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					19b. TELEPHONE NUMBER 912-358-4451

**RPPR Final Report**  
as of 20-Dec-2019

Agency Code:

Proposal Number: 67208CHREP

**Agreement Number: W911NF-15-1-0453**

**INVESTIGATOR(S):**

**Name:** Pascal Binda  
**Email:** bindap@savannahstate.edu  
**Phone Number:** 9123584451  
**Principal:** Y

Organization: **Savannah State University**

Address: 3219 College Street, Savannah, GA 314045254

Country: USA

DUNS Number: 879931509

EIN: 586002069

**Report Date:** 09-Nov-2019

Date Received: 25-Nov-2019

**Final Report** for Period Beginning 10-Aug-2015 and Ending 09-Aug-2019

**Title:** Design and Synthesis of New Heteroleptic Lanthanide Complexes as Catalysts for Ring-Opening Polymerization of Naturally Renewable Unsaturated Gamma Lactones into Cross-Linkable Biodegradable Polyester

**Begin Performance Period:** 10-Aug-2015

**End Performance Period:** 09-Aug-2019

**Report Term:** 0-Other

Submitted By: Pascal Binda

Email: bindap@savannahstate.edu

Phone: (912) 358-4451

**Distribution Statement:** 1-Approved for public release; distribution is unlimited.

**STEM Degrees:** 2

**STEM Participants:** 7

**Major Goals:** The goal of the project at SSU is to synthesize and characterize cross-linkable unsaturated aliphatic polyesters and to strengthen the culture of STEM excellence by expanding outreach, teaching and mentoring activities through the following six objectives:

- to design and synthesize new heteroleptic lanthanide catalytic system,
- to investigate the catalytic activity of these newly synthesized lanthanide catalysts towards the ring-opening homopolymerization (ROP) of gamma lactones,
- to investigate appropriate ROP reaction conditions that will lead to exclusive formation of linear unsaturated cross-linkable polyester without any detectable vinyl addition,
- to develop a general methodology of radiation cross-linking of biodegradable unsaturated polyesters using low dose of gamma radiation (20 kGy at 0.5 kGy/hr using Co-60 radiation source) at Oak Ridge National Laboratory
- to promote K-12 and undergraduate student interest and engagement in science, technology, engineering, and mathematics (STEM) through mentoring activities and outreach opportunities, and
- to promote co-curricular activities that will enhance academic success of undergraduate research assistants towards completion of baccalaureate degree in chemistry and be prepared to be admitted into Ph.D. programs in STEM or enter STEM workforce.

**Accomplishments:** Accomplished goals

Pursuant to the goal, activities are planned with the following objectives:

1) design and synthesize new heteroleptic lanthanide catalytic system: During the reporting period (Year 3), newly synthesized heteroleptic lanthanide complexes were fully characterized and published (Binda, P. I.; Barnes, Z.; Guthrie, D.; Ford, R. Highly branched Poly( $\alpha$ -methylene- $\gamma$ -butyrolactone) from Ring-Opening homopolymerization. Open Journal Polymer Chemistry, 2017, 7, 76–91).

2) investigate the catalytic activity of these newly synthesized lanthanide catalysts towards the ring-opening homopolymerization (ROP) of gamma lactones: During the reporting period (Year 3), new cross-linked poly( $\alpha$ -methylene- $\gamma$ -butyrolactone) network was synthesized from ring-opening homopolymerization using lanthanide complexes. The new polymer network was characterized by Gel Permeation Chromatography (GPC) and Dynamic Mechanical Analyzer (DMA) to ascertain their molecular weights ( $M_n$ ,  $M_w$ , PDI) and thermal properties. (Binda, P. I.; Barnes, Z.; Guthrie, D.; Ford, R. Highly branched Poly( $\alpha$ -methylene- $\gamma$ -butyrolactone) from Ring-Opening homopolymerization. Open Journal Polymer Chemistry, 2017, 7, 76–91). In addition, novel unsaturated poly( $\alpha$ -methylene- $\gamma$ -butyrolactone) was synthesized with very interesting properties.

3) investigate appropriate ROP reaction conditions that will lead to exclusive formation of linear unsaturated cross-

## RPPR Final Report as of 20-Dec-2019

linkable polyester without any detectable vinyl addition: During the entire project, temperatures of -30 to -35 °C and 1:100 catalysts-to-MBL monomer ratio were the best conditions to obtain unsaturated poly( $\alpha$ -methylene- $\gamma$ -butyrolactone) as white powder with some useful properties for future applications. Temperatures below -40 °C afforded viscous polymer samples with low  $T_m$ . This finding is consistent with the thermodynamics of ROP of MBL due to the stability of its five member rings. This year, these reaction conditions were further investigated to ensure reproducibility of similar results for peer-reviewed publications. (Pascal Binda, Synthesis and characterization of unsaturated Poly( $\alpha$ -methylene- $\gamma$ -butyrolactone), DoD Technical Patent Report, Manuscript in preparation)

4) promote K-12 and undergraduate student interest and engagement in science, technology, engineering, and mathematics (STEM) through mentoring activities and outreach opportunities: During the entire project, the PI collaborated with local high schools advertise AEOP HSAP and to recruit 4 high school students for summer HSAP. The PI also allowed visiting high school students to see his DOD funded laboratory at Savannah State University as he explains the importance DOD puts in encouraging STEM education at HBCUs/MIs.

5) promote co-curricular activities that will enhance academic success of undergraduate research assistants towards completion of baccalaureate degree in chemistry and be prepared to be admitted into Ph.D. programs in STEM or enter STEM workforce: Student research assistants were encouraged to attend enriching departmental seminars, writing workshops, career workshops, tutoring, conference presentations, and community outreach. Most of the students accompanied the PI to local high schools during National Chemistry week to perform polymer chemistry demonstrations and also to advertise AEOP HSAP opportunities and to recruit HSAP interns. Some students were accepted for NSF funded summer research experience for undergraduates (REU) at top-tier STEM doctoral research intensive universities after going through competitive recruitment processes. These students gained experience on the workings at an intensive research environment. These students were very impressed to see that the technical skills (such as literature search, literature review, use of SciFinder and ChemDraw, writing an abstract and a manuscript) they learned through this project were being applied at the highest level when conducting research and one student had to write Dr. Binda during the course of the REU program to express her gratitude. Some of the Student Enrichment Activities include:

- STEM students who participated in this research project have presented their research findings at regional and national Conferences to gain communication skills.
- STEM students who participated in this research project attended seminars, workshops, and field trips to gain experience and prepare for graduate school.
- The Quality Enhancement Plan (QEP): In 2011, SSU initiated the "The Write Attitude" as a QEP focus to enhance the student learning by fostering positive attitudes toward writing. The QEP's vision is to produce students who are more effective writers, who have a heightened opportunity to increase their critical thinking skills, reading skills, and increase knowledge in their field of study. STEM students who participated in this research project attended many QEP workshops including plagiarism, The world of sentences, College writing 101, personal statement writing, writing a technical lab report, professional writing etiquette, argumentative writing, and workplace communication.
- GRE Training Workshop: NSF MAGIC STEM PLUS Program has hosted a Graduate Record Examinations (GRE) Workshop by SSU Instructors under the guidance of the Director of Mentoring and Research, Dr. Marilyn Hutchinson. These workshops were conducted to increase the number of SSU STEM majors pursuing graduate studies. Several students involved in this research project have participated in these preparatory GRE workshops, which increased their chances of getting admitted into graduate school programs with full Assistantships. These participants also have access for GRE practice tests in the newly established STEM Center.

Unaccomplished goal

6) to develop a general methodology of radiation cross-linking of newly synthesized biodegradable unsaturated polyesters using low dose of gamma radiation (20 kGy at 0.5 kGy/hr using Co-60 radiation source) at Oak Ridge National Laboratory.

Collaboration with Oak Ridge National Lab for use of gamma irradiation facility for cross-linking of unsaturated PMBL that was scheduled for summer 2019 was not possible because the facility was under renovation most of the year. However, the PI was able to carry out thermal cross-linking of the unsaturated polymer to obtain hard insoluble polymer network material with molecular weights over 500 kDa. A major feature of the newly synthesized unsaturated polymer was its ability to glue metals together via thermal crosslinking at high temperatures above melting points. This is indicative of a particular area of possible applications.

## RPPR Final Report as of 20-Dec-2019

- Training Opportunities:**
- June 29, 2017 DOD HBCU/MI Workshop, Research Triangle Park, NC
  - June 12-15, 2017 cCWCS Active Learning in Organic Chemistry workshop, Atlanta, GA
  - May 19-21, 2017 cCWCS Implementing iPads in the Chemistry Curriculum, Atlanta, GA
  - June 19, 2018 DOD HBCU/MI Workshop, Research Triangle Park, NC
  - March 18-22, 2018 255th ACS National Meeting & Exposition in New Orleans, LA
  - August 30-31, 2018 Naval Opportunity Awareness Workshop program, Atlanta, GA
  - October 31-Nov 4, 2018 70th Southeastern Regional Meeting of American Chemical Society (SERMACS 2018) in Augusta, GA.
  - March 13-15, 2019 African Union Higher Education Summit, Washington, DC
  - March 31-April 4, 2019 257th ACS National Meeting & Exposition in Orlando, FL
  - June 23-26, 2019 DOD ARO Chemical Sciences PI Review workshop

**Results Dissemination:** Pascal I. Binda (April 16-17, 2018) "Poly(?-methylene?-butyrolactone) as Potential Smart Polymeric Material for Healthcare Applications", 6th International Conference on Smart Materials in Las Vegas, NV.

Daniel Inman & Pascal I. Binda (November 14-17, 2018) "Synthesis of Functionalized Biodegradable Poly (alpha – methylene- gamma- butyrolactone) for medical applications", 2018 Annual Biomedical Research Conference for Minorities (ABRCMS) in Indianapolis, IN.

Pascal Binda\* (October 20-23, 2019) "Faculty Research Mentoring Strategy at a PWI versus an HBCU", 71st Southeastern Regional Meeting of American Chemical Society (SERMACS 2019) in Savannah, GA.

Pascal Binda\* (October 20-23, 2019) "Synthesis of Functionalized Biodegradable Poly(?-methylene?-butyrolactone)", 71st Southeastern Regional Meeting of American Chemical Society (SERMACS 2019) in Savannah, GA.

**Honors and Awards:** Faculty Awards and Honors

- May 2016 Promoted to rank of Associate Professor with tenure
- July 2016 Nominated for ACS Stanley C. Israel Regional Award for Advancing Diversity in the Chemical Sciences.
- Nov 2016 Recognized by US Department of Defense for mentoring high school students

**Student Awards**

- Brittany Hill – 2017 AAAS ERN Student Travel Award
- Tiffany Campbell – 2017 AEOP Student Travel Award
- Kiara Parrish – 2017 AEOP Student Travel Award
- Kiara Parrish – 2017 Third Place Poster Award in chemistry, Regional High School Poster Session
- Jhaiquashia Peterson – 2017 NSF REU student poster award
- Brittany Hill – 2018 American Chemical Society Chemistry Senior Award
- Rasaaan Ford – 2018 American Chemical Society Chemistry Senior Award

**Protocol Activity Status:**

**Technology Transfer:** Nothing to Report

**PARTICIPANTS:**

**Participant Type:** PD/PI

**Participant:** PASCAL BINDA

**Person Months Worked:** 11.00

**Funding Support:**

Project Contribution:

International Collaboration:

International Travel:

National Academy Member: N

Other Collaborators:

**RPPR Final Report**  
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**Participant Type:** Undergraduate Student

**Participant:** Princess Merenini

**Person Months Worked:** 3.00

**Funding Support:**

Project Contribution:

International Collaboration:

International Travel:

National Academy Member: N

Other Collaborators:

**Participant Type:** Undergraduate Student

**Participant:** Dahlia Thomas

**Person Months Worked:** 3.00

**Funding Support:**

Project Contribution:

International Collaboration:

International Travel:

National Academy Member: N

Other Collaborators:

**Participant Type:** Undergraduate Student

**Participant:** Torrey Mott

**Person Months Worked:** 3.00

**Funding Support:**

Project Contribution:

International Collaboration:

International Travel:

National Academy Member: N

Other Collaborators:

**Participant Type:** Undergraduate Student

**Participant:** Daniel Inman

**Person Months Worked:** 1.00

**Funding Support:**

Project Contribution:

International Collaboration:

International Travel:

National Academy Member: N

Other Collaborators:

**Participant Type:** Undergraduate Student

**Participant:** Elisha Reed

**Person Months Worked:** 2.00

**Funding Support:**

Project Contribution:

International Collaboration:

International Travel:

National Academy Member: N

Other Collaborators:

**Participant Type:** Undergraduate Student

**Participant:** Savannah Buteaux

**Person Months Worked:** 2.00

**Funding Support:**

Project Contribution:

International Collaboration:

International Travel:

National Academy Member: N

Other Collaborators:

**RPPR Final Report**  
as of 20-Dec-2019

**Participant Type:** Undergraduate Student

**Participant:** Tonyah Smalls

**Person Months Worked:** 2.00

**Funding Support:**

Project Contribution:

International Collaboration:

International Travel:

National Academy Member: N

Other Collaborators:

**ARTICLES:**

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Volume: 07

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Date Submitted:

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Publication Location:

**Article Title:** Highly Branched Poly(?-Methylene-?-Butyrolactone) from Ring-Opening Homopolymerization

**Authors:** Pascal Binda, Zakiya Barnes, Dechristian Guthrie, Rasaan Ford

**Keywords:** Lanthanide, ?-Methylene-? -Butyrolactone, Polyesters, Ring-Opening

**Abstract:** New heteroleptic lanthanide complex [L1LaN{Si(CH<sub>3</sub>)<sub>2</sub>}] (1) containing tridentate [ONO] ancillary ligand was synthesized from an acid-base ligand exchange reaction with ligands H<sub>2</sub>L<sub>1</sub> and corresponding homoleptic lanthanide compound La[N{Si(CH<sub>3</sub>)<sub>3</sub>}<sub>2</sub>]<sub>3</sub>. Meanwhile, dimeric complexes [L1LaCl] (2) and [L1LaCl] (3) were prepared from salt metathesis reaction between one equivalent of ligands H<sub>2</sub>L<sub>1,II</sub>, three equivalent of NaN{Si(CH<sub>3</sub>)<sub>3</sub>}<sub>2</sub>, and one equivalent of LaCl<sub>3</sub>. These compounds were characterized by nuclear magnetic resonance (300 MHz) and elemental analysis. These complexes were used as catalysts in the ring-opening homopolymerization of ?-methylene-?-butyrolactone. While compound 1 did not show any significant reactivity, compounds 2 and 3 gave significant amount of highly branched poly(?-methylene-?-butyrolactone) as confirmed by <sup>1</sup>H NMR spectroscopy and Malvern's triple detector GPCMax analysis in DMSO with molecular weights of over 500,000 Dalton.

**Distribution Statement:** 1-Approved for public release; distribution is unlimited.

Acknowledged Federal Support: Y

# FINAL REPORT for Proposal # 67208-CH-REP

## Principal Investigator:

Dr. Pascal I. Binda; [bindap@savannahstate.edu](mailto:bindap@savannahstate.edu); 912-358-4451

Associate Professor of Chemistry

Department of Chemistry and Forensic Science

Savannah State University

3219 College Street, Post Office Box 40154

Savannah, GA 31404-5425

## Research overview

Our research project aimed to synthesize cross-linkable unsaturated aliphatic polyesters, which are of scientific and technological interest for producing tailor-made functionalized biodegradable materials. The success of this project will provide knowledge in promoting the development of new cross-linked and functionalized biodegradable shape memory materials (smart materials) for drug delivery, tissue engineering, and biomedical applications.

## Educational:

Many undergraduate and high school students will be mentored by the PI through DOD funded URAP and HSAP programs to promote student interest and engagement in science, technology, engineering, and mathematics (STEM). This project's educational opportunity will enable more underrepresented minority students (URMs) to obtain baccalaureate degrees in chemistry and be prepared to be admitted into STEM graduate programs or enter STEM workforce, which is an important area of national need.

## Accomplishments

### What are the major goals of the project?

The goal of the project at SSU is to synthesize and characterize cross-linkable unsaturated aliphatic polyesters and to strengthen the culture of STEM excellence by expanding outreach, teaching and mentoring activities through the following six objectives:

- *to design and synthesize new heteroleptic lanthanide catalytic system,*
- *to investigate the catalytic activity of these newly synthesized lanthanide catalysts towards the ring-opening homopolymerization (ROP) of gamma lactones,*
- *to investigate appropriate ROP reaction conditions that will lead to exclusive formation of linear unsaturated cross-linkable polyester without any detectable vinyl addition,*
- *to develop a general methodology of radiation cross-linking of biodegradable unsaturated*

*polyesters using low dose of gamma radiation (20 kGy at 0.5 kGy/hr using Co-60 radiation source) at Oak Ridge National Laboratory*

- *to promote K-12 and undergraduate student interest and engagement in science, technology, engineering, and mathematics (STEM) through mentoring activities and outreach opportunities, and*
- *to promote co-curricular activities that will enhance academic success of undergraduate research assistants towards completion of baccalaureate degree in chemistry and be prepared to be admitted into Ph.D. programs in STEM or enter STEM workforce.*

## Accomplished goals

Pursuant to the goal, activities are planned with the following objectives:

1) *design and synthesize new heteroleptic lanthanide catalytic system:* During the reporting period (Year 3), newly synthesized heteroleptic lanthanide complexes were fully characterized and published (**Binda, P. I.; Barnes, Z.; Guthrie, D.; Ford, R.** Highly branched Poly( $\alpha$ -methylene- $\gamma$ -butyrolactone) from Ring-Opening homopolymerization. *Open Journal Polymer Chemistry*, **2017**, 7, 76–91).

2) *investigate the catalytic activity of these newly synthesized lanthanide catalysts towards the ring-opening homopolymerization (ROP) of gamma lactones:* During the reporting period (Year 3), new cross-linked poly( $\alpha$ -methylene- $\gamma$ -butyrolactone) network was synthesized from ring-opening homopolymerization using lanthanide complexes. The new polymer network was characterized by Gel Permeation Chromatography (GPC) and Dynamic Mechanical Analyzer (DMA) to ascertain their molecular weights (Mn, Mw, PDI) and thermal properties. (**Binda, P. I.; Barnes, Z.; Guthrie, D.; Ford, R.** Highly branched Poly( $\alpha$ -methylene- $\gamma$ -butyrolactone) from Ring-Opening homopolymerization. *Open Journal Polymer Chemistry*, **2017**, 7, 76–91). In addition, novel unsaturated poly( $\alpha$ -methylene- $\gamma$ -butyrolactone) was synthesized with very interesting properties.

3) *investigate appropriate ROP reaction conditions that will lead to exclusive formation of linear unsaturated cross-linkable polyester without any detectable vinyl addition:* During the entire project, temperatures of -30 to -35 °C and 1:100 catalysts-to-MBL monomer ratio were the best conditions to obtain unsaturated poly( $\alpha$ -methylene- $\gamma$ -butyrolactone) as white powder with some useful properties for future applications. Temperatures below -40 °C afforded viscose polymers samples with low Tm. This finding is consistent with the thermodynamics of ROP of MBL due to the stability of its five member rings. This year, these reaction conditions were further investigated to ensure reproducibility of similar results for peer-reviewed publications. (**Pascal Binda**, Synthesis and characterization of unsaturated Poly( $\alpha$ -methylene- $\gamma$ -butyrolactone), DoD Technical Patent Report, Manuscript in preparation)

4) *promote K-12 and undergraduate student interest and engagement in science, technology, engineering, and mathematics (STEM) through mentoring activities and outreach opportunities:* During the entire project, the PI collaborated with local high schools advertise AEOP HSAP and to recruit 4 high school students for summer HSAP. The PI also allowed visiting high school students to see his DOD funded laboratory at Savannah State University as he explains the importance DOD puts in encouraging STEM education at HBCUs/MIs.

5) *promote co-curricular activities that will enhance academic success of undergraduate research assistants towards completion of baccalaureate degree in chemistry and be prepared to be admitted into Ph.D. programs in STEM or enter STEM workforce:* Student research assistants were encouraged to attend enriching departmental seminars, writing workshops, career workshops, tutoring, conference presentations, and community outreach. Most of the students accompanied the PI to local high schools during National Chemistry week to perform polymer chemistry demonstrations and also to advertise AEOP HSAP opportunities and to recruit HSAP interns. Some students were accepted for NSF funded summer research experience for undergraduates (REU) at top-tier STEM doctoral research intensive universities after going through competitive recruitment processes. These students gained experience on the workings at an intensive research environment. These students were very impressed to see that the technical skills (such as literature search, literature review, use of SciFinder and ChemDraw, writing an abstract and a manuscript) they learned through this project were being applied at the highest level when conducting research and one student had to write Dr. Binda during the course of the REU program to express her gratitude. **Some of the Student Enrichment Activities include:**

- STEM students who participated in this research project have presented their research findings at regional and national Conferences to gain communication skills.
- STEM students who participated in this research project attended seminars, workshops, and field trips to gain experience and prepare for graduate school.
- The Quality Enhancement Plan (QEP): In 2011, SSU initiated the “The Write Attitude” as a QEP focus to enhance the student learning by fostering positive attitudes toward writing. The QEP’s vision is to produce students who are more effective writers, who have a heightened opportunity to increase their critical thinking skills, reading skills, and increase knowledge in their field of study. STEM students who participated in this research project attended many QEP workshops including plagiarism, The world of sentences, College writing 101, personal statement writing, writing a technical lab report, professional writing etiquette, argumentative writing, and workplace communication.
- GRE Training Workshop: NSF MAGIC STEM PLUS Program has hosted a Graduate Record Examinations (GRE) Workshop by SSU Instructors under the guidance of the Director of Mentoring and Research, Dr. Marilyn Hutchinson. These workshops were conducted to increase the number of SSU STEM majors pursuing graduate studies. Several students involved in this research project have participated in these preparatory GRE workshops, which increased their chances of getting admitted into graduate school programs with full Assistantships. These participants also have access for GRE practice tests in the newly established STEM Center.

## Unaccomplished goal

6) *to develop a general methodology of radiation cross-linking of newly synthesized biodegradable unsaturated polyesters using low dose of gamma radiation (20 kGy at 0.5 kGy/hr using Co-60 radiation source) at Oak Ridge National Laboratory.*

Collaboration with Oak Ridge National Lab for use of gamma irradiation facility for cross-linking of unsaturated PMBL that was scheduled for summer 2019 was not possible because the facility was under renovation most of the year. However, the PI was able to carry out thermal cross-linking of the

unsaturated polymer to obtain hard insoluble polymer network material with molecular weights over 500 kDa. A major feature of the newly synthesized unsaturated polymer was its ability to glue metals together via thermal crosslinking at high temperatures above melting points. This is indicative of a particular area of possible applications.

## Participants

### Advancing Diversity in Chemical Science through Research Mentoring

During funding of this project, Dr. Binda mentored 17 students in research through the DOD funded proposal # 67208-CH-REP. Of the 17 students mentored, 14 are underrepresented African American minorities, 4 are high school students, and 11 are females. Dr. Binda has also visited local historically black high schools and worked with high school science teachers to create awareness of the Army Educational Opportunity Program (AEOP) and on-going DOD-funded research projects at Savannah State University. Of the 7 undergraduate students who graduated during funding period, 6 were accepted into a Ph.D. program in STEM or entered STEM workforce, while 2 are still applying to graduate school. This represents an overall 86% career placement. All HSAP participants entered STEM undergraduate programs upon graduation from high schools. Overall, Dr. Binda is a young and energetic mentor to underrepresented minority students at Savannah State University, a facilitator for these students to participate in conferences and research experiences, as adviser to professional organizations, and as a liaison to post graduate institutions seeking to recruit and retain minority students. It is worth noting that 100% of students mentored by Dr. Binda are retained in STEM programs.

Besides direct participants, over 50 undergraduate students, 2 high school teachers, and 30 high school students were indirectly broadly impacted as they became aware of DOD's Army Educational Opportunity Program's goal of increasing the number of underrepresented minorities (URMs) in STEM education at the HBCUs by promoting student interest and engagement in science, technology, engineering, and mathematics (STEM).

**Table 1.** Direct participants, <sup>n/a</sup> Not Applicable

	Position	Duration	Sex	Level	Race	School	GPA	Degree	Graduation date	Career plans
Dr. Pascal Binda	Principal Investigator	4 yrs	M	Associate Prof	Black	SSU	n/a	n/a	n/a	n/a
Zakiya Barnes	Undergraduate	12 months	F	Junior to senior	Black	SSU	3.01	B.S. CHEM	Dec. 2016	Ph.D. student in chemistry at Clark Atlanta University
DeChristian Guthrie	Undergraduate	18 months	F	Junior to senior	Black	SSU	2.65	B.S. CHEM	May 2017	Chemist at Louis Dreyfus Company (formally Imperial Sugar)
Rasaan Ford	Undergraduate	26 months	M	Sophomore to senior	Black	SSU	3.15	B.S. CHEM	May 2018	Ph.D. program in Chemistry at Clark Atlanta University
Brittany Hill	Undergraduate	20 months	F	Sophomore to senior	Black	SSU	3.29	B.S. CHEM	May 2018	Accepted for Ph.D. program in Chemistry at Old Dominion University

**FINAL REPORT for Proposal # 67208-CH-REP, Contract Number: W911NF1510453 Binda, P**

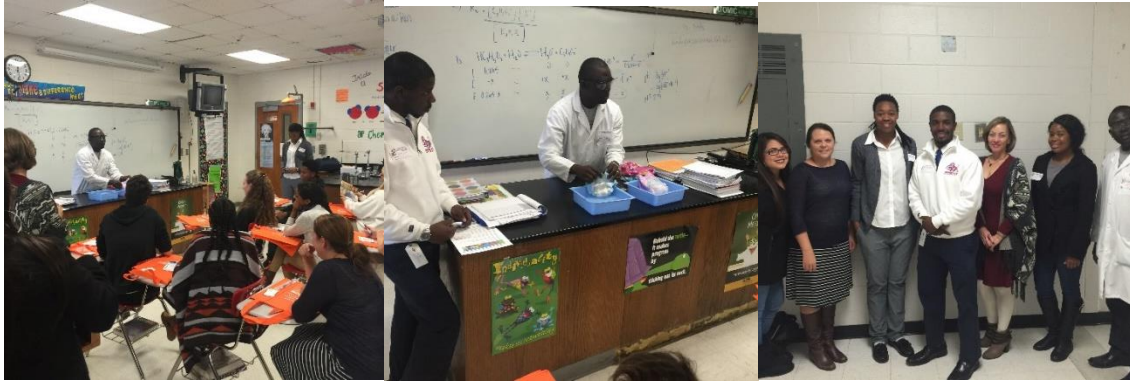
Nathaniel Payne	AEOP URAP	2 months	M	Sophomore	White	SSU	3.32	B.S. CHEM	Transferred to UGA	Graduate school
Tiffany Campbell	AEOP HSAP	2 months	F	High School sophomore	Black	Johnson High School	3.20	n/a	May 2017	Undergraduate student in STEM field
Kiara Parrish	AEOP HSAP	2 months	F	High School sophomore	Black	Jenkins High School	3.30	n/a	May 2017	B.S. degree in mechanical engineering at The Citadel Military College
Jhaiquashia Peterson	Undergraduate	8 months	F	Senior	Black	SSU	3.44	B.S. CHEM	Dec 2017	Graduate school
Candice Vinson	AEOP URAP	2 months	F	Junior	White	SSU	2.82	B.S. Marine Science	May 2018	Works at Virginia Institute of Marine Science
Princess Merenini	Undergraduate	14 months	F	Junior to Senior	Black	SSU	3.99	B.S. CHEM	Dec 2018	Ph.D. program in Chemistry at University of Wisconsin, Madison
Dahlia Thomas	Undergraduate	14 months	F	Junior to Senior	Black	SSU	3.17	B.S. CHEM	Dec 2018	Graduate school
Torrey Mott	Undergraduate	6 months	M	Junior to Senior	Black	SSU	3.26	B.S. CHEM	May 2020	Graduate school
Daniel Inman	AEOP URAP	2 months	M	Junior	Black	SSU	3.56	B.S. CHEM	May 2020	Graduate school
Garrett Derks	AEOP HSAP	2 months	M	High School	White	Jenkins High School	n/a	n/a	May 2019	B.S. degree in STEM
Tanja Garner	AEOP HSAP	2 months	F	High School	Black	Windsor Forest High School	n/a	n/a	May 2019	B.S. degree in STEM
Elisha Reed	Undergraduate	2 months	M	Junior	Black	SSU	3.98	B.S. BIO	May 2021	Graduate school
Savannah Buteaux	Undergraduate	2 months	F	Sophomore	Black	SSU	3.00	B.S. CHEM	May 2022	Graduate school
Tonyah Smalls	Undergraduate	2 months	F	Sophomore	Black	SSU	3.54	B.S. Forensic Science	May 2022	Graduate school

## Undergraduate Student Research Mentoring

### Year 1 in photos







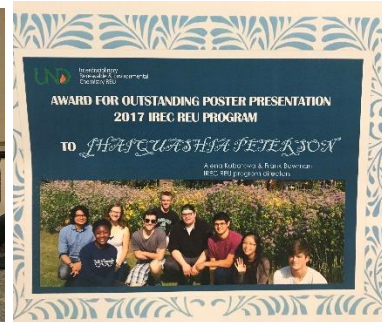
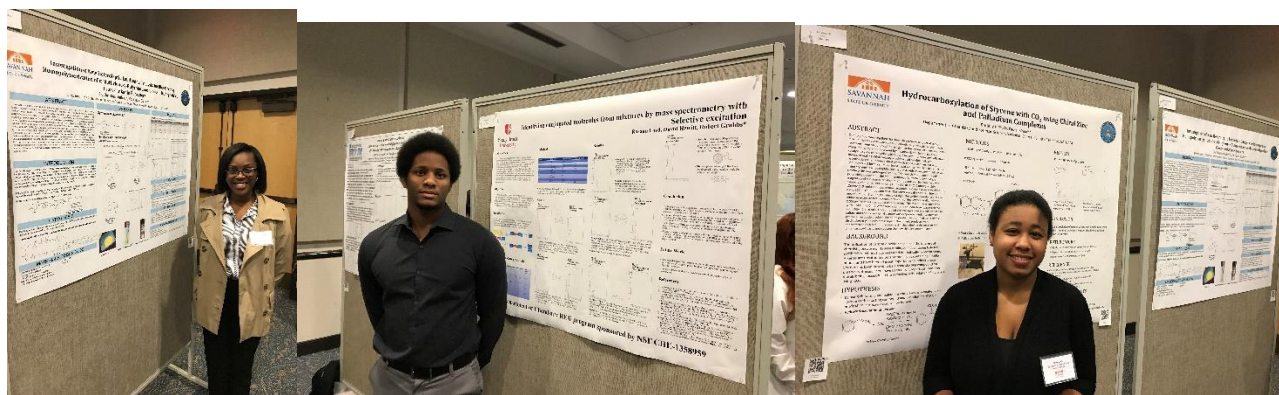
### Year 2 in photos



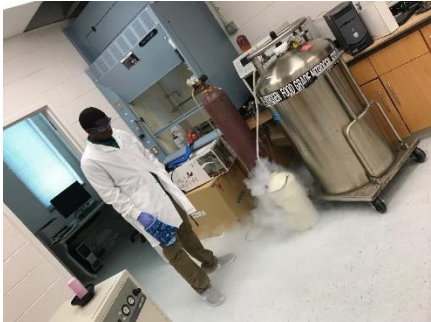
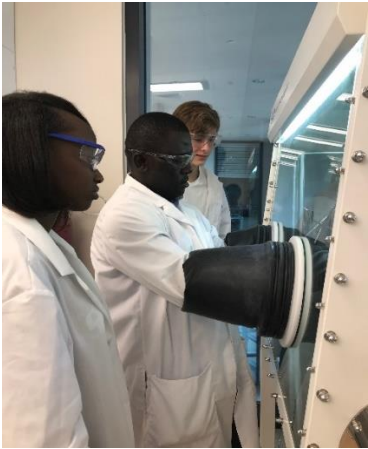
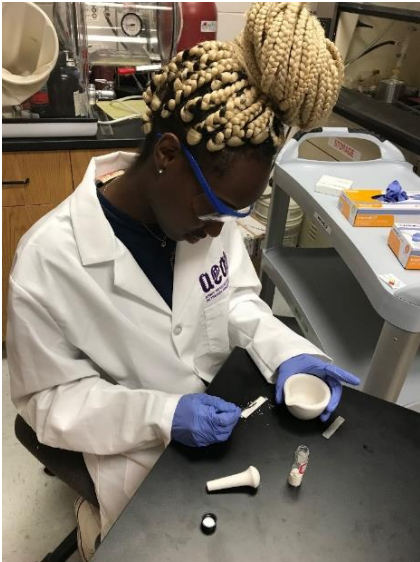
Binda Research Group at SERMACS 2016 Conference

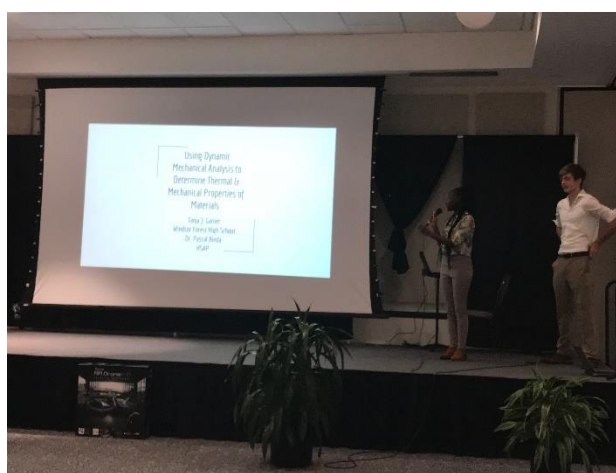
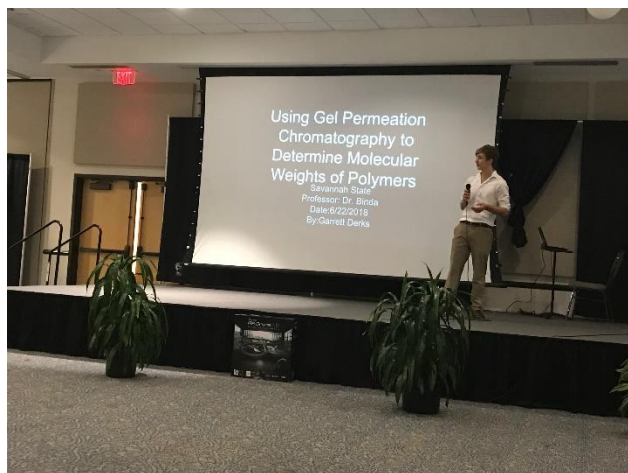
The SSU delegation at the 2016 Southeastern Regional Meeting of American Chemical Society (SERMACS 2016) conference in Columbia, SC, with American Chemical Society president, Dr. Donald J. Nelson, and the 2008 Nobel prize in Chemistry winner, Dr. Martin Chalfie of Columbia University during the Minority Affairs Dinner on Monday October 24<sup>th</sup>. The students were led to the conference by their research mentor, **Dr. Pascal Binda**, Associate Professor of Chemistry. All students presented posters in different chemistry research topics.

Special acknowledgment goes to the U.S. Department of Defense (ARO Proposal No. 67208-CH-REP) for sponsoring Dr. Binda's polymer research group.



Year 3 in photos

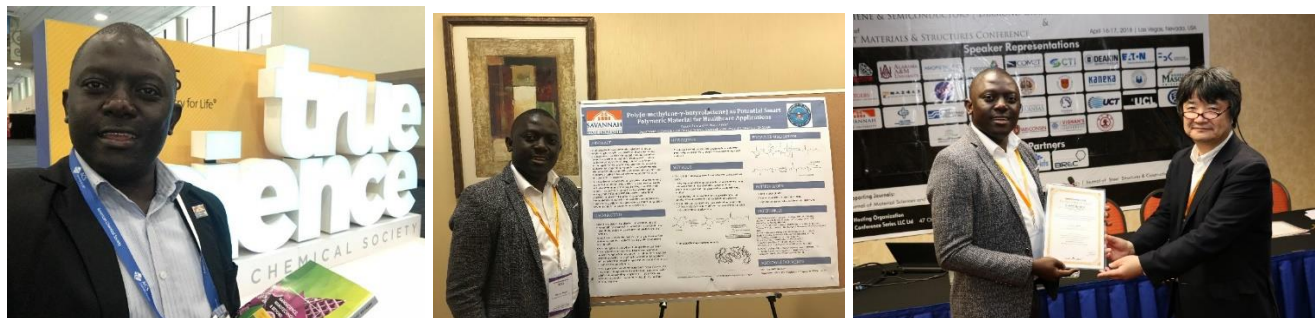




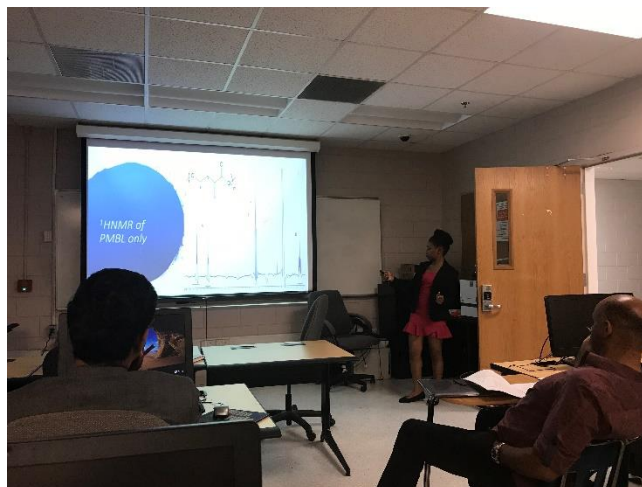
Binda Research Group at SERMACS 2017 Conference

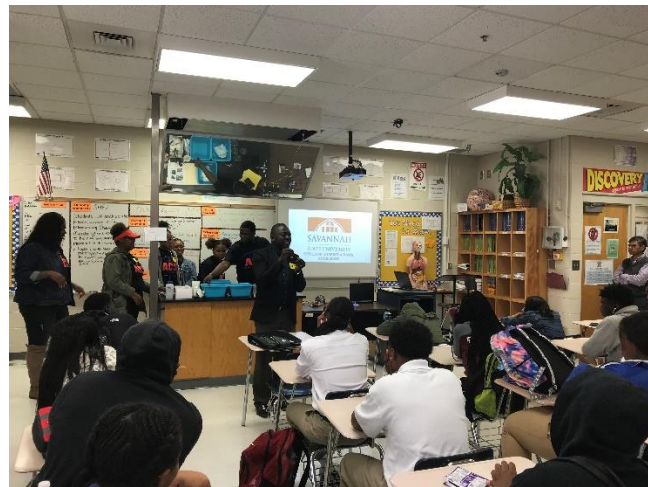
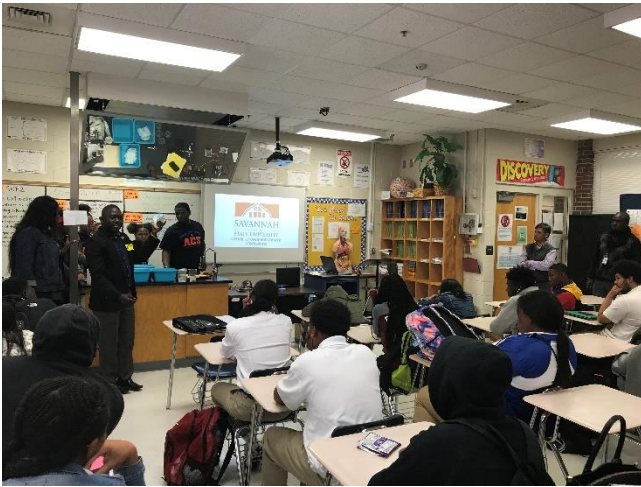


6<sup>th</sup> International Conference on Smart Materials in Las Vegas, NV



### Year 4 (No-cost extension) in photos





## Co-curricular Activities attended by research assistants

### Field Trip to HEERTY Advanced Materials Development Center, April 29, 2016

DOD Undergraduate research assistants, SSU ACS Student Chapter and polymer chemistry class attended a field trip at HERTY Advanced Materials Development Center in Savannah Georgia to see applications of Chemistry in product development



**Survey Results:** Of the 14 students who took a survey, 100% either agreed or strongly agreed that the field trip enhanced their understanding of Polymer Chemistry and relevance in R&D, 71% are more committed to go to graduate school, 85% are more committed to research and development, 85% are more committed to making more effort to succeed in STEM at university and beyond, 57% are more committed to have a career in a high tech manufacturing industry, and 93% recommend the field trip to be repeated for other students.

### Skills and Techniques learned by research assistants, URAP and HSAP scholars

- Reaction stoichiometry
- Writing technical reports including abstracts, lab reports
- Literature search and Literature review
- Use of SciFinder and ChemDraw
- Use of DMA and GPC to characterize polymers
- Critical thinking in relation to problem solving
- Oral communication skills, career workshops and departmental seminars
- Column chromatography and use of a separatory funnel
- Use of separatory funnel, rotavapor, pipets, and analytical balance
- Distillation techniques and Heating at reflux
- Manipulation of air- and moisture-sensitive compounds using glove box and vacuum line manifolds
- Conference presentations and graduate school workshops

## Travel to Conferences (students are underlined)

Pascal I. Binda (March 13-17, 2016) “New lanthanide complexes for the polymerization of  $\alpha$ -methylene- $\gamma$ -butyrolactone to obtain biodegradable cross-linkable unsaturated polyesters”, 251st American Chemical Society National Meeting in San Diego, CA.

Zakiya Barnes, DeChristian Guthrie, Rasaan Ford, and Pascal I. Binda (February 25-28, 2016) “New

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lanthanide complexes for the polymerization of  $\alpha$ -methylene- $\gamma$ -butyrolactone to obtain biodegradable cross-linkable unsaturated polyesters”, 2016 Emerging Researchers National Conference in Washington, DC.

Zakiya Barnes, DeChristian Guthrie, Rasaan Ford, and Pascal I. Binda (March 4 2016) “New lanthanide complexes for the polymerization of  $\alpha$ -methylene- $\gamma$ -butyrolactone to obtain biodegradable cross-linkable unsaturated polyesters”, Savannah State University’s 6th Annual Research Conference, Savannah, GA.

Dr. Pascal Binda (November 2-4, 2015) attended the “Collaborative Research for Transformative Scientific Discovery, Innovation, and Transition that is Critical to National Security”, Army Research Laboratory (ARL) Open Campus, Aberdeen Proving Grounds, Maryland.

Brittany Hill & Pascal I. Binda (March 2-4, 2017) “Hydrocarboxylation of Styrene with CO<sub>2</sub> using Chiral Zinc and Palladium Complexes”, 2017 Emerging Researchers National Conference in Washington, DC.

Pascal I. Binda (January 20-22, 2017) NSF INCLUDES Conference, UC San Diego, CA.

Pascal I. Binda (October 23-26, 2016) “Classroom strategy for promoting understanding of chemistry among underrepresented minority students”, 68<sup>th</sup> Southeastern Regional Meeting of American Chemical Society (SERMACS 2016) in Columbia, SC.

Brittany Hill & Pascal I. Binda (October 23-26, 2016) “Hydrocarboxylation of Styrene with CO<sub>2</sub> using Chiral Zinc and Palladium Complexes”, 68<sup>th</sup> Southeastern Regional Meeting of American Chemical Society (SERMACS 2016) in Columbia, SC.

DeChristian Guthrie & Pascal I. Binda (October 23-26, 2016) “Investigation of new heteroleptic lanthanide catalysts for ring-opening homopolymerization of  $\alpha$ -methylene- $\gamma$ -butyrolactone to obtain biodegradable cross-linkable polyesters”, 68<sup>th</sup> Southeastern Regional Meeting of American Chemical Society (SERMACS 2016) in Columbia, SC.

Zakiya Barnes<sup>1</sup>, Akongnwi Jungong<sup>2</sup>, Rebecca Simmons<sup>3</sup>, Diane Darland<sup>3</sup>, Kathryn Thomasson<sup>\*.2</sup> (October 23-26, 2016) “Evolution of Functionality of the Polycomb Repressive Complex 2 (PRC2)”, 68<sup>th</sup> Southeastern Regional Meeting of American Chemical Society (SERMACS 2016) in Columbia, SC.

Rasaan Ford, David Hewitt, Robert Grubbs<sup>\*</sup> (October 23-26, 2016) “Identifying conjugated molecules from mixtures by mass spectrometry with Selective excitation”, 68<sup>th</sup> Southeastern Regional Meeting of American Chemical Society (SERMACS 2016) in Columbia, SC.

Kareem Blue & Pascal I. Binda (October 23-26, 2016) “Synthesis of New Cinnamaldehyde Derivatives as Potential Anti-Diabetic Agents”, 68<sup>th</sup> Southeastern Regional Meeting of American Chemical Society (SERMACS 2016) in Columbia, SC.

Nathaniel Payne & Pascal I. Binda (October 23-26, 2016) “Polymerization of alpha-methylene-gamma-butyrolactone using Lanthanide Catalyst”, 68<sup>th</sup> Southeastern Regional Meeting of American Chemical Society (SERMACS 2016) in Columbia, SC.

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Kiara Parrish & Pascal I. Binda (October 23-26, 2016) “Polymerization of alpha-methylene-gamma-butyrolactone using Calcium Catalyst”, 68<sup>th</sup> Southeastern Regional Meeting of American Chemical Society (SERMACS 2016) in Columbia, SC.

Pascal I. Binda (November 7-11, 2017) “Ring-opening homopolymerization of  $\alpha$ -methylene- $\gamma$ -butyrolactone”, 69<sup>th</sup> Southeastern Regional Meeting of American Chemical Society (SERMACS 2017) in Charlotte, NC.

Brittany Hill, and Pascal I. Binda (November 7-11, 2017) “Hydrocarboxylation of Styrene with CO<sub>2</sub> using Chiral Zinc and Palladium Complexes”, 69<sup>th</sup> Southeastern Regional Meeting of American Chemical Society (SERMACS 2017) in Charlotte, NC.

Rasaan Ford, and Pascal Binda\* (November 7-11, 2017) “Ring Opening Homopolymerization of  $\alpha$ -Methylene- $\gamma$ -Butyrolactone”, 69<sup>th</sup> Southeastern Regional Meeting of American Chemical Society (SERMACS 2017) in Charlotte, NC.

Pascal I. Binda (April 16-17, 2018) “Poly( $\alpha$ -methylene- $\gamma$ -butyrolactone) as Potential Smart Polymeric Material for Healthcare Applications”, 6<sup>th</sup> International Conference on Smart Materials in Las Vegas, NV.

Daniel Inman & Pascal I. Binda (November 14-17, 2018) “Synthesis of Functionalized Biodegradable Poly (alpha – methylene- gamma- butyrolactone) for medical applications”, 2018 Annual Biomedical Research Conference for Minorities (ABRCMS) in Indianapolis, IN.

Pascal Binda\* (October 20-23, 2019) “Faculty Research Mentoring Strategy at a PWI versus an HBCU”, 71<sup>st</sup> Southeastern Regional Meeting of American Chemical Society (SERMACS 2019) in Savannah, GA.

Pascal Binda\* (October 20-23, 2019) “Synthesis of Functionalized Biodegradable Poly( $\alpha$ -methylene- $\gamma$ -butyrolactone)”, 71<sup>st</sup> Southeastern Regional Meeting of American Chemical Society (SERMACS 2019) in Savannah, GA.

**Student Awards**

- Brittany Hill – 2017 AAAS ERN Student Travel Award
- Tiffany Campbell – 2017 AEOP Student Travel Award
- Kiara Parrish – 2017 AEOP Student Travel Award
- Kiara Parrish – 2017 Third Place Poster Award in chemistry, Regional High School Poster Session
- Jhaiquashia Peterson – 2017 NSF REU student poster award
- Brittany Hill – 2018 American Chemical Society Chemistry Senior Award
- Rasaan Ford – 2018 American Chemical Society Chemistry Senior Award

## Professional Growth of PI

### Promotion

May 2016 Promoted to rank of Associate Professor with tenure

### Professional Membership

2007-present American Chemical Society (ACS) membership

### Awards and Honors

- July 2016 Nominated for ACS Stanley C. Israel Regional **Award** for Advancing **Diversity** in the Chemical Sciences.
- Nov 2016 Recognized by US Department of Defense for mentoring high school students

### Professional Development Workshops Attended

- June 29, 2017 DOD HBCU/MI Workshop, Research Triangle Park, NC
- June 12-15, 2017 cCWCS Active Learning in Organic Chemistry workshop, Atlanta, GA
- May 19-21, 2017 cCWCS Implementing iPads in the Chemistry Curriculum, Atlanta, GA
- June 19, 2018 DOD HBCU/MI Workshop, Research Triangle Park, NC
- March 18-22, 2018 255th ACS National Meeting & Exposition in New Orleans, LA
- August 30-31, 2018 Naval Opportunity Awareness Workshop program, Atlanta, GA
- October 31-Nov 4, 2018 70<sup>th</sup> Southeastern Regional Meeting of American Chemical Society (SERMACS 2018) in Augusta, GA.
- March 13-15, 2019 African Union Higher Education Summit, Washington, DC
- March 31-April 4, 2019 257th ACS National Meeting & Exposition in Orlando, FL
- June 23-26, 2019 DOD ARO Chemical Sciences PI Review workshop

### External Research Funding

#### Current award:

**\$1,300,000**

NIH NIBIB ESTEEMED

08/01/2018 - 06/30/2023

Role: Co-Principal Investigator; **Savannah State University**

“Achieving Diversity through Integrative Scientific Research Experience (ADISRE)”. The funding will provide students with research travel, tuition assistance and a summer bridge program. The grant team will recruit seven incoming freshman each year who have declared biology, chemistry, forensic science or mathematics as a major. These students will also be able to take on two summer internships and gain a competitive advantage when applying to doctoral programs.

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\$60,761

DOD/ARO

08/01/2019 - 07/30/2020

Role: Principal Investigator; **Savannah State University**

“Acquisition of a Seahorse XFe Analyzer for polymer testing with live cells”. **Reference Proposal # 75480-CH-RI**

**Completed:**

\$218,497

DOD/ARO

08/01/2016 - 07/25/2018

Role: Principal Investigator; **Savannah State University**

“Acquisition of a Dynamic Mechanical Analyzer and an EcoSEC GPC for Polymer and Materials Characterization”. **Reference Proposal # 68862-CH-REP**

\$332,633 DOD/ARO

08/01/2015 - 07/30/2019

Role: Program Director/Principal Investigator; **Savannah State University**

“Design and synthesis of new heteroleptic lanthanide complexes as catalysts for ring-opening polymerization of naturally renewable unsaturated gamma lactones into cross-linkable biodegradable polyesters”. **Reference Proposal # 67208-CH-REP**

## News Releases

- True Chemistry, SSU Research Magazine, Spring 2016  
<https://www.savannahstate.edu/news/article.shtml?id=8155718134264775249&type=blogger>
- Leading by Example, SSU Research Magazine, Spring 2016  
<https://www.savannahstate.edu/news/article.shtml?id=3676462389638591774&type=blogger>
- Instrumentation grant for materials characterization  
<https://www.savannahstate.edu/news/article.shtml?id=629&type=news>

## Peer-Reviewed Publications (students are underlined>)

**Pascal Binda**, Brittany Hill, Brian Skelton, Synthesis and crystal structures of sodium phenolate ligands: Coordination Chemistry. *Journal of Coordination Chemistry*, **2018**, 71(7), 941-951.

**Binda, P. I.**; Barnes, Z.; Guthrie, D.; Ford, R. Highly branched Poly( $\alpha$ -methylene- $\gamma$ -butyrolactone) from Ring-Opening homopolymerization. *Open Journal Polymer Chemistry*, **2017**, 7, 76–91.

**Pascal Binda**, Kimberly Rivers, Clifford Padgett; Zinc Complexes of New Chiral Aminophenolate Ligands: Synthesis, Characterization and Reactivity toward Lactide. *Open Journal of Inorganic Chemistry (OJIC)*, **2016**, 6, 205–218.

# Technical Patent Report manuscript in preparation

## Unpublished work

**Pascal Binda**, Synthesis and characterization of unsaturated Poly( $\alpha$ -methylene- $\gamma$ -butyrolactone), Technical Patent Report, Manuscript in preparation

### Abstract:

Due to their good mechanical properties, hydrolyzability and biocompatibility, aliphatic saturated polyesters have been extensively investigated with applications in packaging, drug delivery and medical implantation devices. The best and most reliable method of synthesizing high molecular weight polyesters is via ring-opening polymerization (ROP) of lactones with a relatively high strain energy using metal initiators for chain-growth polymerization. However, unsaturated polyesters, which show great scientific and technological promise for producing tailor-made functionalized biodegradable materials of commercial importance, have not been extensively studied.

$\alpha$ -Methylene- $\gamma$ -butyrolactone ( $\alpha$ -MBL), also known as Tulipaline A, has received much interest in the synthesis of sustainable unsaturated polyesters since it is the simplest member of a class of naturally occurring sesquiterpene lactones found in tulips. The unfavorable thermodynamics involved in the ROP of MBL results in too small negative change of enthalpy ( $\Delta H$ ) to offset a large negative entropy change ( $\Delta S$ ). As a result, MBL prefers vinyl addition polymerization to ROP. Because vinyl-addition is favored over ring-opening at room temperature due to the stability and low strain energy of five membered  $\gamma$ -BL ring making it non-polymerizable. Therefore, special conditions and reagents must be used to favor the ring-opening homopolymerization of MBL. We report the ring-opening homopolymerization of  $\alpha$ -methylene- $\gamma$ -butyrolactone using lanthanide catalyst at very low temperatures under special conditions to afford unsaturated polyesters as soft rubbery materials.

The properties of this novel unsaturated polyester was ascertained using NMR spectroscopy, Malvern's triple detector GPCMax, and TA's Dynamic Mechanical Analyzer, DMA Q800. The  $^1\text{H}$  NMR confirmed the presence of the exocyclic C=C double bonds in the polyester backbone. The GPC studies revealed molecular weights in the range 11,000 to 40,000 kg/mol depending on reaction times while the  $T_g$  and  $T_m$  from DMA studies was around 20-42  $^\circ\text{C}$  and 35-70  $^\circ\text{C}$ , respectively. The unsaturated polyesters can be functionalized by converting the exocyclic C=C double bonds in the polyester backbone into amino, hydroxyl, halogenated, or carboxylic acid functional groups for tailor-made applications in biomedical and shape memory research. Thermal cross-linking of the unsaturated polymer afforded hard insoluble polymer network material with molecular weights in 500 kDa. A major feature of the newly synthesized unsaturated polymer was its ability to glue metals together via thermal crosslinking at high temperatures above melting point. This is indicative of a particular area of possible applications as glue for boat or ship repairs.