

Baumann Scholarship Application 2021

1. Name and Net ID

Ben Schauer, bjs37248

2. Chemistry Faculty Research Advisor

Dr. Joel F. Destino

3. Title: Controlling Germania Nanoparticle Growth Kinetics using Surfactants**4. Project Proposal**

Germania is an important glass material that exhibits desirable qualities that conventional silica glasses lack, such as reduced light dispersion. Today, 3D printing and other additive manufacturing techniques may revolutionize the fabrication of optical glasses, allowing researchers to print ‘freeform optics’, or glasses whose function is independent of geometry.

A prerequisite to 3D printable glass is the creation of optimized inks for printing. 3D printable germania glasses are currently limited by a lack of stable, amorphous, colloidal GeO_2 precursors (stable germania nanoparticles suspended in solution) for inks. This research investigates novel approaches to controlling amorphous nanoparticle growth and stability using sugar alcohols (e.g., mannitol) as surfactants.

The central hypothesis is that polyols, which are well known for forming coordination complexes with $\text{Ge}(\text{OH})_4$ species in solution,^{1,2} should exhibit an affinity for hydroxyls present at the oxide surface, potentially coordinating covalently or via hydrogen-bonding interactions. This will change the particle

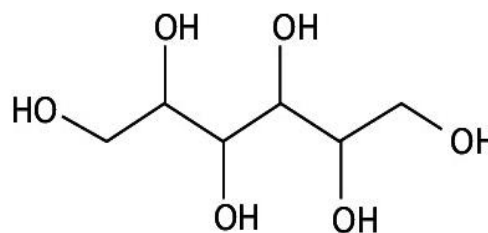


Figure 1. Mannitol chemical structure. Mannitol is the main surfactant of interest in this research project, although investigations with Sorbitol have begun as well. We hypothesize the terminal hydroxide groups react with the surface structures of the growing nanoparticles, chelating them and halting growth.

surface in a manner that stabilizes the colloid in solution, enabling their use as glass precursors. The hypothesis will be tested using surface-specific techniques to pinpoint key chemical interactions.

Dynamic light scattering (DLS) measurements comparing mannitol-germania solutions to control germania solutions have demonstrated the effectiveness of this approach in controlling particle sizing, as shown in Figure 2. The proposed research will use electron microscopy, X-ray photoelectron spectroscopy, and ATR-FTIR to elucidate the chemical interactions between mannitol and other polyols with GeO₂ colloid surfaces. Scanning probe microscopy and zeta-potential measurements will enable the physical and electrostatic characterization of surfactant interactions. The proposed research will explore the underlying research questions: How do surfactants interact with GeO₂ surfaces? Can mannitol, sorbitol, and other polyols serve as capping agents for GeO₂ nanoparticles to tune colloid formation and improve stability? How do these surfactants interact with the colloids, and what is the role of their structure here?

My previous work on GeO₂ nanoparticle growth has covered experimentation on many aspects of GeO₂ sol-gel reaction variables. The effects of varying mol percent water in solution, catalysts present, and initial alkoxide identity (tetraethoxygermane, tetrabutoxygermane, etc) on growth kinetics has been mapped extensively. Summer research made possible by the Dr. Randolph Ferlic grant elucidated which reaction conditions and time frames most suited optimal particle sizing. However, these particles are not stable and a method to fix particles at tunable sizes is highly relevant to this field and therefore the major interest of this project. Surfactants

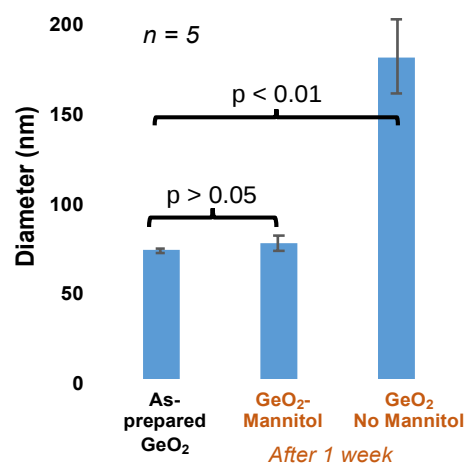


Figure 2. GeO₂-mannitol growth versus a control sample. Note the insignificant growth of the GeO₂-mannitol sample, in comparison to the control.

such as mannitol have so far shown to be very promising in this regard. My investigation will focus on more conclusively creating a stable GeO₂ colloid using surfactants. Results from these fundamental studies will ultimately elucidate the interactions between sugar alcohols and amorphous GeO₂ stability and help enable the fabrication of novel optical materials.

References:

- (1) Cluley, H. J. *Analyst* **1951**, 76 (906), 517–536.
- (2) Geffen, N. et al. *J. Memb. Sci.* **2006**, 286 (1), 45–51.

5. Presentation of Research Results

Past Presentations:

- July 28th, 2021 – All-Iowa Glass Conference student poster presentation (Coe College, Cedar Rapids IA)
- August 5th, 2021 – CURAS SURF end of summer poster presentations (Creighton University, Omaha NE)

Upcoming Presentations:

- November 15th, 2021 – Ferlic Fellows Poster Presentation (Creighton University, Omaha NE)
- March 20th - 24th, 2022 – ACS Conference (San Diego CA)

6. Post-graduate plans

I plan on taking a gap year to work as a research assistant, hopefully at a national lab. During this period, I will be applying to graduate schools; I intend to pursue a PhD. I am interested in synthetic organic chemistry for drug discovery research and in material discovery research for aerospace applications or environmental applications.

7. Number of semesters completed in research

8. Anticipated graduation date

May 2022