

Geoffrey Rivers, PhD Mech Eng (Nano), MSc Matls

CONTACT INFORMATION

Advanced Manufacturing Building,
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RESEARCH INTERESTS

Interested in “active” and “functional” materials for use in advanced manufacturing, including additive manufacturing, focusing on nanocomposites and polymers. Includes nanocomposite structure-process-property relationships, nanoparticle synthesis and functionalization, nanoparticle joining and oriented attachment, thermoset curing, UV-polymerization, the glass transition, nano- to macro-scale property relationships, and the influence of environmental exposure and ageing on mechanical properties. Additive manufacturing experience based in ink-jet printing.

EDUCATION

University of Waterloo, Waterloo, Ontario CAN **June 2017**

Ph.D., Mechanical and Mechatronics Engineering (Nanotechnology),

- Thesis Topic: “Cure and Conductivity: Investigation of Thermal Processing of Silver Nanobelt-Epoxy Composites”
- Advisors: Pearl Lee-Sullivan, PhD and Boxin Zhao, PhD

McMaster University, Hamilton, Ontario CAN **January 2011**

MSc, Materials Science and Engineering,

- Thesis Topic: “Cyclic Fatigue Behaviour of Wrought AZ80 Magnesium Alloy from Forged Automotive Wheel”
- Advisor: Marek Niewczas, PhD

BEng, Mechanical Engineering,

May 2008

PROFESSIONAL EMPLOYMENT

University of Nottingham, Nottingham, Nottinghamshire UK

Post-doctoral Research Fellow

July, 2019 - Present

Experimental research developing transparent functional inks for ink-jet Additive Manufacturing; collaborating towards fully-printed multi-component electronic devices. Functional properties of interest include: electrical conductivity, semi-conductivity, ionic conductivity, and dielectric constant; utilizing materials that thicken or solidify *via* UV-polymerization, dynamic bonding, and physical gel formation.

University of Waterloo, Waterloo, Ontario CAN

Post-doctoral Researcher

August, 2018 - May, 2019

Self-directed research developing multiple novel functional and structural materials. Focuses include nanocomposites, nanoparticle inks, nanometal aerogels, and durability of manufactured high-performance composite laminates. Joint position in the Surface Science & Bio-nanomaterials Laboratory, Chemical Engineering, and the Impact Mechanics and Material Characterization Group, Mechanical Engineering.

Visiting Scholar

May, 2017 - July, 2018

Supporting research projects focused on functional material development. Joint position in the Surface Science & Bio-nanomaterials Laboratory, Chemical Engineering, and the Impact Mechanics and Material Characterization Group, Mechanical Engineering.

Refereed Journal Articles

Yu L., Peng R., **Rivers G.**, Zhang C., Si P., Zhao B., Multifunctional Liquid Crystal Polymer Network Soft Actuators, *Journal of Materials Chemistry A*, 8, 3390-3396, 2020. DOI: 10.1039/C9TA12139K

Rivers G., Cronin D., Influence of moisture and thermal cycling on delamination flaws in transparent armor materials: Thermoplastic polyurethane bonded glass-polycarbonate laminates, *Materials & Design*, 182, 108026, 2019. DOI: 10.1016/j.matdes.2019.108026

Rivers G., Yu L., Zhao B., Cellulose Nanocrystal and Silver Nanobelt Gel: Cooperative Interactions Enabling Dispersion, Colloidal Gels, and Flexible Electronics, *Langmuir*, 35, 48, 15897-15903, 2019. DOI: 10.1021/acs.langmuir.9b02003

Yang F.K, Cholewinski A., Yu L., **Rivers G.**, Zhao B., A hybrid material that reversibly switches between two stable solid states, *Nature Materials*, 18, 874-882, 2019. DOI: 10.1038/s41563-019-0434-0

Yu L., Shahsavan H., **Rivers G.**, Zhang C., Si P., Zhao B., Programmable 3D Shape Changes in Liquid Crystal Polymer Networks of Uniaxial Orientation, *Advanced Functional Materials* 1802809, 2018. DOI: 10.1002/adfm.201802809

Rivers G., Lee-Sullivan P., Zhao B., How Interface Compatibility Affects Conductivity Evolution of Silver Nanobelts-filled Electrically Conductive Composites During Cure and Post-Treatments, *Physical Chemistry Chemical Physics* 20, 17999-18008, 2018. DOI: 10.1039/C8CP01875H

Rivers G., Lee-Sullivan P., Zhao B., Vitrification During Cure Produces Anomalies and Path-Dependence in Electrical Resistance of Conductive Composites. *Composites Science and Technology* 149, 90-99, 2017. DOI: 10.1016/j.compscitech.2017.06.011

Marzbanrad A.E., **Rivers G.**, Rogalsky A., Lee-Sullivan P., Zhao B., Zhou N.Y., Highly Repeatable Kinetically-Independent Synthesis of One-and Two-Dimensional Silver Nanostructures by Oriented Attachment. *RSC Advances* 6 (66), 61641-61649, 2016. DOI: 10.1039/C6RA08031F

Rivers G., Marzbanrad A.E., Hook M.D., Lee-Sullivan P., Zhou N.Y., Zhao B., Highly-Stable Silver Nanobelts Joined *via* Diffusion-Free Attachment. *Nanotechnology* 27 (29), 295606, 2016. DOI: 10.1088/0957-4484/27/29/295606

Marzbanrad A.E., **Rivers G.**, Peng P., Zhao B., Zhou N.Y. How Morphology and Surface Crystal Texture Affect Thermal Stability of a Metallic Nanoparticle: the Case of Silver Nanobelts and Pentagonal Silver Nanowires. *Physical Chemistry Chemical Physics* 17 (1), 315-324, 2015. DOI: 10.1039/c4cp04129a

Amoli B.M., Trinidad J., **Rivers G.**, Sy S., Russo P., Yu A., Zhou N.Y., Zhao B., SDS-Stabilized Graphene Nanosheets for Highly Electrically Conductive Adhesives, *Carbon* 91, 188-199, 2015. DOI: 10.1016/j.carbon.2015.04.039

Rivers G., Rogalsky A., Lee-Sullivan P., Zhao B., Thermal Analysis of Epoxy-Based Nanocomposites: Have Solvent Effects Been Overlooked?, *Journal of Thermal Analysis and Calorimetry* 119 (2), 797-805, 2015. DOI: 10.1007/s10973-013-3613-2

Refereed Conference Proceedings

Rivers G., Lee-Sullivan P., Zhao B., Chen A., Persic J., Lyn R., *In-situ* Resistance Characterization During Cure Progression of a Conductive Adhesive, ICSR (Soldering and Reliability) 2016 Confer-

ence Proceedings, (6 pp.), 2016. URL: <http://remapnetwork.org/wp-content/uploads/2018/05/37-Copy-of-Rivers-ICSR-paper-Submission-Version.pdf>

Manuscripts in Submission

Si P., Jiang F., Cheng Q.S., **Rivers G.**, Kyaw A.K.K., Zhao B., Triple non-covalent dynamic bonds enabled tough and rapid room temperature self-healing elastomer for next generation soft antenna, *Journal of Materials Chemistry A. (Paper)*

HONORS AND AWARDS

QEII-GSST - Plumtree Graduate Scholarship in Mechanical and Mechatronics Engineering, 2014.

Attendees' Choice for Best Presentation, 23rd CTAS Annual Workshop and Exhibition, Oshawa, Canada, May 2013.

CONFERENCE PARTICIPATION

Conference Contributions:

Rivers G., Sirois A., Cronin D., Influence of Moisture and Thermal Cycling on Delamination in Coupon Scale Glass-TPU-PC Transparent Armour Materials, 3rd Workshop on Ageing effects in protective systems, components and materials, French-German Research Institute of Saint-Louis, Saint-Louis Cedex, France, October 2019. (*Presentation*)

Rivers G., Lee-Sullivan P., Zhao B., Path-Dependence in Evolution of Electrical Conductivity in Curing Hybrid Nanocomposites: Important Effects Revealed When Studying Silver Nanobelts in a DGEBA/TETA Epoxy Matrix, 18th European Conference on Composite Materials, Athens, Greece, June 2018. (*Presentation*)

Rivers G., Lee-Sullivan P., Zhao B., Silver Nanobelts: Capping Agent Influence on Synthesis and Annealed Joining., 3rd International Conference on Nanojoining and Microjoining, Niagara Falls, Canada, September 2016. (*Poster*)

Rivers G., Lee-Sullivan P., Zhao B., In-Situ Characterization Method of Sheet Resistance for Conductive Adhesives During Cure. 10th International Conference on Soldering and Reliability, Toronto, Canada, May, 2016. (*Presentation*)

Rivers G., Rogalsky A., Lee-Sullivan P., Zhao B., Misinterpretation of Cure Data Analysis in Epoxy-Based Nanocomposites. 23rd CTAS Annual Workshop and Exhibition, Oshawa, Canada, May 2013. (*Presentation*)

Conference Organizing:

Conference Technical and Venue Organizer, 3rd International Conference on Nanojoining and Microjoining, Niagara Falls, Canada, September 2016.

TALKS AND PRESENTATIONS

Invited Talks

Rivers G., "Cure and Conductivity: Silver Nanobelts and Epoxy Nanocomposites", Ellison Research Group, University of Minnesota Department of Chemical Engineering and Materials Science, September 2017.

Campus or Departmental Talks

Rivers G., Lee-Sullivan P., Zhao B. "Silver Nanobelts in Conductive Nanocomposites", 2014 CAMJ International Workshop on Advanced Materials Joining and Processing, University of Waterloo, October 2014.

Contributed Presentations

Rivers G., Singh D., Sathananthan P., Cronin D., “DND/NSERC Transparent Armor: Delamination Investigations”, Prelco Inc, General Dynamics Land Systems-Canada, DRD-Canada, NRC-Canada, 2019.

Rivers G., Singh D., Sathananthan P., Cronin D., “Experimental Update for DRDC Studies on Delamination”, Prelco Inc, General Dynamics Land Systems-Canada, DRD-Canada, NRC-Canada, 2018.

Rivers G., Singh D., Sathananthan P., Ghoreshi A., Cronin D., “Mechanical Testing: Delamination in Armor Composite Coupons (4)”, Prelco Inc, General Dynamics Land Systems-Canada, DRD-Canada, NRC-Canada, 2018.

Rivers G., Singh D., Sathananthan P., Cronin D. “Mechanical Testing: Delamination in Armor Composite Coupons (3)”, Prelco Inc, General Dynamics Land Systems-Canada, DRD-Canada, NRC-Canada, January 2018.

Rivers G., Singh D., Sathananthan P., Cronin D. “Mechanical Testing: Delamination in Armor Composite Coupons (2)”, Prelco Inc, General Dynamics Land Systems-Canada, DRD-Canada, NRC-Canada, December 2017.

Rivers G., Singh D., Sathananthan P., Cronin D. “Mechanical Testing: Delamination in Armor Composite Coupons (1)”, Prelco Inc, General Dynamics Land Systems-Canada, DRD-Canada, NRC-Canada, October 2017.

Rivers G., Zhao B., “Silver Nanobelts:Synthesis and Composites Update”, Celestica Inc and Microbonds Inc., October 2016.

Rivers G., Zhao B. “Conductive Nanocomposite Development During Curing: Filler Interaction/Sintering and In-Situ Measurement”, ReMap Project with Celestica Inc. and Microbonds Inc., March 2016.

Rivers G., Lee-Sullivan P., Zhao B. “Behaviour of Silver Nanobelts in Mixing and Curing Processes”, Celestica Inc. and Microbonds Inc., June 2015.

Rivers G., Lee-Sullivan P., Zhao B. “Behaviour of Silver Nanobelts in Mixing and Curing Processes”, Celestica Inc. and Microbonds Inc., June 2014.

Rivers G., Lee-Sullivan P., Zhao B. “Thermal Analysis of Electrically Conductive Nanocomposites”, Celestica Inc. and Microbonds Inc., September 2013.

Rivers G., Lee-Sullivan P., Zhao B. “Curing Analysis for Electrically Conductive Nanocomposites”, Celestica Inc. and Microbonds Inc., November 2011.

TEACHING EXPERIENCE

Mentorship

Maggs E.M., Undergraduate Research Assistant, 4 Month Placement, Surface Science & Bio-nanomaterials Laboratory, Chemical Engineering, 2019.

Ma Y., Mitacs Program Research Intern Student, 4 Month Placement, Surface Science & Bio-nanomaterials Laboratory, Chemical Engineering, 2018.

Kesavan Y., Undergraduate Research Assistant, 4 Month Placement, Impact Mechanics and Material

Characterization Group, Mechanical Engineering, 2018.

Kesavan Y., Undergraduate Research Assistant, 4 Month Placement, Advanced Composites and Adhesives Thermal Analysis Lab, 2015.

Reed M., Undergraduate Research Assistant, 4 Month Placement, Advanced Composites and Adhesives Thermal Analysis Lab, 2015.

Silvaroli A., Undergraduate Research Assistant, 4 Month Placement, Advanced Composites and Adhesives Thermal Analysis Lab, 2015.

Teaching Assistant

Thermodynamics of Multicomponent Systems, McMaster University, Fall 2009.

Mechanical Behaviour of Materials, McMaster University, Fall 2008.

SERVICE TO PROFESSION

Manuscript Peer Review:

IPOL-D-20-00181, "Influence of Temperature, Humidity and Infrared Radiation on Transparency of Armoured Glass", Iranian Polymer Journal, June 2020.

MLBLUE-D-18-04177 and -R1, "Forming of Silver Nano-Ribbons with Supersonic Pressure Process", Materials Letters, August and September 2018.

JTAC-D-16-01079, "Optimization of Thermo-Mechanical Performance of Epoxy Nanocomposites Containing Surface Modified Graphene Nanosheets using Statistical Analysis", Journal of Thermal Analysis and Calorimetry, December 2016.

JTAC-D-15-01393, "Epoxy-Matrix Composites Filled with Surface-Modified SiO₂ Nanoparticles", Journal of Thermal Analysis and Calorimetry, December 2015.

JTAC-D-15-00952 and -R1, "Influence of Graphene Nanoplatelets on Curing and Mechanical Properties of Graphene/Epoxy Nanocomposites", Journal of Thermal Analysis and Calorimetry, August and November 2015.

JTAC-D-15-00367, "Fractography and Oxidative Thermal Degradation Studies of Novel 'Core-Shell' Clays Filled Epoxy Composites", Journal of Thermal Analysis and Calorimetry, March 2015.

JTAC-D-14-00869, "Influence of Micro Silver Flakes on the Heat Curing Kinetics of Electrically Conductive Adhesives", Journal of Thermal Analysis and Calorimetry, January 2015.

SKILLS AND EXPERIENCE

Materials and Research Areas

- Composites and nanocomposites, thermosetting cure in composites, nanoparticle synthesis (shape-control, and growth), metallic nanoparticles (especially silver nanobelts), organic nanoparticles (especially cellulose nanocrystals), self-assembly, shape memory polymers, vitrimers (dynamically covalent bonded polymer networks), hydrogels (polymer matrix, as well as nanoparticle-only colloid gels), sol-gels (including sal-gels), polymer physics.
- Thermal analysis, process-structure-property relationships, electrical conductivity, hygrothermal aging, mechanical analysis, crystallography, dislocation evolution in metals under strain.

- Additive manufacturing: formulation and evaluation of novel fluids for use in ink-jet 3D printing. Development of inks with functional properties such as electrical conductivity while transparent and dynamic molecular bonding.

Equipment and Techniques

- *Thermal Analysis Equipment and Techniques:* Differential scanning calorimetry (MTDSC), dynamic mechanical analysis (DMTA), thermo-mechanical analysis (TMA), thermogravimetric analysis (TGA). Includes calorimetry common for studying thermoset polymers and composites (cure rate, progression, glass transition properties), modelling of cure kinetics, mechanical development from hygrothermal aging and thermal cycling, dilatometry and thermal expansion.
- *Analytical Methods and Equipment:* Scanning electron microscopy (SEM: Zeiss Leo 1530 and UltraPlus FESEMs), 2- and 4-wire electrical characterization (including *in-situ* methods during composite curing using custom probes), particle size distribution, *in-situ* pH and light transmittance characterization of a non-equilibrium reaction mixture, oscillating rheology, hyperfrequency visco-elastic spectroscopy (Rheolution RheoSpectris C500+), uniaxial tensile testing, mechanical fatigue testing, High Throughput Screening methodology for inkjet fluid formulation (automated bulk measurement of surface tension and rheology, *via* customized Hamilton Microlab Star liquid handler).
- *Additive Manufacturing Equipment and Techniques:* Fujifilm Dimatix DMP-2850 Inkjet printer, PiXDRO LP50 multihead (2) inkjet printer, PiXDRO Toucan multihead (6) industrial inkjet printer.
- *Research Design and Support:* Statistical design and analysis of experiments: linear and non-linear regression analysis, multi-response estimation, design of experiments including factorial and optimal design. Design and fabrication of specialized analytical equipment. Chemical wet lab experience.
- *Specimen Preparation:* for microscopy (SEM, TEM, tapping mode AFM) and all thermal and mechanical analysis methods listed above.