

## **Report on the Research and Teaching Activities of the Ontario Chair in Green Chemistry and Engineering at Trent University, 2014-2015**

The Ontario Research Chair in Green Chemistry and Engineering at Trent University was slated to have the following research related focus over the course of the program (text in italics is reproduced pasted from the original application to COU):

- 1) *A fundamental understanding of the crystallization of lipid and modified lipid networks to direct the modification of natural molecular ensembles and processing conditions in order to design crystal network structures with specific physical properties in a stable thermodynamic state.*
- 2) *Development of chemical modification techniques that can alter the chemical functionality of lipids, so as to produce high value chemicals, functional monomers and functional supra-molecular assemblies, including nano-scale delivery systems.*
- 3) *A fundamental understanding of the inter-relationships between the chemical functionality of monomers, processing conditions, derived structural hierarchies, and the resultant physical functionality of the polymer networks created from lipid-derived monomers.*

In 2014-2015, the research group made more progress than in any other year since the inception of the Ontario Research Chair in Green Chemistry and Engineering research program, as evidenced by the number of publications and patents outlined below (please note that some publications and patents listed were published or filed in 2016, but these are the result of work done in 2015 and before).

Referring to the list of publications below, the group made a major breakthrough with the synthesis of natural oil polyols from palm oil which produced both flexible and rigid foams that outperformed all reported instances of foams produced from natural oil polyols [4, 5, 6, 7]. Importantly, the feedstock for this work was palm oil, which had been metathesized to produce valuable olefins, and the polyol was synthesized from the remaining by-product. Palm oil, being a highly saturated oil, had not been a recommended substrate for polyol production before. A number of patents [29 – 41] have resulted from this work, and the technology is being actively pursued for commercialization, with initial commercial testing yielding very encouraging results. Publication [8] details work done to demonstrate that CLICK polymers made by the group in 2013 and 2014 had broad-spectrum antibacterial properties, and furthermore, proved that these polymers were effective through contact as opposed to through leaching. Patents [17, 25-26] were filed based on work done in 2013 and 2014 to synthesize polyesterurethanes and polyesters with vastly superior physical properties to both petroleum-derived and biobased polyesters currently in use. These elastomers have superior elongations at break and higher Young's moduli than any other bio-based polyesters in use today or reported in the literature. All of the preceding work was done under the rubric of Fundamental Objective 3, detailed above.

Under Fundamental Objective 2, work in 2014-2015 focused on lubricants and high-value additives to biodiesel. Publications [2,3] details work on lubricants produced by synthesizing aliphatic diesters and their derivatives from vegetable oils, and patent [24] details the unique properties exhibited by the branched aliphatic diester compounds, which position them as very useful base oils for functional lubricants which are oxidatively stable with superior low temperature fluidity properties. Publication [16] is part of a series of work done in 2013 and 2014 on aliphatic monoesters and their branched compounds derived from vegetable oils. These compounds also displayed superior properties a lubricant base oils and that work was captured in earlier patents reported in previous years.

Biodiesel crystallizes and becomes un-pourable and un-pumpable at colder temperatures and this prevents its utilization in colder months of the year in temperate countries. We have been able to design a range of additives which addresses this problem. Publications [9-11, 13-15] details this work, which has also been filed for intellectual property protection in patents [27-28], which are in addition to a number of patents that were filed in 2012, 2013 and 2014.

Our work on the crystallization of lipid derived molecules, under Fundamental Objective 1, resulted in publications [1, 12] and patents [18 – 23]. Publication [12] details incremental understanding of the relationships between symmetry, chain length mismatch and kinetics of crystallization of key triacylglycerol species of importance in food systems. Publication [1] arose out of a collaboration between myself and Professor Neil Emery, to use exogenous hormone treatment on soybean oil so as to influence the fatty acid profile produced by the plant. This fatty acid profile has been determined by our work under Fundamental Objective 1 to be optimum for the formation of solid-like networks without having to resort to hydrogenation.

The patents were filed on our latest work involving crystallization: phase change materials. A series of superior organic, food-safe, biodegradable compounds were synthesized which act as superior phase change energy storage materials. Furthermore, the team designed a new food container with controlled temperature profiles using these materials. In addition, a model and design for using phase change materials to improve the efficiency of compressed air energy storage systems from around 65% to above 85% was disclosed.

The research deliverables of the Chair's program as detailed in the original research program have all been met and significantly exceeded. There are no areas of the proposed research program that have not been addressed by the team, and in several instances these areas have resulted in the filing of very valuable intellectual property.

#### **Manuscripts Published in 2013-2014:**

1. Nguyen, Q.T., A. Kisiala, P. Andreas, R.J. Neil Emery and **S.S. Narine** (In Press, 2016). Soybean seed development: fatty acid and phytohormone metabolism and their interactions. Current Genomics, Bentham Science Publishers 17(3).

2. Raghunanan, L. and **S.S. Narine**, (2016), *Engineering Green Lubricants I: Optimizing thermal and flow properties of linear diesters derived from vegetable oils*, ACS Sustainable Chemistry & Engineering. DOI: 10.1021/acssuschemeng.5b01644
3. Raghunanan, L. and **S.S. Narine**, (2016), *Engineering Green Lubricants II: Thermal Transition and Flow Properties of Vegetable Oil-Derived Diesters*, ACS Sustainable Chemistry & Engineering. DOI: 10.1021/acssuschemeng.5b01708
4. Pillai, P.K.S, S. Li, L. Bouzidi, and **S.S. Narine**, (2016), *Solvent free synthesis of polyols from 1-butene metathesized palm oil for use in polyurethane foams*, Journal of Applied Polymer Science, DOI: 10.1002/APP.43509.
5. Pillai, P.K.S, S. Li, L. Bouzidi, and **S.S. Narine**, (2016), *Metathesized palm oil: Fractionation strategies for improving functional properties of lipid-based polyols and derived polyurethane foams*, Industrial Crops and Products, 84: 273-283.
6. Pillai, P.K.S, S. Li, L. Bouzidi, and **S.S. Narine**, (2016), *Metathesized Palm Oil & Novel Polyol Derivatives: Structure, Chemical Composition and Physical Properties*, Industrial Crops and Products, 84: 205-223.
7. Pillai, P.K.S, S. Li, L. Bouzidi, and **S.S. Narine**, (2016), *Metathesized palm oil polyol for the preparation of improved bio-based rigid and flexible polyurethane foams*, Industrial Crops and Products, 83: 568-576.
8. Floros, M.C., J.F. Bortolatto, O.B. Oliveira, S.L. Salvador, and **S.S. Narine**, (In Press, 2016), *Antimicrobial Activity of Amphiphilic Triazole-Linked Polymers Derived from Renewable Sources*, ACS Biomaterials Science & Engineering.
9. Mohanan, A., L. Bouzidi, S. Li and **S.S. Narine**, (2016). *Mitigating Crystallization of Saturated FAMES in Biodiesel. 1. Lowering Crystallization Temperatures via Addition of Metathesized Vegetable Oil*, Energy, 96: 335-345.
10. Mohanan, A., L. Bouzidi, S. Li and **S.S. Narine**, (2016). *Mitigating Crystallization of Saturated FAMES in Biodiesel 6: The Binary Phase Behavior of 1, 2-dioleoyl-3-stearoyl sn-glycerol - Methyl Stearate*, Energy, 100: 273-284.
11. Mohanan, A., L. Bouzidi and **S.S. Narine**, (2016), *Mitigating Crystallization of Saturated FAMES in Biodiesel. 4. Multi-Length Scale Structural Elucidation of Inhibition Mechanism of FAME Crystallization - The Phase Behavior of 1,3-dioleoyl-2-palmitoyl Glycerol / Methyl Stearate Binary System*, Energy, 96: 242-252.
12. Bouzidi, L., M. Baker, N. Garti and **S.S. Narine**, (2015), *Elucidation of Kinetic and Symmetry Effects on the Viscosity and Flow Behavior of Stearic and Oleic Triacylglycerols*, Journal of the American Oil Chemists' Society, 92(7): 939-946.
13. Baker, M., L. Bouzidi and **S.S. Narine**, (2015), *Mitigating Crystallization of Saturated FAMES in Biodiesel. 2. Multi-Length Scale Structural Elucidation of Inhibition Mechanism of FAME Crystallization - The Phase Behavior of 2-stearoyl diolein/Methyl Stearate Binary System*, Energy, 83: 647-657.
14. Mohanan, A., B. Darling, L. Bouzidi and **S.S. Narine**, (2015), *Mitigating Crystallization of Saturated FAMES in Biodiesel. 3. Multi-Length Scale Structural Elucidation of Inhibition*

*Mechanism of FAME Crystallization - The Binary Phase Behavior of 1,3-dioleoyl-2-palmitoyl Glycerol / Methyl Palmitate*, Energy, 86: 500-513.

15. Mohanan, A., L. Bouzidi and **S.S. Narine**, (2015). *Mitigating Crystallization of Saturated FAMES in Biodiesel. 5. Multi-Length Scale Structural Elucidation of Inhibition Mechanism of FAME Crystallization - The Phase Behavior of a Structured Triacylglycerol Dimer / Methyl Palmitate Binary System*, Energy, 93: 1011-1021.
16. Li, S. & L. Bouzidi and **S.S. Narine**, (2014), *Lubricating and waxy esters. VI. Synthesis and physical properties of (E) didec-9-enyl octadec-9-enedioate and branched derivatives*, Industrial and Engineering Chemistry Research, 53(51): 20044-20055.

#### **Patents Filed in 2013-2014:**

17. U.S. Provisional Patent Application # 62/302,475 (2 March, 2016) *Renewably Derived Polyesters Containing Branched-Chain Monomers and Methods of Making and Using the Same*, Inventors: **S.S. Narine**, S. Li, L. Bouzidi.
18. U.S. Patent Application #14/605444 (26 January, 2015) *Food Beverage Container with Temperature Control*, Inventors: **S.S. Narine**, M.C. Floros, M. Tessier.
19. PCT (International) Application # PCT/IB2016/050176 (26 January, 2015) *Food Beverage Container with Temperature Control*, Inventors: **S.S. Narine**, M.C. Floros, M. Tessier.
20. U.S. Patent Application #14/605,344 (26 January, 2015) *Latent Heat Storage Using Renewable Phase Change Materials*, Inventors: **S.S. Narine**, M.C. Floros.
21. PCT (International) Application # PCT/IB2016/050112 (26 January, 2015) *Latent Heat Storage Using Renewable Phase Change Materials*, Inventors: **S.S. Narine**, M.C. Floros.
22. U.S. Patent Application #14/605,468 (26 January, 2015) *Compressed Gas Energy Storage System*, Inventors: **S.S. Narine**, M. Tessier.
23. PCT (International) Application # PCT/IB2016/050254 (26 January, 2015) *Compressed Gas Energy Storage System*, Inventors: **S.S. Narine**, M. Tessier.
24. U.S. Provisional Patent Application #62/255,582 (16 November, 2015), *Branched Diesters and Methods of Making and Using Same (Base Oil)*, Inventors: **S.S. Narine**, L. Raghunanan and L. Bouzidi.
25. U.S. Provisional Patent Application #62/259,771 (25 November, 2015), *Renewably Derived Polyester-Based Polyurethanes and Methods of Making and Using Same (Segmented)*, Inventors: **S.S. Narine**, S. Shetranjiwalla, S. Li and L. Bouzidi.
26. U.S. Provisional Patent Application #62/259,754 (25 November, 2015), *Renewably Derived Polyester-Based Polyurethanes and Methods of Making and Using Same (Non-Segmented)*, Inventors: **S.S. Narine**, S. Shetranjiwalla, S. Li and L. Bouzidi.
27. U.S. Provisional Patent Application #62/250,577 (4 November, 2015), *Pour Point Depressants and Natural Oil Based Crystallization Modifiers for Biodiesel*, Inventors: **S.S. Narine**, L. Bouzidi and A. Mohanan

28. U.S. Provisional Patent Application #62/247,645 (28 October, 2015), *Certain Triacylglycerols as Crystallization Depressants*, Inventors: **S.S. Narine**, L. Bouzidi and A. Mohanan.
29. U.S. Provisional Patent Application #62/107,935 (30 January, 2015), *Methods of Making Triacylglycerol Polyols from Fractions of Metathesized Natural Oils and Uses Thereof*, Inventors: **S.S. Narine**, P. Pillai, S. Li, L. Bouzidi and A. Mahdevari.
30. U.S. Patent Application #15/005,895 (30 January, 2015), *Methods of Making Triacylglycerol Polyols from Fractions of Metathesized Natural Oils and Uses Thereof*, Inventors: **S.S. Narine**, P. Pillai, S. Li, L. Bouzidi and A. Mahdevari.
31. PCT (International) Application #PCT/CA16/50075 (30 January, 2015), *Methods of Making Triacylglycerol Polyols from Fractions of Metathesized Natural Oils and Uses Thereof*, Inventors: **S.S. Narine**, P. Pillai, S. Li, L. Bouzidi and A. Mahdevari.
32. U.S. Patent Application #15/005,522 (30 January, 2015), *Methods of Making Triacylglycerol Polyols from Fractions of Metathesized Natural Oils and Uses Thereof*, Inventors: **S.S. Narine**, P. Pillai, S. Li, L. Bouzidi and A. Mahdevari.
33. PCT (International) Application #PCT/CA16/50059 (30 January, 2015), *Methods of Making Triacylglycerol Polyols from Fractions of Metathesized Natural Oils and Uses Thereof*, Inventors: **S.S. Narine**, P. Pillai, S. Li, L. Bouzidi and A. Mahdevari.
34. U.S. Provisional Patent Application #62/107,404 (27 March, 2014), *Metathesized Triacylglycerol Green Polyols from Palm Oil for Use in Polyurethane Applications*, Inventors: **S.S. Narine**, P. Pillai, S. Li, L. Bouzidi and A. Mahdevari.
35. U.S. Patent Application #14/670,080 (27 March, 2014), *Metathesized Triacylglycerol Green Polyols from Palm Oil for Use in Polyurethane Applications*, Inventors: **S.S. Narine**, P. Pillai, S. Li, L. Bouzidi and A. Mahdevari. **Publication Date:** 29 October, 2015, Publication # 2015/0307811.
36. PCT (International) Application #PCT/CA15/50234 (27 March, 2014), *Metathesized Triacylglycerol Green Polyols from Palm Oil for Use in Polyurethane Applications*, Inventors: **S.S. Narine**, P. Pillai, S. Li, L. Bouzidi and A. Mahdevari. **Publication Date:** 1 October, 2015, Publication # WO 2015/143562.
37. U.S. Patent Application #14/670,125 (27 March, 2014), *Certain Metathesized Natural Oil Triacylglycerol Polyols for Use in Polyurethane Applications*, Inventors: **S.S. Narine**, P. Pillai, S. Li, L. Bouzidi and A. Mahdevari. **Publication Date:** 22 October, 2015, Publication # 2015/0299099.
38. PCT (International) Application #PCT/CA15/50235 (27 March, 2014), *Certain Metathesized Natural Oil Triacylglycerol Polyols for Use in Polyurethane Applications*, Inventors: **S.S. Narine**, P. Pillai, S. Li, L. Bouzidi and A. Mahdevari. **Publication Date:** 1 October, 2015, Publication # WO 2015/143563.
39. U.S. Provisional Patent Application #61/971,475 (27 March, 2014), *Metathesized Triacylglycerol Polyols for Use in Polyurethane Applications and their Related Properties*, Inventors: **S.S. Narine**, P. Pillai, S. Li, L. Bouzidi and A. Mahdevari.

40. U.S. Patent Application #14/670,028 (27 March, 2014), *Metathesized Triacylglycerol Polyols for Use in Polyurethane Applications and their Related Properties*, Inventors: **S.S. Narine**, P. Pillai, S. Li, L. Bouzidi and A. Mahdevari. **Publication Date:** 26 November, 2015, Publication # 2015/0337073.
41. PCT (International) Application #PCT/CA15/50242 (27 March, 2014), *Metathesized Triacylglycerol Polyols for Use in Polyurethane Applications and their Related Properties*, Inventors: **S.S. Narine**, P. Pillai, S. Li, L. Bouzidi and A. Mahdevari. **Publication Date:** 1 October, 2015, Publication # WO 2015/143568.

### Conferences Attended:

1. **S.S. Narine**, *Lipid based polymers: A biorefinery approach enabled by structure function fundamentals*, PACIFICHEM 2015, December 15 – 21, Honolulu, Hawaii, U.S.A. (**Invited Keynote**).
2. Kishun V and **S.S. Narine**, *Doing it Right: Eliminating Mercury use in Gold Mining in Guyana*, August 24, 2015 Guyana Mining Conference 2015, Georgetown, Guyana.
3. Floros MC, Tessier M and **S.S. Narine**. *Lipid Derived Phase Change Materials for Thermal Energy Storage*, 43rd Annual Conference of the North American Thermal Analysis Society (NATAS), Montreal, Quebec, Canada. August, 2015.
4. Mohanan A and **S.S. Narine**. *Mitigating crystallization Temperature of Biodiesel*, 43rd Annual Conference of the North American Thermal Analysis Society (NATAS)- Pharmaceuticals and Biomaterials session, Montreal, Quebec, August 11, 2015
5. **S. S. Narine**, *Natural Resources Utilization, Sustainability and Development: Mutually Exclusive?* First Guyana Carbon Conversations Event, 22 June, 2015, Plenary Talk, 500 People in Attendance, (**Invited Talk**).
6. **S.S. Narine**, *Vegetable Oil Derived Monoesters for Superior Lubricant Formulations*, 106th AOCS Annual Meeting and Expo, May 3-6, 2015, Orlando, Florida, USA (**Invited Talk**).
7. Bouzidi L and **S.S. Narine**, *Phase Trajectories and Physical Properties of Linear and Branched Fatty Monoesters: Superior Lubricants*, Invite 106th AOCS Annual Meeting and Expo, May 3-6, 2015, Orlando, Florida, USA (**Invited Talk**).
8. Shetranjiwalla S, Raghunanan L. and **S. S. Narine** (2015). *Polymers from Lipids: State of the Art*. Special Symposium in Honor of Nissim Garti, 106th AOCS Annual Meeting & Expo, 1 – 6 May 2015. Orlando, Florida, USA (**Invited Talk**).
9. Raghunanan, L.C. and **S. S. Narine** (2015). *Towards superior bio-based lubricants*. Poster presented at Trent's Graduate Students' Association-Research Matters joint Alumni Networking event, 24 April 2015. Trent University, Peterborough, ON Canada.
10. Shetranjiwalla S and **S. S. Narine**, *Transforming plastics into green materials: Replacing crude oil with vegetable oil*, Poster presentation at Trent's Graduate Student's Association-Research Matters joint Alumni Networking event, April 24, 2015, Trent University, Peterborough, ON, Canada

11. Raghunanan, L.C. and **S.S. Narine**, (2015). *From Oil to Green: Making good lubricants better*. Featured speaker at Trent University's 50<sup>th</sup> Anniversary Chancellor's Event: They Will Change the World, 9 April, 2015. Toronto, Ontario, Canada.
12. Floros MC and **S.S. Narine**, *Antimicrobial Polymers – Eliminating Superbugs and Infections Before they Begin - They Will Change the World Symposium*, Toronto, ON, Canada, April 2015.
13. Thein N.Q., Emery R.J.N. and **S.S. Narine**, *Endogenous Plant Hormone Metabolism and Their Effect on Fatty Acid Composition in Soybean Seed*, Poster session at The 56th Annual Meeting of the Japanese Society of Plant Physiologists, March 16 2015 Tokyo University of Agriculture, Tokyo, Japan
14. Shetranjiwalla S. and **S.S. Narine**, *Transforming plastics into green materials: Replacing crude oil with vegetable oil*, Poster Presentation at Symons Seminar Series Gala, April 17, 2015, Trent University Peterborough, ON, Canada
15. **S. S. Narine**, *Transitioning to Green Materials: Why and How*, Chemistry Department, University of the West India at Mona, Jamaica, February 23, 2015 (**Invited Talk**).
16. Shetranjiwalla S and **S.S. Narine**, *Transforming plastics into green materials: Replacing crude oil with vegetable oil*, Symons Seminar Series, Dec 3, 2014, Trent University, Peterborough, ON, Canada

#### Number of Students Supervised in the Year:

<b>Master's</b>	4
<b>Doctoral</b>	7
<b>Post-Doctoral Fellow</b>	4
<b>Undergraduates who participated in the research program</b>	6
<b>Other: Visiting Scholars</b>	2

#### Members of the Research Team:

##### Principal Investigator

1. Dr. Suresh Narine, Program Director and Professor  
Professor Narine is responsible for the entire program management and for setting and managing research milestones and deliverables, and for liaison with the Research Advisory Committee.

##### Research Associates

2. Dr. Laziz Bouzidi, Materials Science, Condensed Matter Physics, Surface and Interface Science

Dr. Bouzidi assists Professor Narine in the management of deliverables related to fundamental objective 1 (see section on research above) and associated applied objectives and is also actively engaged in the actual research deliverables and in helping to supervise graduate students.

3. Dr. Shaojun Li, Organic Chemistry, Polymer Science:

Dr. Li assists Professor Narine in the management of deliverables related to fundamental objective 2 (see section on research above) and associated applied objectives and is also actively engaged in the actual research deliverables and in helping to supervise graduate students.

### **Research Technician**

4. Peter Andreas

Mr. Andreas is our laboratory manager, and is in charge of safety, calibration, supply management, equipment repair and training for equipment operation. He supports all research activities in our laboratories.

### **Post-Doctoral Fellows**

1. Jinhua Yang, 2014/05 - 2015/03, Synthesis and characterization of bio-based polymers
2. Jesmy Jose, 2011/9 - 2014/7, Bio-based polymers
3. Shaine Joseph, 2011/9 - 2014/3, Modeling of crystallization of lipid systems
4. Bibin Mathew Cherian, 2013/10 to 2014/03, Synthesis Fatty acid/cellulose composites for use as super hydrophobic/super hydrophilic surface coatings.

### **Graduate Students:**

#### **Graduated 2014 – 2015**

1. Prasanth Kumar graduated with a Ph.D. in 2015– a chemist, his work was on lipid-based polyols and polyurethane foams.
2. Latchmi Singh graduated with a Ph.D. in 2015 – a chemist, her work was on the synthesis of green lubricants.
3. Shegufa Merchant graduated with a Ph.D. in 2015 – a chemist, her work was on the synthesis of superior thermoplastic polyesters and polyesterurethanes.
4. Michael Floros graduated with a Ph.D. in 2015 – a chemist, his work was on CLICK and anti-microbial polymer films and phase change materials.
5. Kira Ramphal graduated with a MSc. in 2015 – a biologist, her work was on the use of exogenously applied hormones to influence the fatty acid profile produced by algae.

6. Michael Tessier graduated with an MSc. in 2015, a physicist, his work focussed on models for the use of phase change materials in compressed air energy storage systems.
7. Athira Mohanan graduated with a Ph.D. in 2015, a physicist, her work focussed on the use of additives to reduce the crystallization temperature of saturated fatty methyl esters in biodiesel and the reduction of pour points of biodiesel.

### **Current**

1. Thien Nguyen Quoc is a Ph.D. student in the Environmental and Life Sciences graduate program and is from Vietnam, working with Professors Neil Emery and Suresh Narine on modification of soybeans so as to influence the fatty acid profiles to be more industrially beneficial to producing green chemicals.
2. Benjamin Musclow is a MSc. student in Materials Science, who is working on polymeric coatings for the triggered release of urea fertilizers. He supervised by Dr. Narine and is a Peterborough native with a BSc. degree from Trent University. Benjamin is currently on long term leave of absence due to being ill.
3. Vishol Kishun is an MSc. student in Environmental and Life Sciences who is working on biobased super absorbents for use in the gold mining industry. He is supervised by Dr. Narine and is originally from Guyana.
4. Avinaash Persaud is an MSc. student in Environmental and Life Sciences who is working on isocyanate-free polyurethanes. He is supervised by Dr. Narine and is from Guyana.
5. Kosheela Devi Poo Palam is a Ph.D. student in Environmental and Life Sciences who is working on palm oil based polymers and is supervised by Dr. Narine. Kosheela is originally from Kuala Lumpur, Malaysia.

### **Exchange Students and Visiting Scholars 2014-2015:**

1. Hernane da Silva Barud, Visiting Professor, University of Araraquara (UNIARA), Brazil
2. Sangeetha Nair, Visiting Professor from Mahatma Gandhi University, India

### **Summer and Undergraduate Students 2014-2015:**

1. Phillip Weeber, University of Waterloo, Crystallization of TAGs, Phase change materials
2. Cameron Maltman, Lakefield College School, Characterization of polymers from vegetable oil
3. Chandini Singh, Queens College – Georgetown, Monomeric materials from vegetable oils

4. Asif Mahamad, Queens College – Georgetown, Monomeric materials from vegetable oils
5. Kaitlyn Pinkett, Trent University Undergraduate, working on CLICK Chemistry Polymers
6. Sunil Mahato, University of Virginia Undergraduate, working on Crystallization of Lipids
7. Mark Baker, University of Western Ontario Undergraduate – working on Materials Science, Phase Behavior of Methyl Esters and Triacylglycerols
8. Benjamin McPhail, Trent University Undergraduate, working on Materials Science, CLICK Chemistry Polymers
9. Jennifer Morgan, Trent University Undergraduate, working on Materials Science, Modification of Nanocellulose for Enhanced Miscibility in Hydrophobic Polyurethane Matrices.

## **Linkages and Networks:**

### **1. Industry**

The following companies toured the facilities at Trent and held discussions with our team:

1. Grain Farmers of Ontario – this organization represents some 23, 000 farmers in Ontario whose markets are affected by our research activities. They are a major funder of our program and visited and interacted with the research team four times during this reporting period.
2. Elevance Renewable Sciences – this is our other main industrial partner, with multiple projects underway. We have monthly meetings with this group.
3. Swish – a local industry which manufactures cleaners and the research group met approximately three times during the reporting period to investigate possible collaborations.
4. Northwater Capital – Toronto-based intellectual capital investment firm. This firm has now become a funder of our research program and we met with them approximately three times during the reporting period. We are currently in the process of filing two joint patents with this company.

### **2. Government Ministries**

Staff from the Ontario Ministry of Agriculture, Food and Rural Affairs toured our facilities and held feedback discussions with our staff:

### **3. Enabling Organizations**

Ontario Bioproducts A team has toured our facilities and engaged with our staff. The Bioproducts A Team is a specialized business-savvy biomaterials team providing solutions for industry. This organization was put together by a number of university professors working in the biomaterials area, under the leadership of Ontario Agri-Food

Technologies (OAFT). We have been an integral part of this team, and have had numerous meetings with our counterparts across the country.

#### **4. Universities**

In addition to the above stakeholders, including the universities represented in the Ontario Bioproducts A team, we have also developed close collaborative and communication relationships with the following Professors at other universities:

1. Professor Mohini Sain, University of Toronto (we have had numerous visits from Professor Sain and his group and have visited his facilities at University of Toronto numerous times).
2. Professors Misra and Mohanty, University of Guelph (we have had several meetings with these stakeholders, from the University of Guelph, and have participated in their workshops).

#### **5. International Collaboration Activities**

A number of international collaborations have been set up a part of the Chair's program:

##### **1. India**

Mahatma Ghandi University, Kerala, India

Activity Description: Regular graduate student exchanges and a number of collaborative projects related to bioplastic/nanofibre composites are being actively pursued.

##### **2. Brazil**

Universidade Estadual de Paulista (UNESP), Botucatu, Brazil

Activity Description: The collaboration with the Universidade Estadual de Paulista (UNESP) in Botucatu, Brazil, is focused on projects related to biomedical plastics for body implantation and bioplastics/fibre composites. Student and faculty exchanges have begun around a joint research project between the University of Toronto, UNESP, and Trent University, focused on the study of lightweight bio-sourced plastics for automotive applications (in addition to student and faculty exchanges, Trent University through the Chair's program, the University of Toronto, and UNESP has been successful in securing funding from the Canada-Brazil Research Partnerships Program, and this is resulting in increased collaboration among these universities).

##### **3. Malaysia**

Activity Description: Collaboration is with the Malaysian Palm Oil Board (MPOB), focused on materials for the edible and industrial uses of palm oil. The collaborative projects are between Professor Narine and Dr. Hazima Binti Abu Hassan, Director, Malaysian Palm Oil Board, Kuala Lumpur. There have been multiple visits between the two facilities and a number of projects are underway.

4. Barbados

University of the West Indies, Cave Hill, Barbados. Major collaborative projects are underway in the areas of green chemistry between UWI and Trent, and Professors Narine and Tinto.

5. Israel

Hebrew University, Jerusalem, Israel

Activity Description: There is a research program in collaboration with the Casali Institute for Applied Chemistry at the Hebrew University in Jerusalem, Israel. Collaboration is focused on crystallization of lipids and specialty waxes, gels and polymers (we have had faculty visits from this university and Professor Narine has also visited the Hebrew University. A number of crystallization-based projects have been established).

6. Guyana

Activity Description: The Chair's program is closely aligned with projects at the Institute of Applied Science and Technology (IAST) in Guyana, South America, which is also directed by Professor Narine. Under the rubric of a memorandum of understanding between Trent University and the IAST, there are regular exchanges between graduate students enrolled in the Chair's program and the institute.

**Measures to Publicize and Share Research with Public and Policy Makers:**

**Interviews and Media Relations**

During the reporting period, most of the media interactions occurred in Guyana:

1. 2013-08-26 – Activated carbon from coconut shells, a viable alternative to mercury – 10<sup>th</sup> Biannual Mining and Quarrying Conference at the Guyana International Conference Centre.
2. 2013-08-14 – Guyana faces dark future without hydropower – National Economic Forum at Guyana International Conference Centre, Liliendaal.
3. 2013-07-25 – Seeking Stakeholders' Input on how IAST can service the Private Sector – Meeting hosted at the University of Guyana Board Room by IAST.
4. 2013-07-18 – The importance of collaborating with the Private Sector – Meeting hosted at IAST's Turkeyen headquarters.
5. 2013-04-15 – The importance of an Energy Policy – National Economic Forum held at the Guyana International Conference Centre.
6. <http://guyanachronicle.com/indigenous-producers-receive-quality-assurance-training/>
7. <http://www.gina.gov.gy/home/index.php/home/all-news/item/4428-indigenous-producers-receive-quality-assurance-training-at-ia-st-labs-via-partnership-with-ministry-of-social-cohesion>

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