



**ERICH D. BAIN, PH.D.**  
**SENIOR STAFF CONSULTANT**

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Dr. Bain is a chemical engineer with over 15 years of experience investigating performance of materials on behalf of government, industrial, and academic clients. His extensive product failure analysis experience covers a wide range of polymeric and non-polymeric materials, including engineering thermoplastics, thermosets, composites, elastomers, gels, textiles, glasses, ceramics, and metallic components. His expertise is aimed at solving complex problems involving performance of materials and determining root-causes of product failure based on a deep understanding of material chemistry, processing, structure, and property relationships and how these interact with design, manufacturing, and extreme service environments. His approach is based on reliable and proven scientific techniques applicable to a wide range of industries including piping, transportation, construction, defense, medical devices, adhesives, electronics, consumer products, and more.

Prior to joining ESi, Dr. Bain worked for seven years at the U.S. Army Research Laboratory as a staff scientist and post-doctoral research engineer. His research on polymer and composite materials for body armor, lightweight vehicle protection, ballistic clay replacement, battlefield wound care, additive manufacturing materials and processes, and high voltage electronics resulted in significant advances to soldier capability. Dr. Bain has published numerous peer-reviewed journal papers and two book chapters and has been invited to present his research at domestic and international scientific meetings.

### **Areas of Specialization**

- Polymer Selection, Engineering, Characterization, and Testing
- Failure Analysis and Fractography
- Polymer Processing and Formulation
- Polymer Chemistry-Structure-Property-Performance Relationships
- Chemical Compatibility Testing
- Fracture and Fatigue Analysis
- Non-Destructive Inspection
- Mechanical Testing
- Ballistic Testing
- Fourier Transform Infrared Spectroscopy (FTIR)
- Thermal Analysis (DSC, TGA, DMA)
- Polymer Synthesis and Polymerization
- Product Design Evaluation
- Additive Manufacturing

### **Education**

Ph.D., Chemical & Biomolecular Engineering, North Carolina State University, 2012  
B.S., Chemical & Biological Engineering, The University of Alabama, 2005

*August 2023*

## Professional Affiliations/Honors

### ASTM International

Voting member on subcommittees D20.10.24 Fracture and Fatigue of Plastics, D20.16 Thermosetting Materials (Plastics), D20.18 Reinforced Thermosetting Plastics, and D20.23 Reinforced Thermosetting Resin Piping Systems and Chemical Equipment.  
Five-year review of ASTM D4673: Standard Classification System and Basis for Specification for Acrylonitrile-Butadiene-Styrene (ABS) Plastics and Alloys Molding and Extrusion Materials.  
Keynote Speaker, D20.10.42 Additive Manufacturing Considerations for D20 Standards, Washington, D.C., November 2018.

### Society of Plastics Engineers (SPE)

Member, technical interest groups on Failure Analysis & Prevention, Automotive, Joining of Composites and Plastics, Plastics and Pipe Fittings, Thermoplastic Elastomers.

### The Adhesion Society

Division Chair, Structural Adhesives Division, 2020 meeting, Charleston, SC  
Assistant Division Chair, Structural Adhesives Division, 2018 and 2019 meetings  
Session Organizer: Adhesion and Fracture in Extreme Dynamic Environments, Fracture Mechanics of Structural Adhesives & Composites, Adhesion and Fracture of Complex Additively Manufactured Structures (2018-2020).

### Additive Manufacturing Benchmarks, National Institute of Standards and Technology (NIST)

Scientific Committee, Polymer Powder Bed Fusion Test Series (2021 meeting)  
Test Series Experimental Lead, Polymer Powder Bed (2018 meeting, Gaithersburg, MD)

### Society of Experimental Mechanics (SEM)

Best Paper, Dynamic Behavior of Materials: SEM XIII International Congress, Orlando FL, June 2016. "Failure Processes Governing High Rate Impact Resistance of Epoxy Resins Filled with Core Shell Rubber Nanoparticles"

### American Institute of Chemical Engineers (AIChE)

Session Chair, "Mechanics and Structure in Polymers", 2017 Meeting, Minneapolis, MN  
3<sup>rd</sup> Place, Student Poster Competition, 2004 Meeting, Austin, TX

Peer Reviewer for: Journal of Failure Analysis & Prevention, Soft Matter, Polymer, ACS Sustainable Chemistry and Engineering, Reviews of Scientific Instruments, Additive Manufacturing, ACS Applied Polymer Materials, Journal of Applied Polymer Science, Colloids and Surfaces B

## Positions Held

### Engineering Systems, Inc., Dallas, TX

Senior Staff Consultant, June 2020 – Present

United States Army Combat Capabilities Development Command (CCDC) Army Research Laboratory (ARL) Weapons and Materials Research Directorate (WMRD), Materials and Manufacturing Sciences Division. Aberdeen Proving Ground, MD

Chemical Engineer (Federal Civilian), September 2015 – May 2020.

Security Clearance: Secret

Post-Doctoral Research Engineer, November 2012 – September 2015

North Carolina State University, Dept of Chemical & Biomolecular Engineering, Raleigh, NC  
Ph.D. Student, August 2005 – November 2012

Czech Academy of Sciences, Institute of Organic Chemistry and Biochemistry, Prague, Czech Republic

Visiting Scientist, Summers 2008 and 2009

GE Plastics (currently SABIC Innovative Plastics), Mount Vernon, IN

Co-op Engineer, May – August 2002, January – May 2003, August – December 2003

University of Alabama, Tuscaloosa, AL

NSF REU / Undergraduate Researcher, January 2002-July 2005

## Continuing Education

Principles of Failure Analysis

ASM International, February 1-4, 2021 (presented online by Ronald J. Parrington, P.E, FASM)

Short Course on Penetration Mechanics

Southwest Research Institute (SwRI) April 20-24, 2020 (presented online for ARL)

Adhesion Science and Technology Short Course

The Adhesion Society, Feb 24-25, 2017, St. Petersburg, FL

Practical Design of Experiments for Scientists and Engineers

SPIE SC793, Instructor: O. Manuel Uy. Sep. 11, 2015, Aberdeen, MD

Membranes for Clean Energy and Water

American Physical Society DPOLY Short Course, March 16-17, 2013, Baltimore, MD

## Project Experience Highlights

### Pipes and Plumbing Systems

1. Failure analysis of 30 inch C905 PVC pressure pipes in municipal wastewater force main
2. Failure analysis of CPVC fire sprinkler pipe
3. Failure analysis of dielectric couplings in hospital hot water system
4. Failure analysis of 12 inch rubber expansion joints in hospital hydronic system
5. Failure analysis of braided stainless steel hot water hoses
6. Failure analysis of PEX tubing and manifold in residential hot water system
7. Failure analysis of water filter and fittings in domestic water filtration system
8. Failure analysis of polyacetal domestic bathroom sink faucet
9. Failure analysis of polyacetal ballcock nuts on residential toilet supply line

### Construction Materials and Coatings

10. Failure analysis of PVC roof membrane
11. Failure analysis of commercial and residential window glass
12. Analysis of ceramic floor tile properties and performance
13. Failure analysis of glass coating in AWWA D103 municipal water ground storage tank
14. Analysis of polymeric coatings on concrete
15. Analysis of polymeric coatings on ductile iron fittings
16. Failure analysis of galvanized steel ductwork
17. Failure analysis of adhesively bonded wood veneer

### Industrial Products and Processes

18. Analysis of processing debris in commercial inkjet printers
19. Analysis of zinc oxide particle size and shape distribution and effects on metal oxide varistor performance
20. Analysis of suspected manufacturing defects in plated microelectronic spring connectors
21. Materials analysis of piezo crystal components
22. Analysis of epoxy potting compound

### Transportation and Electronics

23. Failure analysis of metro train door switches following disinfection for COVID-19
24. Failure analysis of fiber-reinforced composite structural channel from refrigerated rail car
25. Analysis of melted plastic debris from fire involving lithium-ion battery

### Peer-Reviewed Publications

- “Emerging Structural Adhesive Chemistries and Innovations,” **E.D. Bain**, M. Pollum, D. Fortman, M.E. Losada, C.M. Jackson, and R. Jensen. In *Advances in Structural Adhesive Bonding (2<sup>nd</sup> Edition)*, ed. D.A. Dillard, Woodhead Publishing in Materials, 2023, ISBN 9780323912143. Chapter 7, pp. 221-249. <https://doi.org/10.1016/B978-0-323-91214-3.00035-1>.
- “Decoupling Toughness and Strength Through Architected Plasticity,” S. Fulco, M.K. Budzik, **E.D. Bain**, and K.T. Turner. *Extreme Mechanics Letters*, 2022, 57, 101912. <https://doi.org/10.1016/j.eml.2022.101912>
- “Modeling Brittle Fractures in Epoxy Nanocomposites Using Extended Finite Element and Cohesive Zone Surface Methods,” J.S. Biswakarma, D.A. Cruz, **E.D. Bain**, J.M. Dennis, J.W. Andzelm, and S.R. Lustig. *Polymers*, 2021, 13, 3387-3403. <https://doi.org/10.3390/polym13193387>
- “Influence of Interfacial Bonding on the Mechanical and Impact Properties of Ring-Opening Metathesis Polymer (ROMP) Silica Composites,” N.T. Tran, B.A. Patterson, D.E. Harris, E. Napadensky, J.L. Lenhart, D.B. Knorr\*, and **E.D. Bain\***, *ACS Applied Materials and Interfaces*, 2020, 12, 53342-53355. <https://doi.org/10.1021/acsami.0c16280>

- “Outcomes and Conclusions from the 2018 AM-Bench Measurements, Challenge Problems, Modeling Submissions, and Conference,” L. Levine, B. Lane, J. Heigel, K.B. Migler, M. Stoudt, T. Phan, R. Ricker, M. Strantza, M. Hill, F. Zhang, J.E. Seppala, E.J. Garboczi, **E. Bain**, D. Cole, A. Allen, J. Fox and C. Campbell, *Integrating Materials and Manufacturing Innovation*, 2020, 9, 1-15. <https://doi.org/10.1007/s40192-019-00164-1>
- “Towards the Development of a Span-wise Extending Unmanned Aerial System,” F.R. Phillips, T. Henry, J.T. Hrynuik, R. Haynes, **E.D. Bain**, and J. Westrich, AIAA scitech 2020 forum, 2006. <https://doi.org/10.2514/6.2020-2006>
- “Benchmark Physical Property Measurements for Powder Bed Fusion Additive Manufacturing of Polyamide 12,” **E.D. Bain\***, E.J. Garboczi, J.E. Seppala, T.C. Parker and K.B. Migler\*, *Integrating Materials and Manufacturing Innovation*, 2019, 8, 335-361. <https://doi.org/10.1007/s40192-019-00146-3>
- “Polymer Powder Bed Fusion Additive Manufacturing: Recent Progress in Materials, Processes, and Applications,” **E.D. Bain\***, *ACS Symposium Series, Vol 1315: Polymer-Based Additive Manufacturing: Recent Developments*, 2019, ISBN13: 9780841234260. Chapter 2, pp. 7-26. <https://doi.org/10.1021/bk-2019-1315.ch002>
- “Mechanics and Nanovoid Nucleation Dynamics: Effects of Polar Functionality in Glassy Polymer Networks,” R.M. Elder, T.R. Long, **E.D. Bain**, J.L. Lenhart and T.W. Sirk, *Soft Matter*, 2018, 14, 8895-8911. <https://doi.org/10.1039/C8SM01483C>
- “Tough, Rapidly Swelling Thermoplastic Elastomer Hydrogels for Hemorrhage Control,” **E.D. Bain**, T.R. Long, F.L. Beyer, A.M. Savage, M.D. Dadmun, H. Martin, J.L. Lenhart and R.A. Mrozek, *Macromolecules*, 2018, 51, 4705-4717, <http://dx.doi.org/10.1021/acs.macromol.8b00428>
- “Influence of Molecular Weight Between Crosslinks on the Rate Dependent Brittle-to-Ductile Transition in Polymers Formed via Ring-Opening Metathesis,” T.R. Long, R.M. Elder, **E.D. Bain**, K.A. Masser, T.W. Sirk, D.B. Knorr and J.L. Lenhart, *Soft Matter*, 2018, 14, 3344-3360, <https://doi.org/10.1016/j.polymer.2016.09.076>
- “Carbon Nanofiber-Filled Conductive Silicone Elastomers as Soft, Dry Bioelectronic Interfaces,” G.A. Slipper, W.D. Hairston, J.C. Bradford, **E.D. Bain** and R.A. Mrozek, *PLoS ONE*, 13(2): e0189415, 2018, <https://doi.org/10.1371/journal.pone.0189415>
- “Mechanical Properties of Silicone Based Composites as a Temperature-Insensitive Ballistic Backing Material for Quantifying Back Face Deformation,” T.D. Edwards, **E.D. Bain**, S.T. Cole, R.M. Freeney, J. Ivancik, J.L. Lenhart, E. Napadensky, J.H. Yu, J.H., J.Q. Zheng and R.A. Mrozek, *Forensic Sciences International*, 285, 2018, 1-12. <https://doi.org/10.1016/j.forsciint.2018.01.014>
- “Role of Weak Particle-Matrix Interfacial Adhesion in Deformation and Fracture Mechanisms of Rigid Particulate-Filled Poly(Methyl Methacrylate),” **E.D. Bain\***, R.A. Mrozek and J.L. Lenhart, *Mechanics of Materials*, 2017, 104, pp. 1-12. <https://doi.org/10.1016/j.mechmat.2016.09.014>
- “Influence of Nano-Scale Morphology on Impact Toughness of Epoxy Blends,” K.A. Masser, **E.D. Bain**, F.L. Beyer, A.M. Savage, J.H. Yu and J.L. Lenhart, *Polymer*, 2016, 103, pp. 337-346. <https://doi.org/10.1016/j.polymer.2016.09.076>

“Failure Processes Governing High Rate Impact Resistance of Epoxy Resins Filled with Core Shell Rubber Nanoparticles,” **E.D. Bain**, D.B. Knorr, A.D. Richardson, J.H. Yu, K.A. Masser and J.L. Lenhart, *Journal of Materials Science*, 2016, 51 (5), pp. 2347-2370. <https://doi.org/10.1007/s10853-015-9544-5>

“Instability of Surface-Grafted Weak Polyacid Brushes on Flat Substrates,” J.C. Galvin, **E.D. Bain**, A. Henke and J. Genzer, *Macromolecules*, 2015, 48 (16), pp. 5677-5687. <https://doi.org/10.1021/acs.macromol.5b01289>

“Progress in Computer Simulation of Bulk, Confined, and Surface-Initiated Polymerizations,” **E.D. Bain**, S. Turgman-Cohen and J. Genzer, *Macromolecular Theory and Simulations*, 2013, 22 (1), pp. 8-30. <https://doi.org/10.1002/mats.201200030>

“Surface-Initiated Polymerization by Means of Novel, Stable, Non-Ester-Based Radical Initiator,” **E.D. Bain**, K. Dawes, A.E. Özçam, X Hu, C.B Gorman, J. Šrogl and J. Genzer, *Macromolecules* 2012, 45 (9) pp. 3802–3815. <https://doi.org/10.1021/ma300491e>

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## Technical Reports (DOD Distribution-Limited)

“Optimization of Poly(Ether Ketone Ketone) / Carbon Fiber Powder Blends for High Temperature Selective Laser Sintering,” **E.D. Bain**, ARL TR-8944, April 2020. Distribution authorized to Department of Defense and US DOD contractors only; critical technology.

“Utilization of Three-Point Bending for Numerical Prediction of Structural Response in Additively Manufactured Parts,” F.R. Phillips, T.C. Henry, J. Hrynuik, R.A. Haynes, **E.D. Bain** and J. Westrich, ARL-TR-8883, January 2020, Approved for public release, distribution unlimited.

“Selective Laser Sintering of High Melting Temperature Polyphenylene Sulfide and Process Optimization by Design of Experiments,” J. Yu and **E.D. Bain**, ARL TR-8535, September 2018, Distribution authorized to Department of Defense and US DOD contractors only, critical technology.

“Development of a Ballistic Clay Replacement That Does Not Require Heating and Exhibits Reduced Temperature Sensitivity,” R.A. Mrozek, T.D. Edwards, **E.D. Bain**, S.T. Cole, R.M. Freaney, V.A. Halls, J. Ivancik, J.L. Lenhart, E. Napadensky, J.H. Yu and J.Q. Zheng, ARL-TR-8310, February 2018, Distribution authorized to Department of Defense and US DOD contractors only, critical technology.

“Nanoengineered Dielectrics and Insulators for Capacitors and Device Packaging,” J.L. Lenhart, R. Jow, J. Ho, O. Borodin, B. Rinderspacher, D. Knorr, M. Hindenlang, **E.D. Bain** and K. Masser, ARL-TR-7038, August 2014.

## Selected Presentations

“Polymers for Defense Applications: Processing-Chemistry-Structure-Mechanics Relationships from Soft to Hard, Slow to Ballistic,” Invited Special Seminar Presentation for: University of Alberta, Edmonton, Canada, November 2019

- “Tough, Rapidly Swelling Thermoplastic Elastomers for Hemorrhage Control,” Poster Presentation for: Gordon Research Conference on Science of Adhesion, South Hadley, MA, July 2019
- “Effects of High Rate Impact on Glassy Polymer Matrix Composites and Soft Human Tissue Surrogates,” Presentation for: Adhesion Society Meeting, Hilton Head, SC, February 2019
- “Benchmarking Polymer Powder Bed Fusion: Laser Sintering of Polyamide 12,” Invited Keynote Presentation for: ASTM D20 Polymer Additive Manufacturing Task Group Meeting, Washington Hilton, Washington, DC, November 2018
- “Processing and Properties of PA12 Benchmark Test Specimens by Polymer Powder Bed Fusion,” Invited Presentation for: AM Benchmarks Conference, NIST, Gaithersburg, MD, June 2018
- “Interfaces in Non-Polar Ring Opening Metathesis Polymer-Based Composites,” Invited Seminar with D.B. Knorr and B.A. Patterson for: NIST, Gaithersburg, MD, June 2018
- “Tough, Rapidly Swelling Thermoplastic Elastomers for Hemorrhage Control,” Presentation for: American Institute of Chemical Engineers (AIChE) Meeting, Minneapolis, MN, October 2017
- “Polymer Powder Feedstock Evaluation & Development for Selective Laser Sintering (SLS),” Invited Talk for: Inspire AG (ETH Zurich), St. Gallen, Switzerland, September 2017
- “Polymers for Defense Applications: Processing-Structure-Mechanics Relationships from Soft to Hard, Slow to Ballistic,” Invited Seminar Presentation for: Mississippi State University, March 2017
- “Role of Weak Adhesion and Craze Shortening in Fracture Mechanisms of Rigid Particulate Filled Poly(methyl methacrylate),” Presentation for: Adhesion Society Meeting, St. Petersburg, FL, February 2017
- “Failure Processes Governing High Rate Impact Resistance of Epoxy Resins Filled with Core Shell Rubber Nanoparticles,” Presentation for: Society for Experimental Mechanics (SEM) XIII International Congress, Orlando FL, June 2016. (winner, best paper, dynamic behavior of materials).
- “Toughening PMMA with Rigid Particulates: Role of Weak Adhesion,” Poster Presentation for: Materials Research Society (MRS) Meeting, Boston, MA, December 2015
- “Polymer Synthesis, Processing, Modification, and Characterization for Advanced Applications,” Invited Seminar, Presentation for: Nova Chemicals, Calgary, AB, Canada, March 2015
- “Failure Processes Governing High Rate Impact Resistance of Epoxy Resins Filled with Core Shell Rubber Nanoparticles,” Presentation for: American Institute of Chemical Engineers (AIChE) Meeting, Salt Lake City, UT, November 2015
- “Microwave-Assisted Surface-Initiated Free Radical Polymerization,” Presentation for: American Physical Society 2013 March Meeting, Baltimore, MD, March 2013

“Novel Synthesis of Surface-Grafted Radical Initiator with Improved Stability and Yield,” Poster Presentation for: American Physical Society 2012 March Meeting, Boston, MA, March 2012

“Instability of SI-ATRP Polyelectrolyte Brushes in Aqueous Solutions,” Presentation for: International Graduate Research Training Group (IGRTG) 2011 Annual Meeting, New Bern, NC, October 2011

“New Base Films for Magnetic Tape with Improved Dimensional Stability,” Poster Presentation for: AIChE national student conference, Austin, TX, November 2004. (3rd place winner).

“New Base Films for Magnetic Tape with Improved Dimensional Stability,” Presentation for: INSPIRE undergraduate polymer research conference, Hattiesburg, MS, October 2004. (2nd place winner).