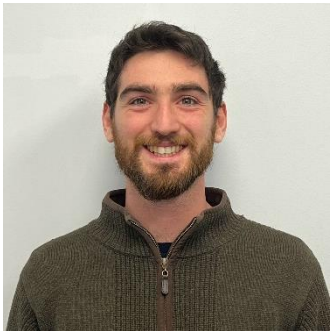
The Photopolymer Science and Technology Award

The Photopolymer Science and Technology Award No. 252100, the Best Paper Award 2025, was presented to Jordan Greenough, Nitinkumar S. Upadhyay, Shaheen Hasan, Munsaf Ali, Ricardo Burke, Greg Denbeaux and Robert L. Brainard (Department of Nanoscale Science and Engineering at the University at Albany for their outstanding contribution published in Journal of Photopolymer Science and Technology, **37**, (2024) 273-278, entitled "Positive-Tone Organoantimony Resists".



Jordan Greenough

Jordan Greenough is the Senior Staff Engineer at Geminatio, developing materials for advanced semiconductor manufacturing. Previously at CNSE in Albany, NY he completed a Master's degree in the Robert Brainard research group studying the use of small molecule organometallic compounds as EUV photoresist. During this time, he characterized over 100 organometallic complexes as EUV photoresists at the Paul Scherrer Institute's EUV interference lithography beamline.

Nitinkumar S. Upadhyay

Nitinkumar S. Upadhyay is a research scientist specializing in organometallic synthesis, medicinal chemistry, and nanotechnology. He completed his Ph.D. at National Tsing Hua University, Taiwan, and pursued a postdoctoral fellowship at the Polish Academy of Sciences, Poland. In 2019, he joined the College of Nanotechnology, Science, and Engineering, University at Albany, where he worked on photoresists for extreme ultraviolet lithography and advanced dry development techniques for photoresist applications.

Shaheen Hasan

Shaheen Hasan is a PhD candidate in the Materials Science & Engineering department of Rensselaer Polytechnic Institute. She received her B.S. degree in Nanoscale Science in 2020 from SUNY Polytechnic Institute Colleges of Nanoscale Science and Engineering, where she synthesized novel organo-metallic molecules for EUV photoresists under the guidance of Dr. Robert Brainard. Her current dissertation work focuses on 3D volumetric patterning with super-resolution interference lithography.

Munsaf Ali

Munsaf Ali is a research scientist in the DNSE at the University at Albany, earned his M.Sc. in 2012 from Maharshi Dayanand Saraswati University and Ph.D. in 2019 from MNIT Jaipur. He began postdoctoral research with Prof. Robert L. Brainard, later joining Dr. Ting Wang's group as a postdoctoral fellow. Returning to the Brainard group, he focuses on organometallic chemistry and lithographic processes to develop innovative metal-containing photoresists.

Ricardo Burke

Ricardo Burke is a Process Integration Engineer at XFAB Texas, developing process integration strategies for the fabrication of SiC devices. He completed his B.S in Chemistry at Claflin University in 2020, where he synthesized and evaluated silica shell coated gold core nanoparticles for novel Alzheimer's Disease treatments. He earned his M.S in Nanoscale Engineering from SUNY Polytechnic Institute Colleges of Nanoscale Science and Engineering in 2022, where he worked on synthesis, characterization, and evaluation of novel organo-metallic molecules for EUV photoresists.

Greg Denbeaux

Greg Denbeaux received his BA degree in physics from Wesleyan University in 1993. He studied free electron lasers and x-ray microscopy for his PhD from Duke University in 1999. He was a staff scientist at Lawrence Berkeley National Laboratory until becoming faculty at the College of Nanoscale Science and Engineering, Albany, New York. Currently, he is an associate professor at University at Albany and studies fundamentals of photoresists including stochastic effects, outgassing, and secondary electron interactions. He also has a research program in nanoparticle detection, quantification, identification and transport, all aimed at defectivity reduction in semiconductor manufacturing. He has published over 200 papers on this research which have been cited over 2,500 times. He has organized the IEUVI Resist Technical Working Group (TWG) for the last few years.

Robert Brainard

Robert Brainard received his B.S. in Chemistry from U.C. Berkeley in 1979. He studied the reaction mechanisms of organoplatinum compounds during his graduate studies with Professor G. Whitesides at MIT and Harvard University. Following his post-doctoral studies with Professor R. Madix at Stanford University, he worked for Polaroid and Shipley/RHEM in the areas of: DUV, EUV and E-Beam Photoresists. He is now a Professor at CNSE investigating new materials for use in EUV lithography. His specific research interests include:

- EUV photoresist exposure mechanisms
- Acid amplifiers for use in EUV Lithography
- Molecular Organometallic Resists for EUV (MORE)

As EUV begins to be incorporated into high volume manufacturing, research is still ongoing to create better performing materials. Many novel photoresist technologies are under development in order to meet industry requirements for highly absorptive resists capable of high resolution, high sensitivity and low line-edge roughness (LER). A novel method to increase EUV absorptivity is the incorporation of highly absorbing metals. This approach has seen significant success since the initial work of Inpria and Cornell [1,2].

Since 2011, this group has developed Molecular Organometallic Resists for EUV (MORE), exploring a diverse range of elements that exhibit high EUV absorbance. To date, Brainard's group has examined over 2000 compounds using metals such as antimony, bismuth, cobalt, palladium, platinum, tellurium and tin [3-13]. One of the most successful MORE platforms from their group consists of antimony complexes of the type $R_3Sb(O_2CR')_2$, such as ***SH-11*** (Fig. 1) [13]. Investigating the relationship between molecular structure and photo-mechanism of these platforms allows for the possibility of further performance enhancement for the next generation of EUV resists [14].

One of the challenges in the MORE project is the scarcity of positive-tone photoresists. Positive-tone photoresists are extremely valuable in the manufacture of integrated circuits, as some features such as contact holes are made preferentially with positive-tone photoresists.

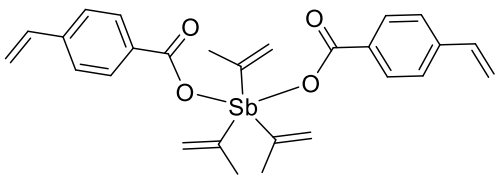


Fig. 1. ***SH-11,*** representative chemical structure of the $R_3Sb(O_2CR')_2$ platform.

They synthesized and evaluated ten triorgano-antimony dicarboxylates for use as positive-tone resists. When combined with the styrenecarboxylate ligand, isopropenyl, propenyl, and isopropyl ligands exhibited a positive-tone response to EUV radiation. These findings highlight the significance of the styrenecarboxylate ligand in generating a positive-tone response to EUV or e-beam exposure. Among these ligands, the isopropenyl group demonstrated the highest sensitivity (E_0 = 20 mJ/cm^2) compared to propenyl and isopropyl (E_0 = 134 and 111 mJ/cm^2 respectively).

Both ***SH-11*** and ***NU-111*** have been effectively utilized in dense-line patterning. ***SH-11*** resolved 30 nm half-pitch lines with a dose of 44 mJ/cm^2 but experienced considerable degradation during SEM imaging. ***NU-111*** resolved 22 nm half-pitch lines at a dose of approximately 53 mJ/cm^2 (Figure 10) and exhibited significantly improved stability in the SEM, but tended to form a crystalline, non-amorphous thin film.

These results were also presented at the 41st International Conference of Photopolymer Science and Technology (ICPST-41) and published in the Journal of Photopolymer Science and Technology. In addition, a follow-up paper aimed at elucidating the mechanisms behind the positive-tone imaging of these resists entitled, "Mechanistic Studies of Positive-Tone Organoantimony Resists" was published by this same group [15].

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