

NC170: Personal Protective Technologies for Current and Emerging Occupational and Environmental Hazards

Annual Meeting Report September 12, 2023, 6 PM

Chair: Chunhui Xiang
Chair Elect: Sumat Mandal
Secretary: Dawn Michaelson

Attendees: Gang Sun, Charles Freeman, Chunhui Xiang, Elizabeth Bye, Sumat Mandal, Dawn Michaelson, Linsey Griffin, Shu Hwa Lin, Fatima Baytar, and Ashley Mueller (NIFA)

The annual meeting was during the first day of AATCC's 2023 Textile Discovery Summit in Greenville, South Carolina, on September 12, 2023 at 6 pm. Ashley Mueller provided the NIFA update and report, then communicated the praise our 2022 Annual Report received at the meeting.

Items of note:

- Gang Sun will be retiring July 2025.
- Elizabeth "Missy" Bye will be retiring, and Lynn Boorady will be taking over as the NC-170 advisor.
- Shu Hwa Lin reported that a Cotton Inc. proposal had been submitted in 2023 but was not selected this year. She stated that they will apply next year.

NC-170 was excited to have its annual meeting at the 2023 Textile Discovery Summit in Greenville, South Carolina, where collaboration could be made with industry leaders and researchers. There was a total of 19 abstracts submitted to the NC-170 session. While the majority were members, there was one abstract from a non-member. Eleven abstracts were chosen for the oral sessions and the remaining 8 were given a poster session during the general sessions.

Attendees broke into two sections; 1- Textile Science related and 2 – Design and Product Development related to discuss progress on the current project. Section 1 held discussions on grant opportunities that would be reviewed and applied for during the 2023-2024 academic year. Section 2 discussed the design project collaboration with Anugrah Shaw (not present at the annual meeting) and the design challenges for pesticide worker PPE garments. Discuss and suggestions for changes to materials and design were given by the members. Additional discussion was conducted on additional research projects and collaborations with the members.

The NC-170 oral presentation session topics and authors are included on the next page.

Meeting was adjourned at 7:55 pm

AATCC 2023 TEXTILE DISCOVERY SUMMIT
NC-170 MEETING SCHEDULE (1:30-6:00PM Tuesday, September 12, 2023)

1:30-1:40 Opening remarks:

- 1:40-2:00** **Developing Protective Coverall Designs for Pregnant Women**
Fatma Baytar, Cornell University, Ithaca, NY
- 2:00-2:20** **Firefighter Turnout Gloves: Holistic Evaluation of Protection, Comfort, and Dexterity**
Rui Li, Iowa State University, Ames, IA
- 2:20-2:40** **Interior Fit of Female Firefighter Gloves Compared to 3D Hand Anthropometry**
Linsey Griffin, University of Minnesota, Saint Paul, MN
- 2:40-3:00** **Intrinsically Conductive Polymer Fibers for Smart Wearables**
Hang Liu, Washington State University, Pullman, WA
- 3:00-3:20** **Analysis of Sweat Moisture Drying Performance of Fabrics Used in Workers' Protective Clothing**
Sumit Mandal, Oklahoma State University, Stillwater, OK
- 3:20-3:40** **Biomechanical, Physiological, and Subjective Perception Assessment of Personal Flotation Devices**
Charles Freeman, Mississippi State University, Starkville, MS
- 3:40-4:00.** **Break**
- 4:00-4:20** **Development of a Colorimetric Nanofiber Sensor for Selective Detection of Organophosphate Pesticide**
Chunhui Xiang, Iowa State University, Ames, IA
- 4:20-4:40** **Smart Textile Applications from Market Analysis**
ShuHwa Lin, University of Hawaii, Honolulu, HI
- 4:40-5:00** **Progresses in Decontaminating and Sensing Textiles for Improved Personal Protections**
Gang Sun, University of California, Davis, CA
- 5:00-5:20** **Investigation of the Reliability of a Smoke Generation System: A Preliminary Study**
Yulin Wu, Iowa State University, Ames, IA
- 5:20-5:40** **A 2D Image-Based Anthropometric Measurements of Human Hands**
Mengying Zhang, Iowa State University, Ames, IA
- 5:40-6:00** **Conclusion remarks**

NC170: Personal Protective Technologies for Current and Emerging Occupational and Environmental Hazards
Multistate Research Project: October 1, 2022 – September 30, 2027

Period of Report: October 1, 2022 – September 30, 2023

Impact Nugget

California

The development of biocidal polymeric materials has resulted in broad applications in personal protective clothing materials and food safety applications. The development of highly sensitive personal use sensors has made progress in the detection of Covid virus and pesticides. The development of highly sensitive e-textile stretch/strain sensors. The development of e-textile bioimpedance spectroscopy system.

Colorado

Firewomen experience fit challenges when selecting turnout coats and pants, leading to concerns about mobility and safety. This research builds an understanding of specific fit problems on the ability of firewomen to do their challenging work in a safe and stress-free manner. Interview and survey data collected for the manuscript pinpointed experiences with the PPE sizing processes that led to poor fit. The data also identified previously undocumented knowledge gaps between NFPA size standards, commercialized products, and processes used by manufacturers and firehouses to fit female practitioners. With effective fire industry partnerships and future research, women can experience fewer injuries, improved comfort, and work performance with their PPE while establishing equality with their male counterparts.

Florida

Evaluated structural firefighting PPE, combat uniforms for subarctic warfighter operations, and fabric cooling mechanisms for construction workers using a dynamic sweating thermal manikin housed at Florida State University in the ThermaNOLE Comfort Lab®. Assessed prototype structural firefighter turnout suits for ergonomic mobility through a full systems human wear trial. Published work on firefighter user needs and migrant agricultural worker thermal comfort. Completed FEMA funded study on female firefighter PPC fit and was awarded \$1.5M grant to continue inquiry into better fitting PPC for women in the fire service.

Hawaii

The development of adopting VitaSigns for monitoring firefighters has resulted in applications in the vest for firefighters and health care applications. During the pandemic, Hawaii was experiencing a short fall of resourcing materials and protective devices. Our goal was to provide instruction in such a way that all testing and construction could be done at home, allowing students to continue testing and making masks outside of school and opening the door for students and community to teach others.

Iowa

The development of a controlled consistent smoke generation system for PPE contamination study, decontamination approach efficacy evaluation, and exposure health effects investigation.

The development of computer vision and AI based anthropometric tool for anthropometric data collection for PPE sizing and fit analysis and PPE development.

Kansas

Most existing brands in the current market do not use separate patterns/designs for firemen and firewomen, causing critical safety and performance issues. Besides, research on fit issues amongst firefighters, particularly firewomen, is limited. Therefore, during this reporting period, the K-State research group focused on developing new firefighting turnout coats and pants for firewomen. The new designs, upon validation and finalization, have great potential for a new patent and commercialization, benefiting the domestic female firefighters' on-site performance and safety greatly.

Minnesota

Developed a new method to measure and compare the interior fit of multi-layered gloves.
Developed new half-mask respirator-specific landmarks and measurements, which enabled the ability to accurately predict N95 mask fit.

Mississippi

MSU contributed to technological innovation by filing disclosures for several devices, including a hand wearable IMU sensor mount in April 2023, a mobile markerless motion capture system in February 2023, and a capacitive non-woven textile stretch sensor in May 2022.

Research led to the acceptance of a publication titled "Closing the Wearable Gap: Foot-ankle Kinematic Modeling via Deep Learning Models Based on a Smart Sock Wearable," which will advance the field of wearable technologies.

New York

Cornell University organized a 3-day Career Exploration Camp in collaboration with New York 4H Group with a theme of "Exploration of STEM through Smart Firegear" in June 28 – 29, 2023 on campus. This extension/outreach program provided teens an opportunity to understand diverse technologies, science, engineering, design and human factors used to develop firegear.

Oklahoma

Oklahoma State University (OK State) mainly focused on developing a Textile and Apparel Science Laboratory (TASL). The purpose of this laboratory will be to analyze the protective and comfort performance of textile materials through bench-/full-scale equipment and modeling.

Washington

The development of side-by-side wet-spun conductive fibers has opened up a new technology paradigm to manufacture unspinnable polymers into fibers. The strain and chemical sensors fabricated from the side-by-side conductive fibers have great potential applications in smart wearables.

New Facilities and Equipment:

Florida

New electrogoniometers were purchased for Biometrics range-of-motion (ROM) measurement system. Renovations are underway for a new Textile Testing Lab space across campus.

Iowa

Smoke generation system
Smoke characterization system
Smoke exposure tunnel

New York

Human Solutions Vitus^{bodyscan} 3D Body scanner

Oklahoma

Smoke and PAH Exposure System and Analysis

Unique Project-Related Findings

California

CA developed photo-induced biocidal films with demonstrated functions against the formation of biofilms on surfaces of food contact containers and materials; developed novel light active biocidal technologies to produce antiviral/antibacterial biodegradable surgical face mask materials, as well as food safety applications funded by USDA, CPS, and NIOSH (through Iowa State University); continued the work on personal use and wearable sensors for trace amount of chemicals in foods and the environment; developed 3D printed, e-textile based auxetic stretch/strain sensors which can be used to monitor and detect body movement and posture; developed an e-textile based bioimpedance monitoring system which can be used to monitor internal organs such as lungs and bladder.

Colorado

Recent activities related to this project include identifying the specific fit problems firewomen have with their turnout coats and pants. These activities build an understanding of specific fit problems on the ability of firewomen to do their challenging work in a safe and stress-free manner.

Florida

Women in numerous occupations requiring the use and wear of PPE are not provided with options that adequately fit. Through design and patterning changes, improvements to firefighting PPE can be made in the form of lowering movement restrictions and improving heat loss, thereby reducing firefighter injuries and fatalities. A proprietary heated base layer technology was proven to effectively heat the body for warfighter operations in temperatures as low as -20C.

Iowa

Fuel composition and combustion condition vary smoke characteristics and toxic chemical contained.

Kansas

1. KS's collaborative research work and creative design work are unique and timely. Our work promotes a better and deeper understanding of the needs and concerns of female firefighters' PPEs to the broader public, which would help them understand the challenging situation female firefighters are facing.
2. The novel female-specific turnout coats and pants designed and developed by KS could potentially enhance female firefighters' on-site performance in emergencies, which could better protect the broader public in dangerous situations.
3. The research process, protocols, and methods employed in this project could be potentially expended to protect other currently underserved populations such as female agricultural workers, elderly workers, and children.

Minnesota

Age impacts N95 mask fit: The older you are, quantitative mask fit is significantly lower.

Mississippi

- A comprehensive assessment of personal flotation devices, considering biological, physiological, and subjective perceptions, which can inform design and safety standards.
- Research quantifying the effectiveness of fabric masks to enhance public health messaging and fit-effectiveness, which can guide public health policies and consumer choices.
- Development of a cottonseed oil polymer that was recognized as Best New Innovation in 2022, highlighting a significant contribution to sustainable material innovation.
- The use of wearable devices to collect kinetic forces during a golf swing, contributing to the understanding of sports biomechanics and performance optimization.
- The closing of the wearable gap in foot-ankle kinematic modeling with deep learning, which may influence the development of future wearable technologies for health and fitness monitoring.
- Studies on the effectiveness of food-grade coatings on ham nets for mite growth control, providing data for food safety and preservation techniques.
- An assessment of the environmental impacts of textile dyeing mills in Bangladesh, aiming to reduce energy and groundwater consumption and contribute to the sustainability of the textile industry.
- Research on the impact of compression socks on postural stability tasks, offering potential benefits for individuals with ankle instability and contributions to healthcare product development.
- The Athlete Engineering BaseLine Ecosystem project which was awarded Best Overall Innovation in 2022, indicating a significant advancement in technologies to enhance human performance

New York

Development and evaluation of fiber-optic wearable respiration monitoring system: This study introduces a machine-embroidered enclosure that guides a soft and extensible lightguide (fiber optic) to react to the strains on a compression shirt caused by the respiration of the wearer. The shape of the stretchable optical fiber changes from serpentine in rest (exhalation) to straight under strain (inhalation), which affects the light transmittance. In tests with 13 healthy adults, the respiratory volume prediction through a deep learning model trained by the light intensity and truth from a commercial spirometer shows a high correlation in both static ($r^2 > 0.880$) and

dynamic postures ($r^2 > 0.690$). This system also accurately measures the respiratory rate under sitting and walking conditions (absolute error < 1.513 BPM). The strain-sensing capability of this sensor depends on the parameters of the embroidery, including the stitch density, stitch tightness, and embroidery shape. Durability tests confirm that the system still functions after 100 000 abrasions and 10 cold washes.

3D foot scanning analysis: Firefighters have reported their protective boots to be bulky and ill-fitting, which they believe restrict the lower body movement on the unpredictable fireground. This study used 3D foot scanning to compare the shape of firefighters' feet to the general population, the shape of female firefighters' feet to males, and the impact of the heavy fire gear on foot shape. The results found the foot breadth of firefighters was larger than the general population and the feet of female firefighters were slimmer than males. Furthermore, it revealed that the feet of firefighters became longer, wider, and flatter when bearing the weight of fire gear. Protective boots should be designed based on the foot shape and dimensions of the actual population, with consideration of sex differences and the impact of weight-bearing for their safety.

Face mask optimization: Two paths to facemask optimization were pursued; optimizing layering of conventional fabrics and nanofibers for effective protection, comfort and durability to cleaning, investigating layering of nanofibers for improved particle capture and investigating fit for children and for adults during dynamic (speaking) activity via 3-D body scanning. Material studies identified fabric layering strategies that are effective yet still comfortable and will withstand repeated cycles of decontamination. These studies include the effect of decontamination on air permeability and filtration efficiency, electrospinning nanofibers onto nonwoven substrate to be used as middle layer in cloth face mask, and modeling air permeability and filtration efficiency of heterogeneous layering of conventional fabrics. Additionally, cloth face mask design has not been addressed formally in research; sizing studies have been conducted on half- and full-facepiece respirators, but none to date have looked at the dynamic fit of face masks. Proper initial (static) and persistent (dynamic) fit of face masks is crucial for both minimizing leakage and maximizing comfort. Therefore, the goal of the design study is to use 3D head scans of dynamic face postures to evaluate specific design features of cloth face masks. The design results can be generalized to both medical and non-medical face masks.

Maternity coverall development: More than two million people in the U.S. work in or near agriculture fields that are treated with pesticides and are at very high risk. Pregnancy further complicates these risks, for both the mother and the fetus, especially if they are exposed to pesticides earlier in pregnancy. Previous studies found that pesticide exposure is linked to infertility, miscarriages, birth defects in babies, and developmental delays in kids. This study focuses on designing protective coveralls (PPE) to accommodate the body changes of female farmworkers during pregnancy. In the first phase of the design research, a comparative design analysis of the existing coveralls as well as maternity wear was conducted and initial designs were developed.

Oklahoma

PAH contamination on protective clothing.

Washington

We have furthered our understanding of the various factors affecting side-by-side fibers' properties. Among the factors, solution viscoelasticity difference between the two solutions plays an important role.

Accomplishment Summaries

Objective 1

Colorado

With collaborators, CO developed a manuscript from data were collected from manufacturer-provided web communications regarding sizing and fit, user surveys (n = 74), and 1:1 interviews (n = 31) with U.S. female firefighters. This manuscript specifically addresses sizing and fitting process challenges experienced by female firefighter's. COLLABORATORS: MO, CO, MN, IA, KS, OR, GA (Brenau)

Iowa

Novel colorimetric nanofiber-based sensors to detect pesticides for chemical protective clothing. Our initial effort focused on the colorimetric change that can be easily detected by the naked eye. The nanofiber-based sensors are lightweight and strong and can be tailored to detect pesticides. In addition, nanofiber-based sensors have a large surface area and 3D nanofiber network, which can increase the potential number of molecules that can react with pesticides and also enhance the roughness of the substrate's surface to increase sensitivity.

Kansas - The KS group investigated factors that impact the selection, use, care, and maintenance of firefighting turnout coats and pants. With collaborators (MN, OR, CO, IA, MO, GA), KS developed a manuscript from data collected from manufacturer-provided web communications regarding sizing and fit, user surveys (n = 74), and 1:1 interviews (n = 31) with U.S. female firefighters. This manuscript specifically addresses sizing and fitting process challenges experienced by female firefighters. Besides, KS independently conducted a market analysis to understand the gap between users' expectations/needs and what is available in the market and prepared a journal manuscript accordingly.

Mississippi

Research and development in the field of smart personal protective equipment (PPE) have led to significant strides in safeguarding workers' health and safety. Textile-based wearable technologies have been crafted to monitor a range of health and environmental conditions, thus providing real-time data that can prevent injury and illness. These smart garments are designed to detect excessive heat, harmful chemicals, biological threats, and even radiation exposure.

The innovative sensors embedded within these textiles can track the wearer's physical stress and exertion, as well as the physiological responses to harsh environmental conditions. The result is a line of PPE that not only fits the wearer's needs but also actively contributes to their safety by alerting them to potential hazards. This proactive approach aims to improve overall job performance while ensuring that safety is never compromised.

The prototypes developed have shown promise in increasing users' performance and enhancing safety measures. They signify a leap forward in PPE technology, combining sustainability with function by using reusable materials that stand up to the rigors of varied work environments. These advancements represent a vital step towards a future where PPE is not just a requirement but a dynamic tool for health and safety management.

New York

Cornell University developed and validated the effectiveness of fiber optic wearable respiration monitoring system and gait monitoring system which can be applied to firefighters' protective gear. Cornell University confirmed the potential of conventional fabrics in layered systems for effective and comfortable face masks.

Oklahoma

Partially developed Textile and Apparel Science Laboratory (TASL) at Oklahoma State University to evaluate the protective and comfort performance of fabrics.

Washington

WA has developed cotton and polyacrylonitrile (PAN) based conductive fibers with intrinsically conductive polymers and liquid metal, and fabricated both strain and chemical sensors. The sensing effects have been evaluated and the results showed promising applications for smart wearables. Fundamental study of understanding the fiber spinning fluid dynamics is ongoing.

Objective 2

California

Develop and evaluate textile-based/wearable smart PPE systems to meet users' needs. Developing and evaluating textile-based wearable and sustainable/reusable sensing technologies for improving PPE that can monitor health conditions and environmental conditions. The outcome of the prototype of the new technologies will enhance users' performance and improve safety. Specifically, the sensors will target physical and physiological strains and environmental conditions such as heat stress, thermal, chemical, biological, ionizing radiation hazards. In addition, sensors will measure indicators related to wearers' physical exertion and strain or physiological and environmental conditions. CA developed novel e-textile stretch/strain sensors which can be integrated into PPE to monitor movement and body postures to assess user's physical exertion. CA developed an e-textile bioimpedance spectroscopy system that can be integrated into PPE to monitor especially lung health of users.

Develop novel functionality and applications of materials for PPE and health/safety solutions:

- a. research novel materials and technologies that can provide desired functions;
- b. research novel textile-integrated sensing techniques
- c. evaluate the performance of the materials for personal protective applications

CA continued the development of rechargeable halamine and photo-active biocidal films, nonwoven fabrics, nanofibrous membranes and hydrogel beads for various applications including food containers and packaging materials that can provide surface self-disinfecting functions; developed colorimetric foam-based ELISA sensors for pesticides and antibiotics for

protection of human and environmental health. In addition, the team has developed detoxifying sensing materials for fumigants and chemicals.

Colorado

CO is currently processing body scans of female firefighters to extract body measurements. Collaborators developed the protocol for placing landmarks in the digital scan for the lower body. CO worked with KS to develop a parallel protocol for land marking the upper body. These data are landmarked and nearly ready to send off to collaborators at KS and FSU to extract measurements, develop the measurement sheet, and analyze the data.

Florida

All projects met objective two to assess and improve the performance of PPE and protective clothing for first responders, military personnel, migrant farmworkers, construction workers, and many other industrial occupations and vulnerable populations.

Hawaii

HI continued the work ECG on personal use and wearable sensors for monitoring health care.

Iowa

The development of a controlled consistent smoke generation system for PPE contamination study, decontamination approach efficacy evaluation, and exposure health effects investigation. The development of computer vision and AI based anthropometric tool for anthropometric data collection for PPE sizing and fit analysis and PPE development.

Kansas - With collaborators (MN, OR, CO, IA, MO, GA), KS processed body scans of female firefighters to extract body measurements. Collaborators developed the protocol for placing landmarks in the digital scan for the lower body. KS worked with CO to develop a parallel protocol for landmarking the upper body. These data are landmarked and nearly ready to send off to collaborators at KS and FSU to extract measurements, develop the measurement sheet, and analyze the data. 2) KS independently designed and constructed prototypes of a new turnout coat and a new pair of turnout pants based on female firefighters' body shapes, which were found to be of great potential for benefitting firewomen.

Maryland – Operator exposure is often higher for hand-held applications. Potential and actual exposure data in the global operator exposure database for hand-held applications was analyzed to determine protection provided by garments in approximately 50 studies. Workwear garments made with fabrics that meet Level C1 requirements can be use as the base requirement based on operator exposure studies analyzed. Data for studies conducted with workwear and impermeable rain suits/rain pants demonstrate the ability of made with “impermeable” materials to mitigate risk in high exposure scenarios. would be required to mitigate risk for high-exposure scenarios.

Kenya was selected for pilot testing of risk assessment and mitigation tool that is being developed as an ICPPE project. PPE partnership project was initiated in Kenya to develop C1 base garment and partial body C3 garment for knapsack sprayers. For this study two 1/3 scale prototypes were developed to obtain input from farmers/operators. User acceptance studies were conducted by BASF and Syngenta in different regions in Kenya. The grassroots approach

allowed approximately 180 farmers/operators to provide input in the color and garment feature for the PPE that is being produced for prototype to be used for wear trials. As part of the partnership project, prototypes were developed for C3 partial body garments for knapsack applicators. These garments as well as a commercially available PPE was used by BASF to obtain initial feedback from users in Indonesia, India and Thailand.

The partnership project in Kenya served as the pilot to develop a global database that includes information on common application scenarios and user preferences. In addition, methodology for qualitative assessment of partial body garments using commonly available dye used for food coloring. The methodology was based on preliminary study information shared by member of an international working group. The methodology was pilot tested in September 2023 in collaboration with Konkuk University and Rural Development Authority in S. Korea.

Material used for C1 garment prototype met ISO 27065 C1 requirements. A database is being developed for C3 materials. Data for 20 materials was entered in the database. This database will be used for the revision of ISO 27065.

Minnesota

Developed a new method to measure and compare the interior fit of multi-layered gloves. Developed new half-mask respirator-specific landmarks and measurements, which enabled the ability to accurately predict N95 mask fit. Conducted civilian mask fit research and discovered that age impacts N95 mask fit: The older you are, quantitative mask fit is significantly lower. Grew civilian dynamic hand database to over 1000 participants and close to 3000 3D hand scans. The database will be analyzed to understand hand clearances (funded by Toyota), glove fit (FEMA & NASA), and general anthropometry.

Mississippi

Research efforts in 2022 included a comprehensive evaluation of the effectiveness of fabric masks, crucial for public health safety during the pandemic. This work contributed to improving public health messaging by quantifying fabric mask effectiveness, potentially influencing personal protective strategies in communities worldwide.

Innovations in wearable PPE were recognized internationally, such as the development of a leakage minimization face barrier and a cottonseed oil polymer, the latter of which was awarded Best New Innovation in 2022. These advancements demonstrate significant strides in creating more effective and sustainable PPE solutions.

Further research delved into the biomechanical, physiological, and subjective perceptions of personal flotation devices, contributing to the safety and performance of such equipment in demanding environments. Additionally, efforts to cultivate rural entrepreneurship highlight the broader implications of this work in community and economic vitality, showcasing the value of aligning PPE development with the needs of diverse occupational groups, including those in underserved rural areas.

New York

Cornell University proposed and evaluated new design, sizing systems, and new materials to improve children's cloth face masks. Cornell University is developing maternity coverall designs to improve fit inclusivity for pregnant pesticide operators.

Published Written Works

- Amaly, Noha, Ahmed Y. EL-Moghazy, Basant Eweida Pramod K. Pandey, Gang Sun. "Development of sulfonated and aminated poly (ethylene-vinyl alcohol) nanofibrous membrane as a solid phase extraction matrix for trace metal ions preconcentration from dairy wastewater for direct ICP-OES analyses." *Reactive and Functional Polymer*, 184, (2023), 1155191.
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- Freeman, C., Orzada, B., Cobb, K., and Talukder, A. (2022). Being Part of a Winning Team: A Problem-based Approach to Teach Sustainability Adoption in Collegiate Athletic Uniforms. *International Journal of Fashion Design, Technology and Education*. pp 1-8.
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Scientific and Outreach Presentations

- Akter, H., Goncu-Berk, G. (2022). Vision Inclusive Clothing Design: A Study on Perception of Clothing by Visually Impaired People, *International Textile and Apparel Association 2022 Annual Conference*, Denver: CO.
- Alam, M., & Xiang, C. (2023). Development of a Colorimetric Nanofiber Sensor for Selective Detection of Organophosphate Pesticides. *AATCC 2023 Textile Discovery Summit*, Greenville, SC, USA, Sep 12-14.
- Baytar, F., Maher, M. & Galada, A. (2022). Evaluating Fit by Using Animated Body Scan Avatars and Digital Coveralls. *3DBODY.TECH Conference & Expo. [Online presentation]*. Lugano, Switzerland.
- Baytar, F., Maher, M., Galada, A. & Yang, Y. (2023). Scan avatar rigging challenges and their effects on clothing simulation. *The International Conference Clothing-Body Interaction 2023*.
- Campbell, L. F., Delp, K., & Baytar, F. (2022). Flat Patterns from Curved Bodies. Bridges Conference (July 27-31) <https://www.bridgesmathart.org/>
- Chowdhury, I. Z., Mandal, S., Agnew, R. J., Petrova, A., Boorady, L. M., & Tushar, S. I. Investigating the Effects of Air Gap on Thermal Protective Performance of Protective Textiles under Different Heat Exposure. *2023 ITAA Annual Conference*, Maryland, USA, November 8- 11, 2023.
- Ferguson, B., Goncu-Berk, G., Young, J., Mishra, T. (2023). S.O.S. Design Manifesto, *9th Congress of the International Association of Societies of Design Research (IASDR 2023)*, Hong Kong. (Reviewed Workshop).
- Freeman, C., Talkuder, A., Black, C., Burch, R., Strawderman, L., & Chander, H. (2022). “Quantifying fabric mask effectiveness to improve public health messaging.” Paper presented at *American Chemical Society Annual Meeting*, Las Vegas, NV.
- Freeman, C., Talkuder, A., Black, C., Burch, R., Strawderman, L., & Chander, H. (2022). “Biomechanical, physiological, and subjective perception assessment of personal flotation devices (PFD).” Paper presented at *American Chemical Society Annual Meeting*, Las Vegas, NV.
- Goncu-Berk, G. (2022). 3D Printing of Flexible Conductive Filaments for Electronic Textile Applications. *8th International Conference on Intelligent Textiles and Mass Customization*, Ontario: Canada.
- Goncu-Berk, G. (2022). From Soft Robotics to Designing Inflatable Wearable Products: A Hands-on Teaching Module for Online Studio Classes, *International Textile and Apparel Association 2022 Annual Conference*, Denver: CO.
- Goncu-Berk, G. (2023). CalmWear: A Smart Tactile Sensory Stimulation Clothing, *21st Turkish Neuroscience Conference*, Virtual.
- Goncu-Berk, G. (2023). Future of Wearables: E-textiles and Smart Clothing, Royal College of Art, Textiles Department, London: UK.
- Goncu-Berk, G. (2023). Technology meets Fashion: Smart Textiles and Clothing, *Costume Culture Association Annual Conference*, Korea.
- Goncu-Berk, G. (2023). When Garments to more than Fashion: Wearables for Health and Wellbeing, COEH Builds Bridges: Algorithm based Work, Wearables & Surveillance, UC Davis Health Campus.
- Goncu-Berk, G., DeLong M. (2022). Post Pandemic Accessible Pedagogy: The Case for Collaborative Online Class Resources for Trend Research and Forecasting. *International Textile and Apparel Association 2022 Annual Conference*, Denver: CO.

- Grace, G., Islam, M.M., Mandal, S., Limbaugh, D., Evaluating physical properties of textiles to use for digital textile assets in design. 2023 ITAA Annual Conference, Maryland, USA, November 8-11, 2023.
- Graciano, C. & Wu, Y. (2022). Undergraduate Research Award from *the Office of Undergraduate Research & Creative Inquiry*, Kansas State University, Manhattan, KS, United States.
- Graciano, C. & Wu, Y. (2022, November). Protecting Women Who Protect Us: Designing Female-Specific Firefighting Personal Protective Turnout Coat & Pants. *International Textile and Apparel Association Annual Conference*. Denver, CO. October (2022 ITAA Paper of Distinction Award in the Undergraduate Research Track).
- Islam, M., Mandal, S., Chowdhury, I. Z., Agnew, R. J., Petrova, A., Schnitzler, E., Boorady, L. M., Studies of polycyclic aromatic hydrocarbon exposure to wildland firefighters' protective clothing. *Institute of Textile Science Symposium 2023*, Edmonton, Canada, March 7-8, 2023.
- Islam, M.M., Mandal, S., Schnitzler, E., Habeeb, A.M., Agnew, R. J., Petrova, A., Boorady, L. M., Studies of polycyclic aromatic hydrocarbon exposure to wildland firefighters' protective clothing. *2023 ITAA Annual Conference*, Maryland, USA, November 8-11, 2023.
- Jo, J., & Park, H. (2022). Machine Embroidery Enclosure for Stretchable Fiber Optic Respiration Sensor. *2022 Annual Conference of ITAA (International Textile and Apparel Association)*, Denver, CO.
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- LaPier, J., Blum, A., Brown, B., Kwiatkowski, C., Ray, H., Philips, B., and Sun, G. (2022) Evaluating the Performance of PFAS Finishes on Upholstery Fabrics, AATCC Textile Discovery Summit, Charlotte, NC, October 4-6, 2022.
- Li, R., Joshi, A., Xiang, C., & Song, G. (2022). Achieving high-performance protective gloves: effects of glove area factor and microclimate properties. *ACS WRM 2022*, Las Vegas, NV, Oct 20-22.
- Li, R., Wu, Y., & Song, G. (2023). Firefighter Turnout Gloves: Holistic Evaluation of Protection, Comfort, and Dexterity. *AATCC 2023 Textile Discovery Summit*, Greenville, SC, USA, Sep 12-14.
- Lin, A., & Park, H. (2023). A Modular Framework for Smart Garment Design. *2023 Annual Conference of ITAA (International Textile and Apparel Association)*, Baltimore, MD.
- Luczak, T., Jackson, K., Neff, M., Freeman, F., Burch, R. F., Barlow, J., Chen, J., Lamberth, J., Chander, H., Ball, J., Nelsen, P., Parker, E., Middleton, C., Duclos, M., Taquino, M., & Grice, S. (2022). "The opportunity to collect kinetic forces during a round of golf using wearable devices: Single-person pilot study." Paper presented at *World Scientific Congress of Golf*, Sioux Falls, SD.
- Maher, M., Goodge, K., Du Puis, J. L., Frey, M., Park, H., & Baytar, F. (2022). Cloth Face Mask Fit and Function for Children: Sizing and Fit Analysis. *2022 Annual Conference of ITAA (International Textile and Apparel Association)*, Denver, CO (Best paper award)
- Mandal, S., Chowdhury, I. Z., Agnew, R. J., Boorady, L. M., Petrova, A. (2023). Characterization of flame protective performance of textile fabrics used in firefighters'

- bunker gear under different extreme fire environments. *AUTEX 2023 International Conference*, Melbourne, Australia, June 26-28.
- Mandal, S., Chowdhury, I. Z., Boorady, L. M., Agnew, R. J. (2023). Analysis of sweat moisture drying performance of fabrics used in workers' protective clothing. *AATCC Textile Discovery Summit*, South Carolina, USA, September 12-14.
- Mandal, S., Nasrin, S., Islam, M., Petrova, A., Boorady, L. M., Agnew, R. J. (2023). Investigating the effect of structural properties on sweat drying performance in sportswear fabrics. *AATCC Textile Discovery Summit*, South Carolina, USA, September 12-14.
- Mazumder, S., Mandal, S. (2022) Characterizing the tensile strength of the fabric materials used in firefighters' protective clothing under radiant heat exposure. *AATCC Virtual Showcase on Protective Textiles*. November 8.
- McQuerry, M & Easter, E. (November 2022). Wildland firefighting personal protective clothing cleaning practices in the United States. *4th Global Summit on Future Materials Science and Research*. Las Vegas, NV (virtual).
- McQuerry, M. & Kwon, C. (2022). Investigation of design, comfort, and mobility issues for female firefighter personal protective clothing. *National Fire Protection Association, Fire Protection Research Foundation, Technical Panel*. (presented virtually).
- McQuerry, M. & Kwon, C. (2022). The future of women's gear: a comparison of NFPA 1971 and 1977 sizing standards to U.S. female firefighter anthropometrics. *National Fire Protection Association, Fire Protection Research Foundation, 2022 Webinar Series*. (virtual webinar).
- McQuerry, M. & Kwon, C. (2023). Women in the fire service and the female PPE study. *International Association of Fire Fighters Redmond Health and Safety Symposium*. New York City, New York. August 23.
- McQuerry, M. & Kwon, C. (March 2023). Outfitting Female Firefighters: Why female specific personal protective clothing is important for the fire service. *8th Biennial Fire Industry Education Resource Organization (FIERO) PPE Symposium*. Greenville, SC.
- McQuerry, M. & Kwon, C. (May 2023). Evaluating female firefighter anthropometrics for improved mobility and design in personal protective clothing for the United States fire service. *10th European Conference on Protective Clothing (ECPC)*. Arnhem, the Netherlands.
- McQuerry, M. (2022). Equitable Sizing Standards for Female Firefighter PPE. *Centers for Disease Control (CDC), National Institute for Occupational Safety and Health (NIOSH), National Personal Protective Technology Laboratory (NPPTL), Equitable Personal Protective Equipment (PPE) Protections Workshop*. Invited Presenter/Panelist, (virtual).
- Nazmy, H., Hebert, P. R., Mandal, S., & Agnew, R. Considering textiles flammability tests in interior design education [Poster Presentation]. *Environment and Health: Global/Local Challenges and Actions. Environmental Design Research Association 54th Annual Conference*, Mexico City, Mexico, June 20-23, 2023.
- Purandare, S., Xiang, C., Li, R., & Song, G. (2022). ε-Poly-L-lysine/polyamide nanocomposite membrane for respiratory protective devices. *ACS WRM 2022*, Las Vegas, NV, Oct 20-22.
- Riedy, R. & McQuerry, M. (October 2022). Analyzing the heat loss of motorsports racing suits. *International Textile and Apparel Association Conference*. Denver, CO.

- Song, G., & Li, R. (2022). A convergent multidisciplinary approach for cold weather protection. *ACS WRM 2022*, Las Vegas, NV, Oct 20-22.
- Song, G., Wu, Y., & Li, R. (2023). Polycyclic Aromatic Hydrocarbons (PAHs) Simulation for standardized PPE contamination using a cone calorimeter. *10th European Conference on Protective Clothing*, Arnhem, Netherlands, May 9-12.
- Sun, G. (2022). Development of Antibacterial and Antiviral Fibrous Materials for Improved Personal Protection, *ACS WRM (NC-170)*, Las Vegas, NV, October 21.
- Sun, G. (2022). Development of Antibacterial and Antiviral Textiles, *IFAI Expo Functional Textile Symposium*, Charlotte, NC. October 12, 2022
- Sun, G. (2022). Developments of Textile Materials with Novel Biocidal and Chemical Detoxification Functions for Improved Personal Protection, *Ulpas 11th Conference, Gebze Technical University*, November 4, Turkey.
- Sun, G. (2022). Polymeric Fibers with Novel Antibacterial and Antiviral Functions, *Golden Gate Polymer Forum*, California, USA. July 19.
- Sun, G. (2022). Progresses in Sustainable and Eco-friendly Textiles, *2022 International Conference on Frontier Textile Research and Technologies, Donghua University*, December 1-4. Shanghai China
- Sun, G. (2023). Developments of Functional Materials for Improved Personal Protection and Safety, *Empa*, St Gallen, Switzerland, May 25.
- Sun, G. (2023). Photo-Active Vitamins as Biocidal Agents for Improved Personal Protections, *University of Auckland*, New Zealand, March 13.
- Sun, G. (2023). Reusable and Rechargeable Biocidal Fibrous Materials for Improved Medical Protection, *38th International Conference of Plastic Processing Society*, St Gallen, Switzerland, May 22-25.
- Talukder, A., Freeman, C., Chander, H., Burch, R., & Saucier, D. (2023). "Biological, physiological, and subjective perception assessment of personal flotation devices." Poster presented at *Mississippi Academy of Sciences Annual Meeting*, Biloxi, MS.
- Tang, P. & Sun, G. (2022). Super Sorptive and Super Active Cotton Fabrics for Biological and Chemical Protections, *AATCC Textile Discovery Summit*, Charlotte, NC, October 4-6, 2022.
- Tushar, S. I., Mandal, S*., Chowdhury, I. Z., & Boorady, L. M. Developing a State-of-the-art Textile Laboratory: Utilizing the Maximum Space with Flexible Configuration. *2023 ITAA Annual Conference*, Maryland, USA, November 8-11, 2023.
- Ul Islam, S., Zhang, Z., Sun, G. (2023). Reusable and Daylight Induced Antibacterial Ethylene-Vinyl Acetate Copolymer Films, *ACS 2023 Spring Meeting*, Indianapolis, IN, USA, March 26-30.
- Wang, L., Zou, J., Sun, G. (2023). Development of Green, Reusable, and Self-Cleanable "ICE" Cubes to Reduce Temperature Abuse in Cold Chain, *USDA A1364 Novel foods and Innovative Manufacturing Technologies*, June 5-7, 2023.
- Wu, Y., Li, R., & Song, G. (2023). Investigation of the Reliability of a Smoke Generation System: A Preliminary Study. *AATCC 2023 Textile Discovery Summit*, Greenville, SC, USA, Sep 12-14.
- Yilmaz, C., Goncu-Berk, G. (2022). Resistance Intravehicular Activity Clothing for Microgravity, *International Textile and Apparel Association 2022 Annual Conference*, Denver: CO.

- Zhang, M., Li, R., & Song, G. (2023). A 2D Image-Based Anthropometric Measurements of Human Hands. *AATCC 2023 Textile Discovery Summit*, Greenville, SC, USA, Sep 12-14.
- Zhang, R., Fang, R., Fang, C., Homayoun, H., Goncu Berk, G. (2023). Privee: A Wearable for Real-Time Bladder Monitoring System. In *Adjunct Proceedings of the 2023 ACM International Joint Conference on Pervasive and Ubiquitous Computing & the 2023 ACM International Symposium on Wearable Computing* (pp. 291-295).
- Zhang, Z. & Sun, G. (2022) Vitamins suitable for preparation of daylight induced antibacterial and antiviral nanofibers and textiles, *Fiber Society Fall Meeting*, Raleigh, NC, October 19-21.
- Zhao, C. & Sun, G. (2022). Structural Features of Nanofibrous Membranes on Developments of Personal Use Biosensors, *ACS Fall meeting*, Chicago, August, 2022
- Zong, W., Elangovan, T., McQuerry, M., Poley-Bogan M., Simonson, N., & Park, H. (October 2022). Recycled tent converted to a survival jacket for homeless people. *International Textile and Apparel Association Conference*. Denver, CO.

Funds Leveraged

Baytar, F. (PI). Development of protective coveralls for female farmworkers to use before, during, and after pregnancy, National Institute of Food and Agriculture, USDA, Amount Funded: \$90,000, Period: October 2022 – September 2025.

Burch, R., Ball, J., Gurbuz, A., Strawderman, L., Knight, A., Smith, B., Wang, J., Burch, R., Hill, E., & Freeman, C. “MSU iCORPS Hub” Sponsored by the National Science Foundation, Federal, \$140,001. Awarded, Contracted. (1/1/24 – 6/30/25).

Frey, M. (PI). (2023). Atkinson Center for a Sustainable Future fast grant \$10,000.

Goodge, K. (PI) (2023). AATCC dissertation research grant, \$4000.

Griffin, L. (2022-2023) 3D Anthropometric Head Assessment and Respirator Design for Occupational Workers in the United States (MAES)

Griffin, L. (2022-2023) Kusske Design Initiative, Co-Principal: Linsey Griffin. Interdisciplinary design for PPE Development.

Griffin, L. (2023) U.S. Department of Homeland Security (DHS), Federal Emergency Management Agency (FEMA), Enhancing Firefighter Glove Fit and Performance: Design and Implementation of a Comprehensive Sizing and Analysis Tool Utilizing AI Aided Hand Measurements and Anthropometric Data.

Griffin, L. (2023) UMN-Toyota: Dynamic Hand 3D Anthropometry & Analysis

Jordan, J., Gelston, K., Bounds, C., McCall, T., Hill, E., & Freeman, C. “Regional Engines Developmental Program: SmartTech MS – Regional Manufacturing Automation and Industry 4.0.” Sponsored by the National Science Foundation, Federal, \$1,000,000. Awarded, Contracted. (05/23 – 06/24).

Kundu, S., Freeman, C., & Elmore, B. “Enhancing and Validating the Performance of Bio-Based Polymers.” Sponsored by Mississippi Research Council, State, \$87,400. Awarded, Contracted. (1/1/23 – 12/31/24).

Luczak, T., Burch, R., Ball, J., Chander, H., Freeman, C., Saucier, D. “The Smart Health Sock App: Improving Fall Detection to Reduce Injuries.” Sponsored by Mississippi Research Council, State, \$87,400. Awarded, Contracted. (1/1/23 – 12/31/24).

Lui, H. (2022). CAREER: Processing Intrinsically Conductive Polymers for Fibers via Side-by-Side Spinning”, National Science Federation, Funding Period: 3/2022 – 2/2027

Mandal, S. (2023). Article Processing Charge (APC) for publications MDPI Publisher, Switzerland. \$900 (In-Kind).

Mandal, S. (2023). Funding Application to Purchase and Equipment for Evaluating the Rain Protective Performance of Textile Fabrics – Rain Shower Tester (RST) College of Education and Human Sciences (CEHS) Resources, Equipment, Software and Technology (REST) Program \$19,475.

Mandal, S. (2023). Funding Application to Purchase Knitting Machine OSU College of Human Sciences Technology Seed Funding. \$44,663.

Mandal, S. (Co-PI) (2023). Investigating the Effects of Moisture and Airgap on Thermal Protective Performance of Protective Textiles under Different Heat Exposure AATCC Student Research Grant. \$500

Mandal, S. (P.I.), Park., J. (Co-PI). (2023). “Farm-to-closet” sourcing from farmers to retailers: The role of cotton in the sustainable fashion movement. Cotton Incorporated Curriculum Grant, USA, \$33,908.00.

Mandal, S.& Chowdhury, I. (2023). Presenting the Research work on Fire Textiles in India Don and Cathey Humphreys Travel Grant. \$5,000.

Mandal, S.& Nasrin, S. (2023). Presenting the Research Work on Sportswear in India Don and Cathey Humphreys Travel Grant. \$5,000.

McQuerry, M. (2022-2023). Dynamic Heat Flux Analysis of Heated Garments for Warfighters under Arctic Conditions. *U.S. Army Medical Research Institute of Environmental Medicine (USARIEM)*. (\$61,500).

McQuerry, M. (2023). Physiological Performance Analysis of Heated Garments for Warfighters under Arctic Conditions. *Congressionally Directed Funding (Army)*. (\$180,890).

McQuerry, M. (PI) & Kwon, C. (Co-PI). (9/20/20123-9/19/2026). Development of Novel Personal Protective Clothing Designs for Structural and Wildland Female Firefighters.

Department of Homeland Security (DHS), Federal Emergency Management Agency (FEMA), FY 2022 Assistance to Firefighters Grant Program. (\$1,539,374).

Mohammadi-Aragh, J., Seitz, H., Panse-Barone, C., Gillen, Z., Freeman, C., McCubbins, O.P. “Acquisition of Biomechanical Movement and Body Volumetric Baseline Technology Suite for Motion Capture Improvement and Sensor-based Validation of Lower Body Characteristics.” Sponsored by National Science Foundation, Federal, \$770,000. Awarded, Contracted. (8/1/22 – 7/31/23).

Park, H. (PI). Smart Firegear Development Research with STEM Education Outreach Component for 4H groups PI: Park, H, National Institute of Food and Agriculture, USDA, Amount Funded: \$156,966, Period: October 2022 – September 2025

Poley-Bogan, M.* (PI). & McQuerry, M. (Co-PI). (2023). Analysis of thermal comfort cooling mechanisms to combat heat stress in the construction industry. *AATCC Student Research Foundation Grant Program*. Faculty Advisor (\$550).

Shaw, A. (2022-2023). NC-170 funds were leveraged to support the operator safety initiative coordinated by the International Center for PPE for Pesticide Operators (ICPPE), University of Maryland, Eastern Shore.

Xiang, C. (2022). Iowa Board of Regents, Regents Innovation Fund, Development of hand-specific thermoregulation model and systematic tool for PPE design and evaluation.

Xiang, C. (2022). U.S. Department of Homeland Security (DHS), Federal Emergency Management Agency (FEMA), Developing a systematic tool for contaminant protection and reducing exposure to contaminated PPE.

Xiang, C. (2023). 2023 National Institutes of Health, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health U01, A systematic approach to enhance extremity protection in Alaska fishing industry.

Xiang, C. (2023). Iowa Board of Regents, Innovation Acceleration Fund, Project NanoShield: Advanced Material and Treatment Solutions for Fine Particle Exposure.

Xiang, C. (2023). U.S. Department of Homeland Security (DHS), Federal Emergency Management Agency (FEMA), Enhancing Firefighter Glove Fit and Performance: Design and Implementation of a Comprehensive Sizing and Analysis Tool Utilizing AI Aided Hand Measurements and Anthropometric Data.

California

Continuously funded by USDA-NIFA (August, 2018-April, 2023) for colorimetric sensors for antibiotics in foods.

Continuously funded in 2020-2023 by “An Integrated Approach to Eliminate Cross-Contamination during Washing, Conveying, Handling and Packaging of Fresh Produce” May, 2015-April, 2023.

Continuously funded by USDA-NIFA (June, 2020-May, 2023) for development of reusable and green ice cubes.

Continuously funded by USDA-NIFA (May, 2020-April, 2023) for development of antimicrobial waxing agents for fruits and vegetables.

Funded by Center for Produce Safety (January 2021-December 2022) Bio-based antimicrobial coatings for reducing risk of cross-contamination during harvesting

Funded By CDC/NIOSH through Iowa State University (September 2021-August 2024)
Biodegradable, reusable and antiviral facemask materials

Funded by UC Davis, Academic Senate, Collaborative Large Interdisciplinary Grant (July 2023-September 2024 for development of e-textile based bioimpedance spectroscopy system.