Betty A. and Donald J. Baumann Family Scholarship Fund Application Form

1. **Name and NetID**

Hannah Reynolds
hmr42006

2. **Chemistry faculty research director**

Dr. Stephen Gross

3. **Proposal title**

Composites containing biodegradable, polymeric ion-releasing fillers (PIRFs)

4. **Proposal description. Please limit the proposal to about 500 words and include figures as appropriate. Your proposal should briefly outline the overall project and its goal(s). If you have previous results related to your proposed project, concisely summarize those results and describe what you expect to accomplish during the time frame of the scholarship.**

Secondary caries is one of the biggest problems dentists deal with on a day-to-day basis. It is a disease caused by the incursion of bacteria and other acidic causing conditions in the margin between the tooth and existing fillings. In addition, the European Union has tightened restrictions on microplastics being disposed into the environment. The goal of this research is to develop biodegradable polymeric ion-releasing fillers (PIRFs) from renewable resources that can prevent these cavities from forming by releasing calcium ions over an extended period of time to aid in remineralization. The PIRFs are not only biodegradable but are also synthesized with renewable resources. These PIRFs were synthesized under a variety of synthetic conditions and colloids prepared with them were characterized by standard ISO tests such as degree of conversion, viscosity, and depth of cure measurements.

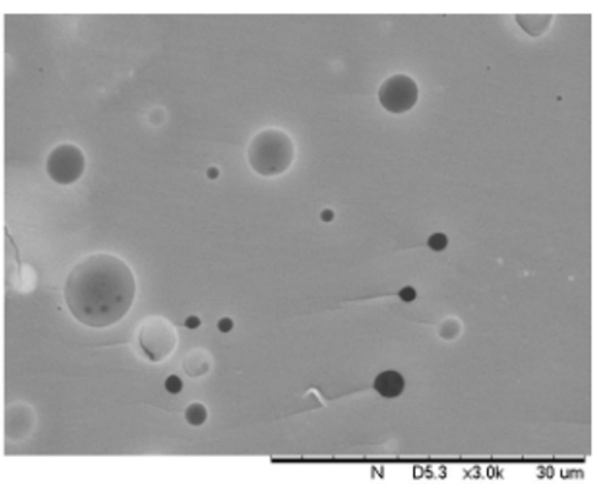

__Figure 1.__ SEM image of the cross section of a dental material containing biodegradable polymeric calcium ion releasing fillers.

PIRFs containing 5M calcium chloride ($CaCl_2$) were successfully synthesized under a variety of conditions in which the volume of $CaCl_2$ and sodium alginate, the emulsifying agent concentrations, and the shear rate of the reactor rotor were varied. From these different synthetic conditions, the stable PIRF yield and average PIRF sizes were measured.

When the shear rate of the rotor in the reactor was reduced below 1,884 s-1, a bimodal size distribution was produced. A fraction of macro-sized PIRFs were synthesized under those specific conditions. When the quantity of sodium alginate was doubled, the stable PIRF yield increased. An optimal concentration of emulsifying was discovered for maximum yield. To isolate the PIRFs after synthesis, the method of centrifugation was chosen. This resulted in the PIRFs separating from the supernatant and forming a pellet that was able to be isolated and incorporated in the various dental formulations. Scanning electron microscopy (SEM) was used to demonstrate that the PIRFs can withstand the shear force of formulation and centrifugation. The SEM images also demonstrate the PIRFs do not agglomerate on mixing in the formulation.

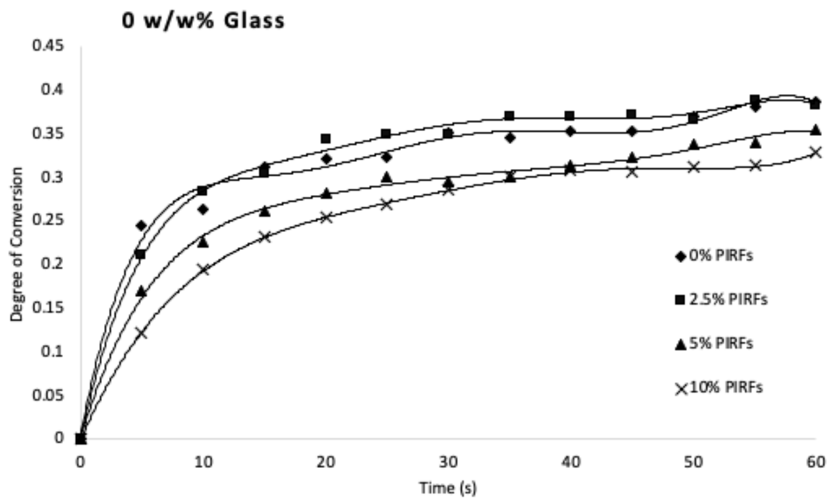

Figure 2. *The degree of conversion as a function of time for dental formulations with 50 w/w% glass filler and PIRF loading from 0 to 10 w/w%.*

A dental material needs to polymerize typically between 20-60 seconds in the oral environment. FTIR-ATR crystal was used to determine the polymerization kinetics for each of the dental materials loaded with the PIRFs (0-10 w/w%). Figure 2 shows the effect of the PIRFs on the degree of conversion for a composite with 0 w/w% glass filler. As the PIRF concentration increased, the rate of polymerization decreased, but typically to a level acceptable for use in a dental resin.

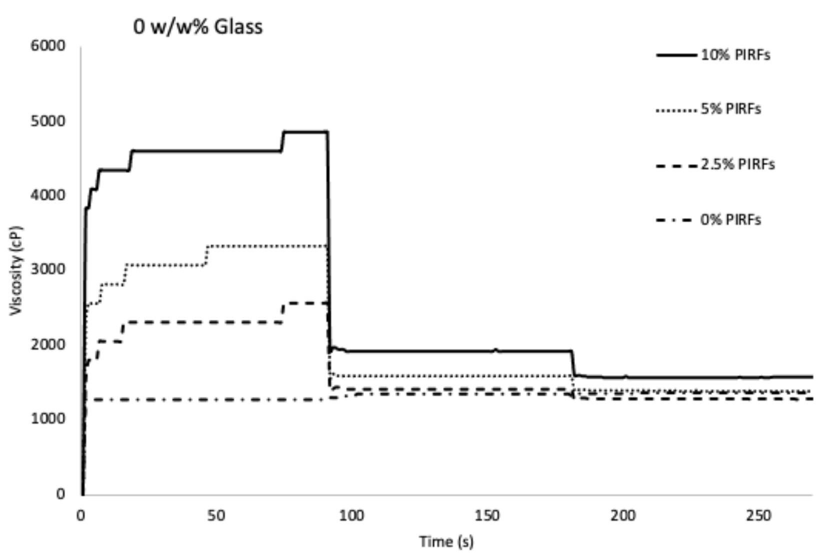

Figure 3. *The viscosity as a function of time of a dental formulation with 0 w/w% glass filler and PIRF loading from 0 to 10 w/w%.*

The handling characteristics of a dental material are very important to dentists. Due to this, it is necessary to understand the viscosity of these samples and how it will be altered when PIRFs are added. Figure 3 shows the viscosity of the colloid as a function of time w/w% loading PIRFs for a sample with 0 w/w% glass. As seen in Figure 3, the viscosity of the colloid increased as PIRF loading increased. The formulations appear to be non-Newtonian as a function of time, with the 10 w/w% PIRF loaded sample exhibiting much stronger pseudoplastic behavior as a function of time.

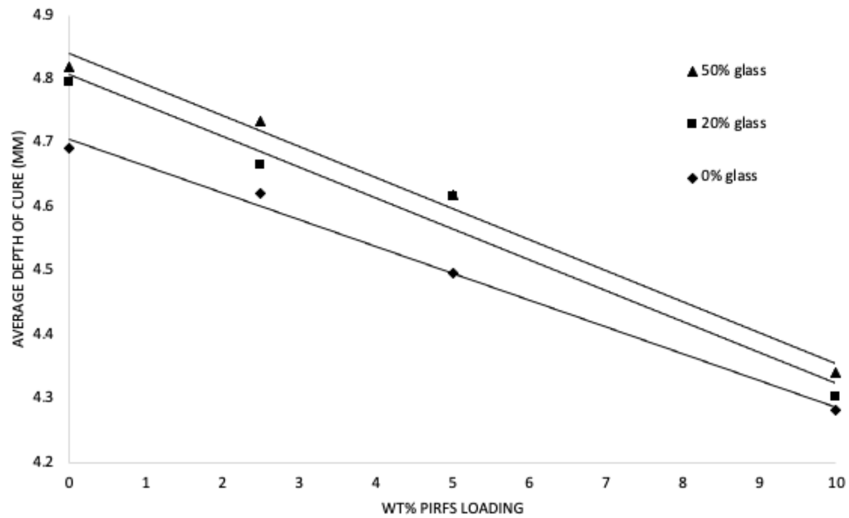

Figure 4. *The depth of cure (mm) as a function of PIRF loading is shown for dental formulations with 0-50 w/w% glass loading and 0-10 w/w% PIRF loading.*

Dental materials are typically no more than 2-4 mm thick in the oral environment. For the varying glass loading samples displayed in Figure 4, as PIRF loading increased, the average depth of cure of the material decreased. Within each PIRF loading sample, the three glass loading samples are statistically similar. All formulations, regardless of PIRF or glass loading had a depth of cure over 4 mm, which is above the standard for a typical dental material.

As mentioned previously, the handling characteristics of dental materials are very important. This also includes the behavior of the material after it has been cured in the oral environment. Future work on this project will include extending the characterization tests to examining the mechanical properties of a dental composite loaded with the PIRFs. This includes specifically testing the flexural strength and adhesion properties of a PIRF-loaded composite. These tests will be done with the same goal, to determine if the addition of higher PIRF loading will significantly alter the handling properties of a dental material. The effort of this research aims to improve the health benefits of current dental materials in an environmentally responsible manner, without significantly altering the physical properties of the material which could limit the use of the PIRFs.

5. **Presentation of research results (past and future conferences, publications, seminars, etc.)**

Publications

Reynolds, H., Bravo, B., Fulford, G., Martinez, A., Latta, M., Gross, S. Composites containing biodegradable, polymeric ion-releasing fillers. 2024. *Journal of the American Dental Association.* Submitted for review.

National and Regional Presentations

Reynolds, H., S. Gross. Synthesis and Characterization of Polymeric Ion Releasing Fillers. Poster presentation at ACS Fall 2024 National meeting, Denver, CO; August 18-22, 2024.

Reynolds, H., S. Gross. Synthesis and Characterization of Polymeric Ion Releasing Fillers. Poster presentation at ACS Midwest 2024 Regional meeting, Omaha, NE; October 13-15, 2024.

- Awarded the PMSE Undergraduate Student Best Poster Award

State and Local Presentations
Reynolds, H., S. Gross. Synthesis and Characterization of Polymeric Ion Releasing Fillers. Poster presentation at Creighton University Research week, Omaha, NE; March 26-27, 2024.

6. **Post-graduate plans (job market, graduate school, medical school, etc.)**

After graduation at Creighton, I plan to continue my education and attend graduate school in the Fall of 2025 to pursue a PhD in polymer chemistry. Afterwards, I plan to go into polymer chemical industry research.

7. **Number of semesters involved in research, including current semester (summers count as two semesters)**

Eight semesters

8. **Anticipated graduation date**

May 17th, 2025