

Daniel Foucher-146403- Research Contributions:

49 Scientific Publications

47 Issued US patents

15 US Published Patent Applications

1) Contributions to Research:

Ryerson University, Associate Professor, 2007-Current, Dept. of Chemistry and Biology

Interim Program Director, Molecular Sciences Graduate Program, July 2010-Sept 2011

Project#1

NSERC Funded Research Title: Towards Stable Polystannanes

Renewed 2011 Research Title: Structurally Stabilized Polystannanes

Publications: 2007-2011 (9 accepted, one submitted, two in preparation)

1) Synthesis, Characterization and Theoretical Analysis of Soluble Poly(oxothiazenes): The Ambient Temperature Lewis Acid Catalyzed In Situ Polymerization of N-silylsulfonimidoyl Chlorides, Gesahegn, S.; Aldeva, V.; Panahi, B.; Shuoprasad, M.; Foucher, D. A.; Gossage, R. A., McWilliams, A. R., *Macromolecules*, **2012** (submitted).

2) Pd-catalyzed Reactions of Alkynes with Model Distannanes and Poly[di-(*n*-butyl)]stannane Khan, A.; Lough, A. J.; Gossage, R. A.; Foucher, D. A. (**2011** manuscript in preparation).

3) Dehydrocoupling of a Cyclic Asymmetric 5-Coordinate Tin Dihydride, Komejan, S.; Khan, A.; Wylie, S.; Foucher, D. A. (**2012** manuscript in preparation).

4) Assessment of the working range and effect of sodium dichloroisocyanurate on *Pseudomonas aeruginosa* biofilms and planktonic cells, Morgenthau, A.; Nicolae, A. M.; Laursen, A. E.; Foucher, D. A.; Wolfaardt, G. M.; Hausner, M. *Biofouling*, 2012, 111-120.

5) Unusual Cationic Tri-nuclear Nickel Clusters Incorporating Oxazolines or tmeda: Applications in Olefin Polymerization Resanović, S.; Wylie, R.; Quail, J.; Foucher, D.; Gossage, R. *Inorg. Chem. Commun.* **2011**, 50, 9930-9932

6) A convenient route to distannanes, oligostannanes and polystannanes. Khan, A.; Gossage, R.; Foucher, D. *Can. J. Chem.*, **2010**, 88, 1046-1052.

7) Wurtz Coupling of Perfluorinated Dichlorostannanes. Miles, D.; Burrow, T.; Lough, A., Foucher, D. A. *J. Inorg. Organomet. Polym. Mat.*, **2010**, 20, 544-553. (DOI. 10.1007/s10904-010-9376-3).

8) The Unexpected Synthesis of Oligomeric (Dimethylsilyl) Bridged Ferrocenes from the Desilylative Coupling of Tertiary 1,1'-Bis(dimethylsilyl)Ferrocene. Miles, D.; Ward, J.; and Foucher, D.A. *Organometallics*, **2010**, 29, 1057-1060.

Impact of research: The core research of my group is to prepare new Group 14 containing polymers, in particular, polystannanes that could function as molecular wires. Two pathways towards those materials are underway, including the preparation of air and light stable polystannanes, and the preparation of ferrocene containing silanes, stannanes, siloxanes, and stannoxanes. The tin work, in its third year of funded research, has prepared and identified two potentially moisture resistant fluorine containing tin monomers and 5-coordinate structurally stabilized stannanes. The new fluorinated diaryl polystannanes were found to be extremely light sensitive, negating any expected benefit from their hydrophobic properties. Considerably more light and moisture stable polystannanes were prepared from a 5-coordinate tin dihydride. Additionally, a series of acetylene inserted polystannane polymers and model distannanes have been investigated. These materials show exceptional light stability, but remain moisture sensitive and early results indicate that conjugation has been preserved in the backbone of these systems. DFT modeling of these systems is now

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underway, including linking bandgap to the thermal behaviour (Tg's) and UV-vis spectra of these systems. The second pathway includes the discovery and reporting of new non-ring opening dehydrocoupling routes of disubstituted silicon and stannane hydride ferrocene monomers leading to polyferrocenyldisiloxanes and polyferrocenydistannoxanes. These are low Tg materials metal containing polymers that cannot be prepared by any other readily available synthetic route.

Role: Supervising a team of 6 researchers, both undergraduate(3) and graduate(one MSc, one PhD) research students, new materials are being developed and tested according to the discovery grant application. This work has been presented at two major conferences in the past year.

Collaborators: Dr. Robert Gossage, Dr. Steve Wylie.

Project #2

MITACS/Accelerate Ontario/AFM-Net Funded Research (2009-2012)

Title: Quaternary Ammonium Antimicrobials

As co-PI on these two grants, our research over the last 18 months has been focused specifically on the development of 1) new sensitive analytical detection methods for antimicrobials 2) the preparation of proprietary new antimicrobials with adhesion to difficult non-porous surfaces such as metals, glass and plastics. To date we have developed an in-house fluorescent detection method on surfaces and in solution for antimicrobial quaternary salts and have synthesized 12 new antimicrobial candidates for evaluation.

Role: Supervising a team of 3 researchers, (two undergraduate and one Ph.D. candidate) new materials are being designed and tested with collaboration of the Wolfaardt lab. This proprietary work has not yet been presented.

Collaborators: PI, Dr. Gideon Wolfaardt.

Funding: Initially funded by MITACS, now supported by AFM-Net industrial partner program.

Project #3 Started January 2010

OCE of Excellence Funded Research

Title: Very Light Weight Composite Materials for Security Vest Applications

As co-PI on this grant, our research over the last 9 months has been focused specifically on the development of lightweight materials for use in security vest. We have developed a woven Kevlar and ultra-high molecular weight composite that includes intercalated nanoparticles. These non-Newtonian materials strongly resist puncture, are lighter weight and when combined with a ceramic offer protection against bullets. These materials have been computationally engineered to give maximum resistance properties. In its early stages, we anticipate several publications from this new project.

Role: Supervising a team of 2 researchers, (one undergraduate and one MSc. candidate) new composite materials are being designed and tested for knife and bullet resistance. This proprietary work has not yet been presented.

Collaborators: PI Dr. Habiba Bougherara, Mechanical Engineering.

Funding: OCE and one industrial partner

Contributions to Research

2) Industrial Research and Development, 2002-2007, Chemque, Inc. (1 US Patent Issued)

Four filed Research Patents

- 1) **Pat Application 20100196618** Actinic Radiation Curable Coating Compositions Botrie; Alex, Nguyen; T.; Foucher, Daniel.

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- 2) **Pat Application 200602519026** *Silylated Polyurethane Moisture Cured Doming Resins*, Botrie; Alex, Deng, Yuan; Foucher, Daniel, Cooke, Jeffery.
- 3) **Pat Application 20060269756** *Actinic radiation curable coating compositions*, Botrie; Alex, Deng, Yuan; Foucher, Daniel.
- 4) **Pat Application 20060251902** *Silylated polyurethane moisture cured doming resins* Botrie; Alex, Deng, Yuan; Foucher, Daniel, Cooke, Jeffery.

Patents:

- 1) **USP 7,713,628** Issued May 11, 2010. Title: **Actinic radiation curable coating compositions**. Botrie, A.; Deng, Y.; Foucher, D.; Nguyen, T.

For 5 years I have led the research efforts in the development of new polyurethane and UV curable polymer systems for the polymer specialty company Chemque (www.chemque.com). My contributions to all of the research areas listed below include idea generation, direct synthesis and preparation, training, mentoring, scale-up and evaluation. This has resulted in bringing 40 new or improved products to the market place, ten of which now account for more than 35% of all current revenues. Average time to market for a new product from concept to sales was approximately 5-6 months, which included time for in-house product testing, aging studies and customer trials. The research and development over this time period was specifically focused in four areas, construction, two-component lensing resins, gasketing products, and one-component UV curable materials for High Definition Graphics. In the construction area, the development of LEED's compliant (Leadership in Energy, Efficiency and Design) green wood flooring moisture cure adhesives resulted in North American sales > \$4 million dollars in 2006. Moisture cure polyurethanes were specifically designed to have excellent shelf life, good trowelability (low viscosity) and high bond strength.

For the lensing resin applications, the research and development efforts were focused on the preparation of low or non-mercury snap-cure two-component lensing resins. During my time at Chemque, I have oversaw the reduction in mercury content in these products reduced by 50-100%, with the final goal of zero mercury by 2010, well ahead of pending legislation for automobiles, toys, and other applications. The non-mercury lensing resins represent a significant new option for customers who are environmentally motivated to bring the best and safest products to market. The sales of non-mercury lensing resins have now grown to approximately 5% of total lensing resin sales (> \$2 million dollars in 2006) and continue to grow. The chemistry that led to these developments included low toxicity urethane catalysts, new snapcure isocyanates, and formulation principals that have radically altered the polymer backbone of these systems.

New statically mixed two component polyurethane gasketing materials were developed as a low cost alternative to expensive dispensing equipment. These materials have found application as enclosure door seals, automobile door and light gaskets, as well as lids for metal and plastic containers. These materials have now moved from the lab into full customer trials. Finally, the preparation of new light stable, one-component, instant cure UV curable resins for High Definition applications was undertaken. These resins are typically high build, low viscosity, low shrinkage UV curable systems that are used as backfilling, molding, and lensing resins. These materials possess excellent UV stability and do not suffer the yellowing typical of other UV curable systems. This work was presented at FESPA tradeshow, http://www.fespa.com/3b/fespa_2005_seminars_synopsis_doming_01.htm, and are in customer trials now.

Impact of research: The research has resulted in two green technologies in the development of the LEED's Wood adhesive and the non-mercury lensing resins. These green initiatives are now driving sales of these products and have distinguished the Chemque brand in the marketplace. The new one-component instant cure technology in development over the last two years will revolutionize the market place for these products.

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Role: As technical manager, oversaw all R&D efforts including: concept contribution, material design, project supervision, test and evaluation, scale-up responsibilities. Work was managed directly with R&D staff at Chemque under my supervision.

Collaborators: Alex Botrie, CEO and R&D Program Manager,

Funding: Internally funded with Chemque.

3) Contributions to Research: Industrial Research Experience with Xerox: (1995-2002) 46 US patents issued

The bulk of my experience with the Xerox Research Centre of Canada and Xerox Inkjet Business unit in Webster, NY involved the preparation of novel organic polyester materials and photopatternable polymers for electronics. Specifically, key contributions were made in the preparation of persulphonated polyesters resins that could be readily made water dispersible to form emulsions. These emulsions were then aggregated in the presence of pigment, surfactant, and charge control additives to yield the first examples of emulsion aggregated polyester pigmented toners. My direct involvement was in the design, transesterification and scale-up of these novel polyesters. This work resulted in the filing of 20 US patents and represents a significant technology advance in EA toners. Through these efforts, I discovered a new patentable route to a polyester resin precursor that has Xerox to realize a \$25-30 million dollar saving per year. The work involved a lower cost route to the propoxylation of bisphenol A with propylene oxide (USP **6,063,827** and **6,127,080**), which normally requires high-temperature, high-pressure reaction conditions and expensive starting materials. The new route involved the low temperature ring-opening of propylene carbonate and subsequent reaction with Bis Phenol A to produce the same starting materials. Also at Xerox, I developed and implemented a simplified 3-part synthesis of photopatternable polyarylene ether ketones for use in silicon wafer development. Working together with wafer development team, a new photoresist was developed and photopatterned successfully to overcome constraints in shrinkage, moisture resistance, and aspect ratio that was found with polyimide photoresists. Savings of over \$3000 per kilo were realized over commercially available resins.

Research Impact: The preparation of sulphonated polyesters led to the development of a new type of toner composition, resulting in a significant licensing opportunity for Xerox. The preparation of a new route to polyester precursors resulted in substantial annual savings (\$25 million per annum) to the company and exclusive patent rights. Photoresist work was demonstrated and became a key part of the licensing portfolio of the Xerox Inkjet business unit when it was dissolved in 2003.

Role: Synthesis and characterization of new resins for EA based toners, lead researcher. Photoresist team leader and supervisor

Collaborators: Guerino Sacripante, Senior Scientist, Hadi Mahabadi, Center Manager, Peter Kazmaier, Principal Scientist, Beng Ong, Senior Scientist and Lab Manager, Raj Patel, Scientist, Louis Isganitis, Lab Manager 5 Co-op students on summer/fall/research terms.

Funding: Internally funded with Xerox.

4) Contributions to Research: 1995-2002 Publications with Xerox

Publications: 2 publications on this topic as primary author.

- 1) Copper-Mediated Polycondensations of Substituted Diiodoferrocenes and Bis(stannyl)ferrocenes: Synthesis and Properties of Soluble Polyferrocenylenes Containing Trimethylsilyl or Methyl Groups. Park, P., Lough, A, and Foucher, D.A. *Macromolecules*, **2002**, *35(10)*, 3810-3818. **12 Citations**

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I continue to have a strong interest in ferrocene chemistry and decided to prepare a series of soluble polyferrocenes that have a backbone consisting of only ferrocene. Unlike the work done with the Manners group, this involved condensation polymerization of ferrocene monomers with very soluble side groups such as methyl or trimethylsilyl. I was able to prepare several new monomers with diiodo functionality and polymerized them successfully with Ullmann couplings using copper. My working objective was to prepare a ferrocene polymer that could function as a molecular switch, by having a large degree of cooperative interaction along the backbone. Cyclic voltammetry studies of these soluble polyferrocenes demonstrated the highest degree of metal to metal interaction at 0.5V representing the sequential oxidation of ferrocene centers along the polymer backbone whereby comparison polyferrocenylsilanes show a much smaller metal to metal interaction of around 0.25V. This work resulted in the publication of one communication and one full-length paper.

Research Impact: The first well-characterized examples of polyferrocenes with an alternating backbone of ferrocene were prepared. These materials represent the best examples of this type of metal containing polymers with a high degree of metal-to-metal cooperation.

Role: Idea conception, synthesis and characterization, lead author.

Collaborators: Peter Park, chemist, Alan Lough Crystallographer.

Funding: Received \$10,000 USD internal grant from the Xerox Foundation to undertake work.

5) Contributions to Research:

1992-1998 Discovery of Poly(ferrocenylsilanes), University of Toronto

Publications: 33 publications on this topic as primary or contributing author

This work, which I initiated as a graduate student and continued as a postdoctoral student, turned out to be a watershed of ideas, research direction and interest in the Manners' research group. The work continues to be a central focus for the Manner's research group in Bristol and his collaborators. A seminal publication was communicated in 1992 and has resulted in over 250 related publications for Manners, in addition to the interest now being reported by other groups with these materials. Polymers with an alternating backbone of ferrocene and organosilane units has been the desire of several research groups, but had been hampered by the fact that these materials are generally insoluble. My discovery stems from the reaction of dilithoferrocene.TMEDA with dichlorodimethylsilane yielding the thermal strained monomer, 1,1'-dimethylsilyl-ferrocenophane. A subsequent thermal ring-opening polymerization of this strained monomer led to the first high molecular weight, castable films of poly(ferrocenylsilanes). These materials represent one of the first examples of a soluble, and processable organometallic polymer. I was also able to determine the exothermic enthalpy of the polymerization by placing a small amount of the monomer in a DSC cell, and watch in real time the ring-opening polymerization of the species. Follow-on work included the full characterization of the high molecular weight polymer by GPC, light scattering, electrochemistry, Mössbauer, and NMR. I was also able to show that the neighbouring iron atoms displayed strong cooperative interactions by having two distinct oxidation potentials that could be characterized. Further work in my Ph.D. thesis and Postdoc term also investigated other heteroatoms, including phosphorus, tin, and germanium.

Research Impact: The discovery of soluble poly(ferrocenylsilanes) has continued to yield interesting new applications. The impact factor for the initial JACS publication (Foucher, D.; Tang, B.Z.; Manners, I., *J. Am Chem. Soc.* **1992**, *114*, 6246-6248) is **410** citations, with a total of **> 1000** citations for the 33 publications I completed in the Manners Group.

Role: Discovery, synthesis and characterization, lead author and contributing author on several publications.

Funding: Received University of Toronto Open fellowship to support this work.