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EXECUTIVE SUMMARY

YEAR 3 Progress

Year 3 of the ORF-RE project started in July 2020, and in general, 2020 has been an difficult year for everyone due to COVID-19. Nevertheless, our researchers have made remarkable progress under limited research capacity.

The COVID-19 pandemic resulted in the restriction of all on-campus activities at McMaster University and similar limitations applied to our collaborators. For example, in year 3 of the project at McMaster, distancing requirements necessitated shift work in most labs, and also imposed limitations in instrument access. However, our ORF students, PDFs and faculty have been amazing, adapting to all of the new requirements, tolerating less than ideal work routines, and finding ways to keep their ORF research on track!

Continuing from the success of year 2, where we incorporated several new academic and industry partners and delivered multiple conference presentations, construction and programming of the ALD reactors is now complete, and they are running smoothly. Testing is also now complete, including initial Al_2O_3 and ZnO ALD experiments. Several ALD-focused collaborations within the ORF network are now underway, including those focused on battery and laser devices.

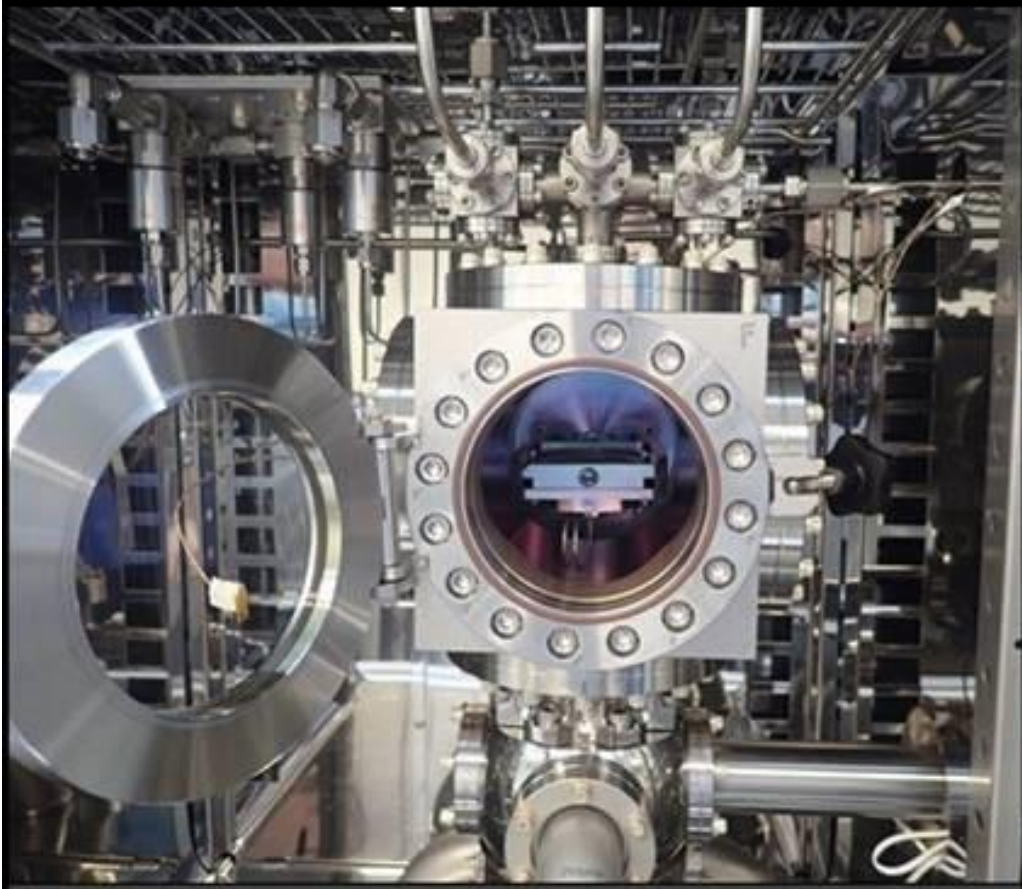
In the fall semester of Year 3, we welcomed four new graduate students – Aya Kadri, Ali Atwi, Amanda Ciezki, and Pooya Ahmadi – to our ORF team. Aya is working in the ALD precursor and reactivity development team in the Emslie group, while Amanda, Ali and Pooya are working in the optical and electrical device fabrication and characterization team in the Goward, Xu and Bradley groups, respectively. We also have two new undergraduate co-op students (Christina McCabe and Malaika Hussain) working in the Emslie and Goward groups joining the ORF team. Several students have also successfully graduated, taking their ORF experience and expertise with them to achieve their next career milestones. More detail on the students and PDFs currently/previously working on the ORF project is provided on pages 3 and 4.

*Our reactors are
now fully
operational!*

David Emslie

THE ALD REACTORS

Reaction chamber showing the heated substrate stage and 8 precursor inlets at the top of the reactor



One of the two **new ALD reactors**. Featured here is the reaction chamber, attachment points for room temperature bubblers, and mass flow controllers for gas delivery.

To schedule an in-person ALD lab tour, contact Majeda Al Hareri



The two new ALD reactors in the vented enclosure. The substrate heater controls are visible underneath the enclosure

Additional infrastructure associated with the new reactors



Dry semiconductor vacuum pumps

Dry Scrubber Abatement System

Hazardous gas cabinets + Switchover and purifier for Ar gas

Gas lines entering the vented enclosure

STUDENTS AND POSTDOCS

ALD Precursor and Reactivity Development

Jeffrey Price started his chemistry journey in the Emslie group in his undergraduate study and obtained his PhD in 2018. He continued as a postdoctoral fellow in January 2019. His research targets highly-reactive new organometallic ALD precursor molecules.

Kevin Yu graduated with his PhD from Shantou University in China, in 2018. He joined the Emslie group as a postdoctoral fellow in June 2019. His research centres around the development of novel co-reactants for transition metal ALD.

Majeda Al Hareri obtained her BSc in Chemistry from Brock University, and started as a graduate student in Sept 2016. She was awarded an NSERC PGS-D in 2018. Her research is focused on main group element and metal oxide ALD. Majeda has also taken over as ORF-RE project manager during Blossom Yan's maternity leave.

Nick Hoffman obtained his BSc in Chemistry from the Western university. He started as a



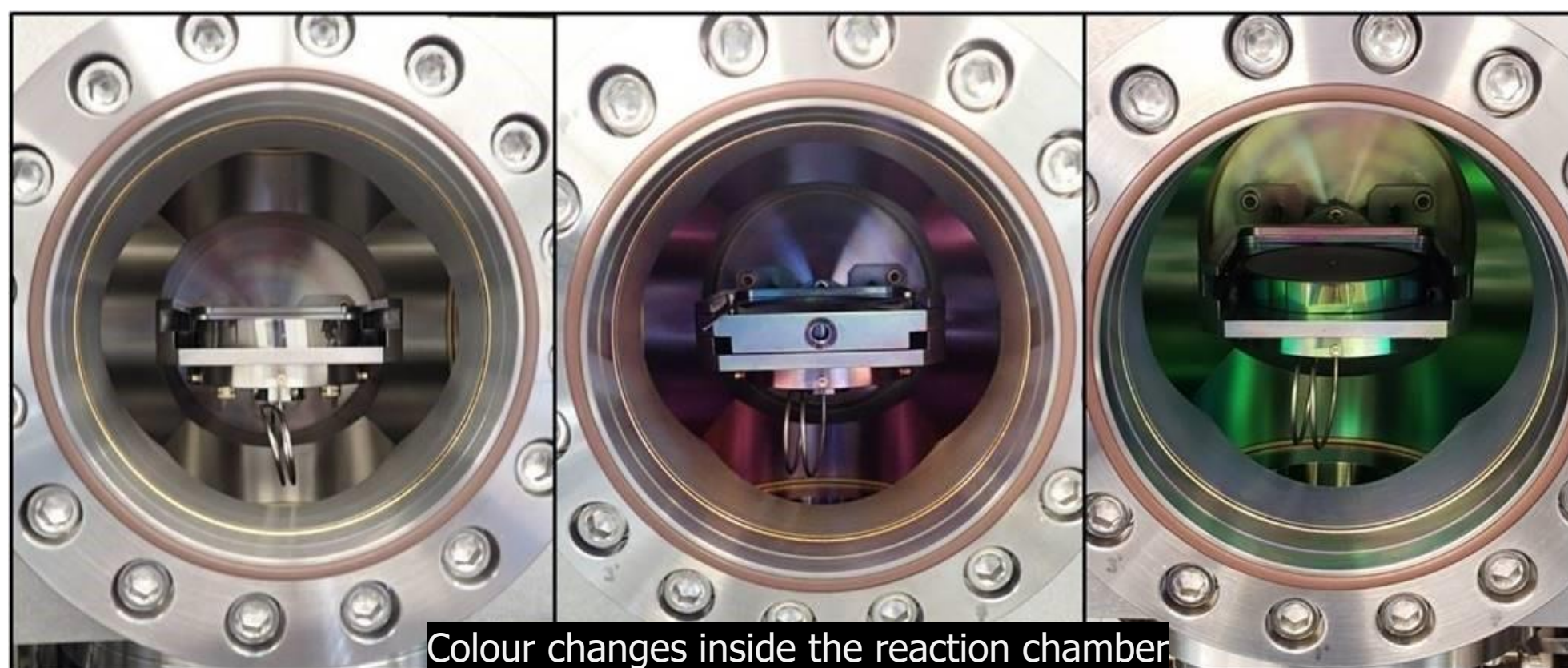
Colourful ALD-coated SiO₂ wafers

graduate student in Sept 2019. He was awarded an NSERC CGS-M scholarship in 2020. His research focuses on late transition metal ALD.

Aya Kadri obtained her BSc in Chemistry with a minor in Mathematics from Carleton University. She joined the Emslie group in September 2020 with an NSERC CGS-M scholarship. Her research focuses on early transition metal ALD.

Christina McCabe is a 3rd year co-op student from the Chemistry program at McMaster. She started working in the Emslie group in January 2021. She has been working on the development of new late transition metal ALD precursor molecules.

Jocelyn Sinclair obtained her BSc in Chemistry from Dalhousie University. She is currently a graduate student in the group of Eric Rivard at the University of Alberta. Her research involves group 14 complexes and their applications in thin film deposition.



Colour changes inside the reaction chamber



Optical and Electrical Device Fabrication and Characterization

Josh Kneller obtained his BSc in Engineering Physics at McMaster University, and he joined the Xu Group in 2017 working towards his PhD. His research focuses on development and applications of mid-IR lasers.

Ali Atwi obtained his BSc in Mechanical Engineering at American University of Beirut, and he joined the Xu Group in 2021 as a MSc student. His research focuses on development and applications of high performance solid state lasers.

Amanda Ciezki obtained her BSc in Chemistry from The King's University in Alberta. She joined the Goward group in 2020 as a MSc student. Her research focuses on advancing techniques for in-situ monitoring of full electrochemical cells.

Zoya Sadighi obtained her PhD in Mechanical Engineering and Aerospace from The Hong Kong University of Science and Technology. She joined the Goward group in April 2020 as a postdoctoral fellow. Her research focuses on all solid-state batteries development.

Malaika Hussain is a 3rd year co-op student from the Chemistry program at McMaster. She has been working in the Goward group since January 2021. She has been working on the characterization of novel polymer electrolyte for batteries.

Khadijeh Mirabbas Kiani received her Masters in Electrical Engineering, Electronics from Shiraz University, Iran. She joined the Bradley Group as a PhD student in 2018, studying photonics, silicon photonics, nanophotonics, etc.

Cameron Naraine completed his MSc and is currently a PhD student in the Bradley group, co-supervised by Dr. Pavel Cheben from NRC. His research interests include design and simulation of silicon photonics systems.

Xiuping Ding joined the Moran-Mirabal group as a PhD student in 2016. Her research focuses on the development of stretchable electronic devices and solar cells.

Pooya Ahmadi received his MSc in Material Science and Engineering from Iran University of Science and Technology (IUST). He joined the Bradley group in 2020, and his research focuses on light-emitting rare-earth-doped thin films.

Past Members

Declan DeJordy, MSc – Graduated in 2020, currently working in Kingston, ON

Kasuni Wedisinghe, MSc – Graduated in 2021, currently working in Toronto, ON

Annica Freytag, PhD – Graduated in 2021, currently working as a Postdoc in Germany

Jeremy Miller, PhD – Graduated in 2020, he is currently a Mitacs Postdoc in collaboration with Intlvac, supervised by Prof. Bradley and Prof. Mascher

Tyler Kashak – Successfully transferred to the PhD program working on other projects in the Xu group

EVENTS & PUBLICATIONS

UPCOMING EVENTS

Year 3 Student Symposium

Summer, July 2021 at McMaster University
Chaired by: D. Emslie and B. Yan

ALD Reactor Tours

Fall, 2021 at McMaster University
Chaired by: D. Emslie and M. Al Hareri

RECENT PUBLICATIONS

D. J. H. Emslie, *et al.* *Dalton Trans.* 2020, 49 (29), 9983–9994.
<https://doi.org/10.1039/DoDT01726D>

J. D. B. Bradley, *et al.* *Opt. Express* 2020, 28 (12), 18538–18547.
<https://doi.org/10.1364/OE.393729>

G. R. Goward, *et al.* *Journal of The Electrochemical Society* 2020, 167 (7), 070557.
<https://doi.org/10.1149/1945-7111/ab7fb8>.

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