2024

First Quarter

PTC Newsletter

Polymer Technology Consortia

UPCOMING EVENTS

Mark Your Calendars for the PTC Fall meetings!

Scratch Behavior of Polymers Consortium-SCRATCH	Polymer Technology Industrial Consortium-PTIC
SCRATCH SPRING meeting-TBA	PTIC SPRING meeting-April 18th & 19th, 2024 Texas A&M University-College Station, TX

Inside the Newsletter

Electric Fields for Heating Polymer Composites

MICAH GREEN

Chemical Engineering

Dr. Micah Green's group in the Artie McFerrin Department of Chemical Engineering has developed a number of devices that can apply an electric field to polymer composites. Certain fillers (including carbon fiber and carbon nanotubes) rapidly heat up in response to these electric fields. The ability to heat materials out-of-oven presents a number of exciting new processing techniques for polymer composites.

For example, the Green group used electric fields generated by a Dielectric Barrier Discharge generated plasma to heat, cure, and patch damaged composites (Figure 1). When a composite is damaged, an epoxy-impregnated patch can be applied to the cracked area. Normally such a patch would require an oven or a heat blanket, but instead, a simple plasma applicator is able to induce an electric current and heat the fibers inside the patch. A ~78% increase in ultimate tensile strength of the DBD-repaired sample was observed compared to the damaged sample. (This work was published here: https://doi.org/10.1016/j.apmt.2023.101821)

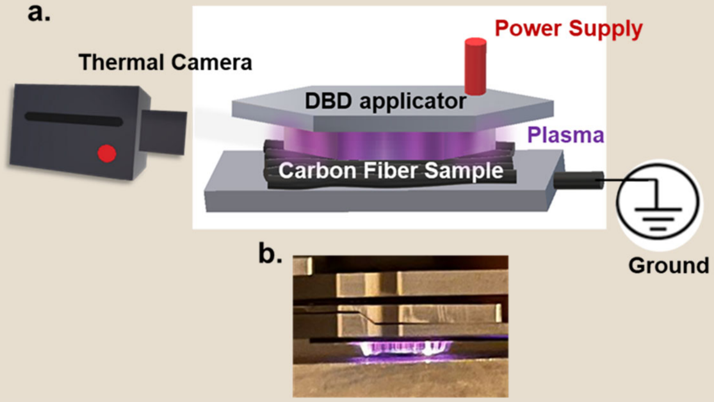

Figure 1: (a) Schematic of Dielectric Barrier Discharge (DBD) applicator connected to a power supply and generating an electric field plasma. The plasma induces electric currents in the carbon fiber sample, thus generating heat. A thermal camera records the maximum temperature reached by the sample. (b) Digital image of a carbon fiber composite sample exposed to plasma.

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Dr. Micah Green, CHEN

Intriguingly, at even higher temperatures, applied electric fields can actually cause parts to reach temperatures so high that the matrix will be degraded away. This is actually desirable for recycling continuous carbon fibers from end-of-life thermoset composite parts. The Green group and Naraghi groups at TAMU (along with collaborators at TRI Austin and the University of Washington) used a Joule-heating process to rapidly heat and degrade the polymer matrix away. This process addresses the longstanding challenge of efficiently recovering carbon fibers from composite scrap and reusing them to make fresh composites. Fibers reclaimed using this method were characterized to determine their tensile properties and surface chemistry, and compared against both as-received fibers and fibers recycled using conventional oven pyrolysis. The DC- and oven-recycled fibers yielded similar elastic modulus when compared against as-received fibers; however, we observe a ~10-15% drop in the tensile strength of fibers recycled using either method. Surface characterization showed that DC-recycled fibers and as-received fibers had similar types of functional groups. To demonstrate the reusability of recycled fibers, composites were fabricated by impregnation with epoxy resin and curing. The mechanical properties of these recycled carbon fiber composites (rCFRCs) were compared against conventional recycling methods, and similar modulus and tensile strength values were obtained. This study establishes DC heating as a scalable out-of-oven approach for recycling carbon fibers. (This work was published here: https://doi.org/10.1002/cssc.202200989)

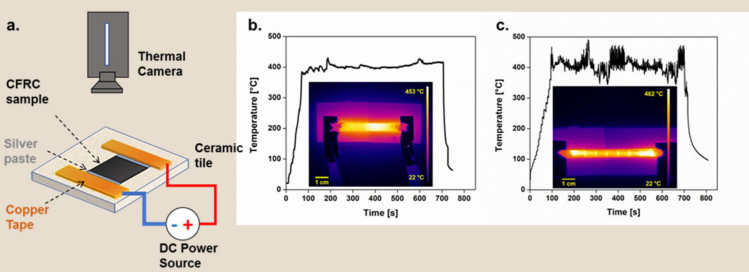

Figure 2: (a) Schematic of DC heating setup. Carbon fiber-reinforced composite (CFRC) sample (black) is placed on the ceramic tile; electrical contact is established using copper tape and conductive silver paste. The sample is connected to a DC power source using alligator clips; temperature is monitored using a thermal camera. (b) Time-temperature data (inset: thermal image from FLIR at t = 200 s) during DC heating of cross-weaved IM7 and (c) unidirectional IM7 composite.

These are just two examples of how conventional composite processing can be carried out via electric fields. The Green group continues to apply these techniques not only to carbon fiber composites, but also nano-filled composites as well, often in conjunction with other processing techniques such as 3D printing.

Shape memory polymers for biomedical applications and the importance of mentorship in research

Courteney T. Roberts, Mabel Prejean, and Melissa Grunlan
Department of Biomedical Engineering

Dr. Melissa Grunlan, Professor in the Department of Biomedical Engineering, and her research group are dedicated to creating polymeric biomaterials for the next generation of medical devices and regenerative engineering applications. A central project is the development of shape memory polymer (SMP) scaffolds to heal complex bone defects. More recently, this platform has been leveraged to develop other shape actuating devices, including gynecological stents.

Cranial bone defects of irregular geometries are challenging to treat due to the inability of biologic and alloplastic grafts to achieve good bone-to-graft contact. Regenerative engineering is an attractive alternative, but requires a resorbable scaffold that is able to achieve conformal fit, as well as other key properties (e.g., porosity, degradation, and rigidity). To meet this challenge, the Grunlan Lab has developed "self-fitting", thermo-responsive shape memory polymer (SMP) scaffolds. In earlier studies, such biodegradable scaffolds were prepared from *linear*-poly(e-caprolactone)-diacrylate (***linear*-**PCL-DA, M_n ~ 10k g/mol) (Zhang *et al*., Acta Biomaterialia 2014). A solvent-casting, particulate leaching (SCPL) process with a fused salt template afforded ***10kℓ*** scaffolds with the targeted pore size (~200 µm) and pore interconnectivity. The melting temperature of the ***10kℓ*** scaffold (T_m ~55 °**C)** of PCL scaffold lamellae ("switching segments") serves as the

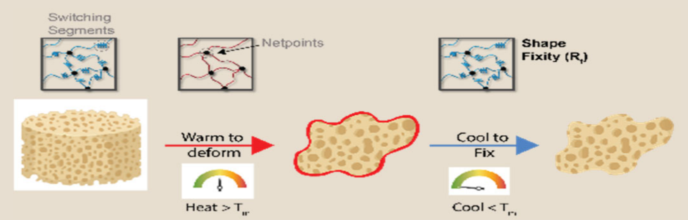

***Figure 1**. Process of using "self-fitting" shape memory polymer (SMP) scaffolds to fill irregular bone defects.*

actuation temperature. Thus, when these scaffolds are heated above its T_m (T > 55 °C), the crystalline lamellae melt causing the scaffold to become malleable and able to be press-fit into an irregular bone defect (Fig. 1). When the scaffold is cooled to body temperature (T < 55 °C), the scaffold returns to its rigid state in the new, fixed shape. Owing to this conformal fit, these scaffolds have demonstrated promising potential to heal bone defects **(**Pfau *et al*., Acta Biomaterialia 2021)**.**

Current work is focused on lowering the shape actuation temperature (T_m) of these scaffolds. When used to treat bone defects, a T_m of 55 °C precludes the use of 55 °C saline at the surgical site to prolong the working time as this may cause tissue necrosis. In other applications, it is desirable for shape recovery to occur at body temperature (i.e., when implanted). For instance, this would be the case for devices implanted in a temporary (fixed) shape such as self-expanding stents as well as self-closing sutures. Thus, we have leveraged PCL macromers having a star architecture and of reduced molecular weight (M_n) to produce PCL scaffolds with systematically lower T_m values: 37 °C < T_m < 55 °C [self-fitting bone scaffolds] and T_m ≤ 37 °C [self-expanding stents, etc.] UV-curable PCL macromers were prepared with linear or 4-arm star architectures and with M_ns of 10k, 7.5k, and 5k g/mol, and used to

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Dr. Melissa Grunlan, BMEN

used to fabricate six porous scaffold compositions (**10kℓ, 5kℓ, 5kℓ, 10k★, 7.5k★**, and **5k★**). The thermal profiles of these scaffolds were determined

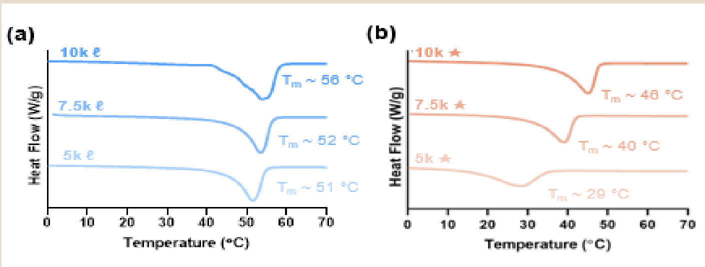


Figure 2. *DSC thermograms and resulting T_m values (midpoint) of for (a) linear- scaffolds of decreasing M_n, and (b) star- scaffolds compositions of decreasing M_n.*

(Fig. 2). For *linear-* scaffolds, the T_m values did not vary substantially with reduced M_n. In contrast, *star-* scaffolds of exhibited pronounced decreases in T_m as M_n was decreased. Thus, *10k*★ and *7.5k*★ meet the requirement for tissue-safe bone scaffolds, while the *5k*★ meets the target for self-expanding stents (Fig. 2). Because of the associated decrease in % crystallinity, the *star-* scaffolds also exhibited relatively faster rates of degradation during *in vitro* assessments. Because the slow degradation rate conventional PCL limits new bone tissue ingrowth, the faster degradation rates of *star-* scaffolds should enhance bone regeneration. Faster degradation rates are also useful for implanted devices.

These recent efforts have been led BME students, Courteney Roberts (Ph.D. candidate) and Mabel Prejean (undergraduate student). Roberts recently presented this work at the 2023 Fall Materials Research Society (MRS) Meeting in Boston. Roberts’ mentorship of Prejean was essential to achieving research outcomes. Mentoring activities focused on central themes of technical skills and critical analysis, as well as communication and teamwork. As a graduate student mentor, Roberts wanted to emulate her own current and past mentors who have impacted her journey as an academic researcher. These mentors demonstrated knowledge and patience, while also providing academic and professional guidance. The mentor-mentee relationship between Roberts and Prejean has turned into more of a partnership based on open communication, teamwork, and a love for science! Mentees such as Prejean bring a fresh, new perspective, enthusiasm, and innovation to research. This is shown through Prejean’s initiative to create and present a poster at 2023 PTIC poster session which in turn prompted her to complete an honors thesis. This mentorship dynamic allows for a symbiotic process of growth, learning, and development between the graduate and undergraduate researcher.

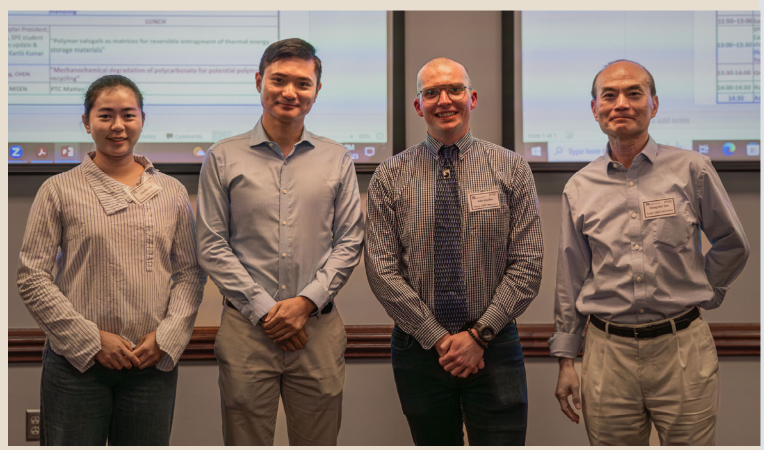
SPE South Texas section

SPE Fall 2023 scholarship recipients recognized

PTC is excited to announce the SPE scholarship recipients for FALL 2023. These students were recognized at the PTIC Consortium meeting on Friday, October 13th, 2023. Mr. Parvin Purvin Shah, MSEN Graduate Candidate, received the SPE Henry Kahn Scholarship. And Taeseung Hwang MSEN Graduate candidate received the SPE Dale Walker memorial scholarship. Taeseung Hwang was not present for picture.

The PTIC student poster session was held on October 12th—13th, 2023 with the following students placing in the event.

PLACE MENT	STUDENT	MAJOR	POSTER TITLE
1st place	Dacheng Kuai	CHEN	"Electron-Induced Electrolyte Degradation and Polymerization near Lithium Metal Anode"
2nd place	John Hoefler	CHEM	"Surface-Assisted Selective Oxidation of Phosphines with Air"
3rd place	Xiuzhu Zhu	MSEN	" Physical Aging Effect on Scratch Performance of Polycarbonate."



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The retired four-star general served as Bush School dean and as A&M's interim president.

Former Air Force Chief Of Staff Mark A. Welsh III Named 27th President Of Texas A&M

"The board is certain that General Welsh will make a Texas-sized impact as president of our world-class flagship," Chairman Bill Mahomes said. "His remarkable career embodies Aggie core values. Now his mission is to raise Texas A&M's national stature in research, education and student experience."

Welsh, who has been interim president since July, was named the board's sole finalist for president on Nov. 17 at the recommendation of John Sharp, chancellor of The Texas A&M University System.

"In his first few weeks as interim president, General Welsh has moved quickly and decisively to reach out to all the stakeholders who hold Texas A&M University dear and near to their hearts," Sharp said. "We are lucky to have such an experienced leader in our midst who supports our Aggie core values."

Full story: **https://bitly.ws/39aH5**

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Polymer Specialty Certificate Updates

Students that have applied for the Polymer Specialty Certificate	87
Students that have received the Polymer Specialty Certificate	75

For more information, please visit: http://ptc.tamu.edu/polymer-specialty-certificate/

Have Questions?

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