Margaret Frey

Web Bio

Information

Biography

Biographical Statement

Prof. Margaret Frey is Associate Dean for Undergraduate Affairs in the College of Human Ecology, and an Associate Professor and the Director of Undergraduate Studies in the department of Fiber Science & Apparel Design at Cornell University. She is a Faculty Fellow for Atkinson Center for a Sustainable Future, for the Cornell Institute for Fashion and Fiber Innovation and for Balch Residence Hall at Cornell University.

Research themes Prof. Frey’s laboratory fall under two interconnected umbrellas: rapidly renewable polymers as engineering materials and interfacing fiber science and nanotechnology. The success and the range of the research have resulted from strong collaboration with researchers in both related and dissimilar fields. Combining the tools and capabilities of fiber science with expertise in fields including entomology, horticulture, biological and environmental engineering, materials science, chemical and biomolecular engineering and biomedical engineering has resulted in synergistic leaps in materials research that would not be possible without close collaboration between experts in diverse fields. Several research goals have developed over the past year along the theme of creating functional nano-fibers and nanofiber fabrics for specific end uses. Specific targets include controlling phase separation during fiber formation in electrically charged jets to 'self-assemble' co-axial fibers with different phases at the core and shell. Examples include hydrophobic core with hydrophilic shell, liquid crystal core with polymer shell. Additionally, research continues and spinning capabilities have been upgraded to allow formation of fibers with pH sensing, chemically reactive, conductive or +/- charged capabilities and piezoelectric power generation. Functional nanofibers are incorporated into nano-fiber fabrics, conventional fabrics, lateral flow assay devices or microfluidic devices in specific patterns to create fiber-based devices.

Prof. Frey earned a BS in Chemical Engineering and an MS in Fiber Science from Cornell University. She earned her PhD in Fiber & Polymer Science from NC State University and currently serves on the scientific advisory board for the Textile Engineering, Chemistry and Science program in The College of Textiles at NCState.

Department Website Summary

Since my initial appointment as Assistant Professor in 2002, research in my group has developed along two main themes: nanofibers as functional surfaces and processing cellulose. Current research efforts funded by US government agencies focus on inventing functional nanofibers and assembling those fibers into devices for capture and detection of pathogens and toxic chemicals. Expertise in cellulose processing developed during my graduate work and early faculty research remains important and has resulted in requests from industry and Cotton, Inc. to work on current challenges in the cotton industry. Overall, research has been consistently collaborative with colleagues at Cornell, at other universities and in Industry.

I have taken great pride in continual innovation and excellence in teaching at both the undergraduate and graduate level. This commitment and the success of my initiatives have been recognized by the SUNY Chancellors award for excellence in teaching. Additionally, I earned a Certificate of Teaching Excellence from the Cornell Center for Teaching and Learning based on innovations in converting FSAD 2370: Structural Fabric Design to an active learning format. On a regular rotation, I have taught FSAD 1350/1360 Fibers, Fabrics and Finishes with laboratory, FSAD 2370 Structural Fabric Design and FSAD 6660 Fiber Formation Theory and Practice.

Teaching

Teaching and Advising Statement

On a regular rotation, I have taught FSAD 1350/1360 Fibers, Fabrics and Finishes with laboratory,FSAD 2370 Structural Fabric Design and FSAD 6660 Fiber Formation Theory and Practice. In each class, I have continually developed my teaching methods and strategies to keep up with new developments in the industry and to help students connect the course material to the larger field of textiles and apparel.

Students in the undergraduate courses (FSAD 1350/1360 and FSAD 2370) are overwhelmingly (90%) Fashion Design and Management majors rather than science or engineering oriented students. These students tend to be visual learners and need coaching to comprehend and process mathematical, chemical and mechanical properties of textiles and fibers.

I initiated addition of the FSAD 1360 laboratory as an accompanying course for FSAD 1350. In this course the students learn basic fiber identification skills using standardized test methods and observe effects of dyebath additives and mercerization. Since many of my Fashion Design and Management students have negative associations with laboratory courses, this course is purposefully designed to be a friendly and cooperative experience while familiarizing students with the basics of fiber chemistry and American Association of Textile Chemists and Colorists (AATCC) test methods.

In FSAD 1350, connections between the textbook material and ‘real world’ examples of fibers, fabrics and finishes are made in every class meeting, on homework assignments and on exams. Advertising and popular press articles describing the fibers, yarns, dyeing and finishing techniques used on fashion and performance garments are used as the basis of discussion on how each of these aspects affects performance and aesthetics of finished projects. Relevant industry innovations and trends are also introduced. In Fall 2014 prominent innovations and trends include: development of a new flax fiber 'KRailar®', sustainability efforts including 'Zero Discharge in Hazardous Chemicals' and reusing textile scrap materials, and international worker safety issues. Discussing these issues in the context of fibers, fabrics and finishes adds relevance and meaning to students' experience in the course.

The FSAD 2370 Structural Fabric Design course has been completely revised to a flipped classroom model in the past 3 years. Students now cover course material using online courseware 'Textile Resources for Cornell' developed at The College of Textiles, North Carolina State University. The courseware includes videos and animations of textile processes and quizzes to monitor understanding of the topics. In class, students work in groups to reverse engineer samples from their swatch books and write basic fabric specifications. In this course, the students measure and calculate fabric parameters including yarn numbers, fabric weight and cover factor. The TA and I circulate among the groups and work closely with students as they analyze their fabrics. In this way we can correct errors and misperceptions in real time and insure that all students master the techniques and understand the meanings of the values they calculate. Students also prepare computer drawings of the fabrics using Kaledo Weave software to input the weave structure, thread counts, yarn sizes and yarn colors to create a simulation of the fabric. Additionally, the course uses the Weavebird Dobby loom to provide some hands?on weaving experience. This experience crystallizes student understanding of the weaving process and loom functions. The flipped experience extends to the final exam where students are asked to identify approximately 16 different fabric samples and describe how each would be produced. Feedback on this approach has been increasingly positive after the initial bugs were worked out of the system.

At the graduate level, I take both the 'theory' and 'practice' aspects of FSAD 6660 Fiber Formation Theory and Practice quite seriously. Theory is approached in the course starting with polymer chain dynamics and crystallization habits and incorporating fluid dynamics, momentum and energy balances for melt spinning, dry spinning, wet spinning and electrospinning systems. The theory is most well developed for melt spinning, and Clemson University has kindly allowed the course to use a version of the FiSIM software to run simulations of Nylon, Polyester and Polypropylene spinning processes. For the first time, in Spring 2014, the course was able to use the new Hills melt extruder located in our building to run a melt spinning experiment. After running an experiment varying the extrusion speed, take?up speed and spinning temperature, each student ran a different characterization experiment on the resulting samples and the group worked as a whole to analyze changes in the fiber properties as a function of process conditions. To further understand the practice of fiber formation the class also runs an electrospinning experiment and has a field trip to a monofilament melt extrusion plant. This course concludes with critical reading of current literature. Students participate in discussion of papers published in peer reviewed journals within 18 months. With one student leading discussion of each paper, the class addresses the strengths, weaknesses, interesting results and even writing styles of each manuscript. For many students, this is the first experience with both leading a discussion and deep reading of scientific papers.

Outside the classroom, I have been very active in supervising undergraduate research. Twenty six undergraduates from FSAD, Cornell University and other universities have contributed significantly to research, presented posters and oral presentations on campus and at regional and national meetings and been co?authors on peer reviewed papers. Seventeen of these students have continued to graduate school. Three undergraduate research associates from my group have been awarded NSF graduate fellowships to date.

I have also trained graduate students from Fiber Science and from the former Cornell Masters in teaching program. Supported by an NSF grant, 3 graduate students training to become K?12 science teachers worked with my research group to translate my current research to museum displays. The displays were used for hands?on activities at the Franklin Institute in Philadelphia and the Science Center in Ithaca. Fiber Science Graduate students trained in my research group have won student paper competitions from the American Chemical Society Division of Cellulose and Renewable Materials, the Fiber Society and the International Non?wovens Technical Conference. Recently, students have taken the opportunity for industry internships with Invista (spandex) and Universal Fibers and NSF funded International Research Exchange Programs with University of Luxembourg and the Otto von Guericke University in Magdeburg, DE. These internships and exchanges have had the added benefit of cementing relationships and resulting in student placements for permanent jobs in the companies and further study in Luxembourg. Post?graduation, students have found employment as faculty in the US and China and in industry in the US.

Professional

Current Professional Activities

- **American Chemical Society - Division of Cellulose and Renewable Materials**: Councilor, Treasurer, Member-at-Large and Symposium Chair,
- **Fiber Society**: Symposium Chair
- **Society of Women Engineers:** Participated in Cornell STEM recruiting

Research

Current Research Activities

My research in the area of micro and nanofibers has focused on potential uses for high specific surface area materials with tailored surface chemistry. In applications ranging from air and water filtration to lab?on?chip micro chemical analysis systems, I have demonstrated that functional surfaces for capture and isolation of specific compounds can be effectively created using nanofibers. Nanofibers have the unique advantages of high surface to volume ratios, easy handling and compatibility with a wide range of substrates including textiles, plastics, papers and metals. I have made significant contributions in developing nanofibers as functional surfaces and structures for microfluidic systems. Nanofibers invented in my laboratory can perform important functions including sample purification, analyte concentration and reagent mixing in microfluidic channels. These nanofibers perform better than the generally used structures produced via expensive and slow gold lithography processes which must be performed in a clean room. Compared to conventional fibers in conventional textile applications, nanofibers have inherent draw backs, including slow production rate, high cost, and poor abrasion resistance. However, in comparison to other high surface/low volume materials typically produced by lithographic methods, nanofibers have huge advantages. These advantages include simplicity of production without requiring a clean room, great material flexibility to create a wide range of surface chemistries and material patterns, and comparatively low cost. In collaboration with colleagues from the Colleges of Agriculture and Life Sciences and Engineering, I have developed unique fiber solutions for agricultural chemical delivery, microfluidic diagnostic devices and lateral flow assay systems. Based on the needs of specific systems,we have been able to develop a broad array of nanofiber functionalities, including hydrophilic and hydrophobic surfaces, positively and negatively charged surfaces, chemically active surfaces, and conductive and piezo electric fibers. All of these functionalities have beendemonstrated in model devices.

In my research, micro and nanofibers are produced primarily by electrospinning with a focus on using the process variables to drive final morphology of individual fibers and non?woven membranes. The strong elongational flow field, electrical gradient and thermodynamics of solvent evaporation and polymer phase separation all contribute to production of fibers with fine diameters, high concentration of active components at the fiber surface and membrane structures ranging from random to well aligned. In a one step process utilizing phase separation, functional materials including small molecules, non?fiber forming polymers and proteins are added to nanofibers. By co?dissolution or suspension of the active material with a fiber forming polymer, nanofibers combining the desired surface chemistry with good mechanical properties and uniform morphology are produced rapidly and reproducibly . Additionally, post spinning methods, including layer?by?layer deposition, covalent bonding and polymerization of a second material via gamma grafting or vapor phase deposition, have been utilized to add additional active properties. Nanofiber membranes have been further incorporated into larger
structures by directly spinning into microfluidic channels or cutting shapes from larger membranes for use in microfluidic channels, lateral flow assay devices, filtration systems or agricultural trials.

Extension

Education

Education

Education:
Cornell University Chemical Engineering B.S. 1985
Cornell University Fiber Science M.S. 1989
North Carolina State University Fiber and Polymer Science Ph.D.1995

Courses

Courses Taught

- FSAD 1350 - Fabrics, Fibers and Finishes
- FSAD 1360 - Fiber Laboratory
- FSAD 2370 - Structural Fabric Design
- FSAD 6660 - Fiber Formation Theory and Practice
- IGERT Module: Sustainable Industry Practices
- IGERT Module: Nanomaterials for Biosensors

Websites

Administration

Administrative Responsibilities

Associate Dean for Undergraduate Affairs

Faculty Fellow: Balch Residence Hall

Faculty Fellow: Cornell Institute for Fashion and Fiber Innovation

Faculty Fellow: Atkinson Center for a Sustainable Future

Scientific Advisory Board (SAB) member for the Department of Textile Engineering, Chemistry and Science (TECS) at NC State University

Publications

Selected Publications

45. Buttaro, L., Drufva, E., Frey, M.W., 'Phase Separation to Create Hydrophilic yet Non-Water Soluble PLA/PLA-b-PEG Fibers via Electrospinning', Journal of Applied Polymer Science, 2014, **131(19)** 41030.

44. Hendrick, E., Frey, M.W., 'Increasing Surface Hydrophilicity in Poly(Lactic Acid) Electrospun Fibers by Addition of Pla-b-Peg Co-Polymers', Journal of Engineered Fibers and Fabrics,2014, **9(2)**, www.JeffJournal.org

43. Xiang, C., Frey, M.W., 'Hydrolytic Degradation of Nanocomposite Fibers Electrospun from Poly(Lactic Acid)/Cellulose Nanocrystals' in Cellulose Based Composites: New Green Nanomaterials, Hinestroza, J. and Netravali, A. eds. 2014

42. Xiang, C., Frey, M.W., Increasing Mechanical Properties of Electrospun Nylon-6 Non-woven Fabrics, *Journal of Engineered Fibers and Fabrics*, submitted.

41. Mukai, M., Woods, L. W., Stump, S., Ebel, J.G., Levitt, A.S., Frey, M.W., Smith, J., Uzal, F.A., Poppenga, R.H. Puschner, B., Detection of diisocyanates in nesting material associated with mortality in pigeon chicks, J. Vet Diagn Invest, 2014, DOI: 10.1177/1040638713520543.

40. Reinholt, S. J., Sonnenfeldt, A., Naik, A., Frey, M.W., Baeumner, A.J., Developing new materials for paper-based diagnostics using electrospun nanofibers, *Analytical and Bioanalytical Chemistry* 2013 DOI: 10.1007/s00216-013-7372-5.

39. Pehlivaner Kara, M.O., Frey, M.W., The effects of solvents on the morphology and conductivity of poly(3,4-ethylenedioxythiophene):poly(styrenesulfonate) nanofibers, *Journal of Applied Polymer Science*, 2014, **131(11)** 40305.

38. Cho, D.; Naydich, A., Frey, M.W., Joo, Y.L., Further improvement of air filtration efficiency of cellulose filters coated with nanofibers via inclusion of electrostatically active nanoparticles, *Polymer*, 2013 **54**:2364-2372.

37. Xiang, C., Taylor, A.G., Hinestroza, J.P., Frey, M.W., Controlled release of nonionic compounds from poly(lactic acid)/cellulose nanocrystal nanocomposite fibers. *Journal of Applied Polymer Science,* **2013**: 127.(1) p. 79-86.

36. Schrote, K. and M.W. Frey, Effect of irradiation on poly (3, 4-ethylenedioxythiophene): poly (styrenesulfonate) nanofiber conductivity. *Polymer, 2013.* 54: 737-742.

35. Cho, Y.; Cho, D.; Park, J. H.; Frey, M.; Ober, C.; Joo, Y., Preparation and Characterization of Amphiphilic Triblock Terpolymer-Based Nanofibers as Antifouling Biomaterials, *Biomacromolecules,* **2012**, 13(5): p. 1606-1614.

34. Matlock-Colangelo, L.; Cho, D.; Pitner, C. L.; Frey, M. W.; Baeumner, A. J., Functionalized electrospun nanofibers as bioseparators in microfluidic systems. *Lab on a Chip* **2012,** 12(9): p. 1696-1701.

33. Cho, D.; Lee, S.; Frey, M. W., Characterizing zeta potential of functional nanofibers in a microfluidic device. *Journal of Colloid and Interface Science* **2012,** *372* (1), 252-260.

32. Cho, D., Hoepker N., Frey M.W., Fabrication and characterization of conducting polyvinyl alcohol nanofibers. *Materials Letters,* **2012**. **68**(0): p. 293-295.

31. Cho, D. W.; Matlock-Colangelo, L.; Xiang, C. H.; Asiello, P. J.; Baeumner, A. J.; Frey, M. W., Electrospun nanofibers for microfluidic analytical systems. *Polymer* **2011,** 52(15): p. 3413-3421.

30. Cho, D.; Bae, W. J.; Joo, Y. L.; Ober, C. K.; Frey, M. W., Properties of PVA/HfO(2) Hybrid Electrospun Fibers and Calcined Inorganic HfO(2) Fibers. *Journal of Physical Chemistry C* **2011,** *115* (13), 5535-5544

29. Buyuktanir, E.A., West J.L., Frey M.W., Optically responsive liquid crystal microfibers for display and nondisplay applications. *Proc. SPIE,* **2011**. 7955: p. 79550P.

28. Reiffel, A., Henderson, P.W., Sohn, A.M., Lekic N., Frey M.W., Spector J.A., Creating Surgically Relevant de novo Tissue Engineered Constructs Using Biocompatible Biodegradable Polymers. *Journal of Surgical Research,* **2011**. 165(2): p. 208.

27. Rebovich, M.E., Vynias D., Frey M.W., Formation and functions of

high-surface-area fabrics. *International Journal of Fashion Design, Technology and Education*, **2010**. **3**(3): p. 129 - 134.

26. Li, L.L., Frey M.W., Preparation and characterization of cellulose nitrate-acetate mixed ester fibers. *Polymer*, **2010**. **51**(16): p. 3774-3783.

25. Li, L., Frey, M.W., Browning, K.J., Biodegradability Study on Cotton and Polyester Fabrics. *Journal of Engineered Fibers and Fabrics*, **2010**. **5**(4): p. 42-53.

24. Buyuktanir, E.A., M.W. Frey, and J.L. West, Self-assembled, optically responsive nematic liquid crystal/polymer core-shell fibers: Formation and characterization. *Polymer*, **2010**. 51(21): p. 4823-4830.

23. Sohn, A.M., Henderson, P. W. , Koppius, A.; Reiffel, A. J., Bonassar, L., Frey, M.W.; Spector, J. A., Endothelialization of Sacrificial Polymer-Derived Vascular Channels: Advancement towards the Creation of Surgically Relevant Tissue Replacements. *Plastic and Reconstructive Surgery*, **2010**. 126: p. 58.

22. Xiao, M. and M.W. Frey, *Study of cellulose/ethylene diamine/salt systems*. Cellulose, **2009**. **16**(3): p. 381-391.

21. Xiang, C.H., Y.L. Joo, and M.W. Frey, *Nanocomposite Fibers Electrospun from Poly(lactic acid)/Cellulose Nanocrystals*. Journal of Biobased Materials and Bioenergy, **2009**. **3**(2): p. 147-155.

20. Xiao, M. and M.W. Frey, *Rheological Studies of the Interactions in Cellulose/Ethylene Diamine/Salt Systems*. Journal of Polymer Science Part B-Polymer Physics, **2008**. **46**(21): p. 2326-2334.

19. Frey, M.W., *Electrospinning cellulose and cellulose derivatives*. Polymer Reviews, **2008**. **48**(2): p. 378-391.

18. Xiao, M. and M.W. Frey, *The role of salt on cellulose dissolution in ethylene diamine/salt solvent systems*. Cellulose, **2007**. **14**(3): p. 225-234.

17. Xiang, C.H., Frey, M.W. , Taylor A. G., Rebovich M. E., *Selective chemical absorbance in electrosupun nonwovens*. Journal of Applied Polymer Science, **2007**. **106**(4): p. 2363-2370.

16. Li, D., Frey M.W., Vynias, D., Baeumner A. J., *Availability of biotin incorporated in electrospun PLA fibers for streptavidin binding*. Polymer, **2007**. **48**(21): p. 6340-6347.

15. Frey, M.W. and L. Li, *Electrospinning and Porosity Measurements of Nylon-6/Poly(ethylene oxide) Blended Nonwovens*. Journal of Engineered Fibers and Fabrics, **2007**. **2**(1): p. 31-37.

14. Frey, M.W., Li, D., Tsong, T., Baeumner, A.J., Joo Y.L., *Incorporation of biotin into PLA nanofibers via suspension and dissolution in the electrospinning dope*. Journal of Biobased Materials and Bioenergy, **2007**. **1**(2): p. 220-228.

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12. Li, L., Bellan, L.M., Craighead, H.C., Frey, M.W ., *Formation and properties of nylon-6 and nylon-6/montmorillonite composite nanofibers*. Polymer, **2006**.

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8. Frey, M.W., H. Chan, and K. Carranco, *Rheology of cellulose/KSCN/ethylenediamine solutions and coagulation into filaments and films*. Journal of Polymer Science Part B-Polymer Physics, **2005**. **43**(15): p. 2013-2022.

7. Frey, M.W. and M.H. Theil, *Calculated phase diagrams for cellulose/ammonia/ammonium thiocyanate solutions in comparison to experimental results*. Cellulose, **2004**. **11**(1): p. 53-63.

6. Cuculo J. A., N. Aminuddin and M.W. Frey *"Solvent Spun Cellulose Fibers"*, J. A in *Structure Formation in Polymeric Fibers*, 296-328, D.R. Salem Ed., Hanser Publishers: Munich (**2000**).

5. Frey, M.W., J.A. Cuculo, and R.J. Spontak, *Morphological characteristics of the lyotropic and gel phases in the cellulose/NH3/NH4SCN system*. Journal of Polymer Science Part B-Polymer Physics, **1996**. **34**(12): p. 2049-2058.

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3. Frey, M.W., Cuculo, J.A., Ciferria, A., Theil, M.H., *A Review of Lattice Theory for Lyotropic Liquid-Crystalline Polymers, Spinodal Decomposition, and Gel Formation*. Journal of Macromolecular Science-Reviews in Macromolecular Chemistry and Physics, **1995**. **C35**(2): p. 287-325.

Publications (Non-Refereed):

2. H. S. Whang, N. Aminuddin, M. Frey, S. M. Hudson*, and J. A. Cuculo, *Conversion of cellulose, chitin and chitosan to filaments with simple salt solutions*, In *Biodegradable and Sustainable Fibers*, R.S. Blackburn, Ed. Woodhead Publishing, London, 2005.

1. C.Jordan, B. Crawford and M. Frey*, "Investigation of Textile Finishing – A scientific discovery experiment for children of all ages" *Journal of Textiles and Apparel, Technology and Management*, **4(3)** (online journal) *http://www.tx.ncsu.edu/jtatm/volume4issue3/tex_finishing.htm*, 2005.