces*, 2015, 7, 5051-5055. **(Intel, TEL)**

7. *"Evaluation of plasma damage to low-k dielectric trench structures by multiple internal reflection infrared spectroscopy"* Rimal, S.; Mukherjee, T.; Abdelghani, J.; Goswami, A.; Chyan, O.; Stillahn, J.; Chiba, Y.; Maekawa, K., *ECS Solid State Letters* 2014, 3(3), N1-N4. **(TEL)**

8. *"Bonding Structure of Model Fluorocarbon Polymer Residue Determined by Functional Group Specific Chemical Derivatization"* Mukherjee, T.; Rimal, S. ; Koskey, S.; Chyan, O.; Singh, K.J., Myers, A.M., *ECS Solid State Letters,*2013, 2(3), N11-N14. **(Intel)**

9. *"Study of Pyrazole as Copper Corrosion Inhibitor in Alkaline Post Chemical Mechanical Polishing Cleaning Solution"* Goswami, A.; Koskey, S.; Mukherjee, T.; Chyan, O., *ECS J. Solid State Sci. Technol.* 2014*, 3(10), P293-P297.* **(SRC, ATMI)**

10. *“Characterization of Boron Doped Amorphous Silicon Films by Multiple Internal Reflection Infrared Spectroscopy”* Ross, N.; Shrestha, K.; Chyan, O. M.R.; Littler, C. L.; Lopes, V. C.; Syllaios, A.J.; *MRS Proceedings*, 2013, 1536. **(L-3)**

11. *"A 5 nm Ruthenium Thin Film as a Directly Plate-able Copper Diffusion Barrier ",* Arunagiri, T.N.; Zhang, Y.; Chyan, O. ; El-Bounani, M. ; Kim, M.J.; Wu, C. T.; Chen, K. H.; and Chen, L. C., *Appl. Phys. Lett.* , 2005, *86*, 083104. **(SRC, TI)**