CENTER FOR ADVANCED RESEARCH IN DRYING

A National Science Foundation Industry/University Cooperative Research Center

Low Temperature Workshop - Center for Advanced Research in Drying

Jamal Yagoobi
Worcester Polytechnic Institute

February 3, 2021

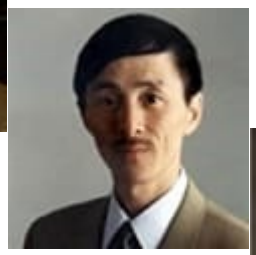
virtual presentation

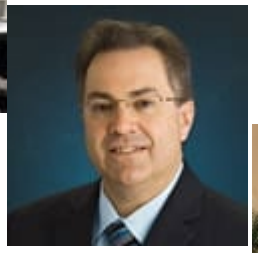
Center for Advanced Research in Drying (CARD)

CARD was established as a U.S. National Science Foundation (NSF) Industry University Cooperative Research Center (IUCRC) in July 2016.

CARD is located at WPI and UIUC (co-site).

CARD Executive Directors





[Jamal Yagoobi](#) (WPI)
CARD Director
Mechanical Engineering
[Hao Feng](#) (UIUC)
UIUC Site Director
Food Science and Human Nutrition
[Irfan Ahmad](#) (UIUC)
Illinois Site Co-Director
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[Cosme Furlong](#) (WPI)
WPI Site Co-Director
Mechanical Engineering
[Mark Lippi](#)
CARD Program Manager
Owner, MSSL, LLC
[Pat Howe](#) (WPI)
CARD Administrator

CARD Team: 10 faculty members from WPI and 10 faculty members from UIUC

Impact of Drying

- The removal of water and organic compounds through drying processes is one of industry's most energy-intensive activities.
- **Drying accounts for approximately 10% (1.2 quads) of all process energy used in American manufacturing.**
- With new efficient drying technologies 0.5 quads of energy per year may be saved.
- One-quad of energy reduction in manufacturing process is worth $21 billion.
- Drying directly affects product quality.

- Industries such as Food and agriculture, paper and forestry products, chemicals, textiles, and biopharmaceuticals all depend on inefficient drying technologies that have not substantially changed in many decades.

CARD Objectives

- Reduce energy consumption (and water usage) in drying and related heat and mass transfer processes - *Cost Reduction*
- Reduce energy/carbon footprint of companies - *Sustainability*
- Improve product quality while drying faster – *Product Quality and Throughput*
- Train the next generation workforce for 21st century jobs – *New Hires*

CARD Members – 2021

- AGCO
- Alliance for Pulp & Paper Technology Innovation (APPTI)
- Flint Hills Resources
- Ingredion
- Massachusetts Clean Energy Center
- Mondelez International
- Nutriom
- PepsiCo
- Reading Thermal
- Smart Tech Feed
- US Army Soldier Research, Development and Engineering Center (NSRDEC)

Projects – Year 5 (2021)

- Tip-based Optical Fiber **Sensors** for Continuous, In-situ Measurements of Trapped Moisture and Pressure (PI: Liu – WPI)
- Infrared **Sensors** for Optimization of Drying Food Materials (PIs: Irudarayaj and Lee – UIUC)
- An Integrated Multiscale **Modeling** and **Sensors**-Based Approach to Study Strains and Stresses in Foods Undergoing Glass Transition During Drying (PIs: Takhar – UIUC and Liu – WPI)
- **Ultrasound**-mediated Ethanol Dewatering/Dehydration (PI: Feng – UIUC)
- **Ultrasonic** Drying of Vegetable Proteins (PIs: Padua and Feng – UIUC)

Projects – Year 5 (2021) (Cont'd)

- Spray Drying Using **Novel Nozzle** Design to Improve Droplet Formation for Fine Powders (PIs: Yagoobi – WPI and Lee – UIUC)
- Enhancement of Drying Rate of Moist Porous Media with **Electric Field** (PI: Yagoobi – WPI)
- Removal of Water Trapped Inside a Single Cellulose Fiber – **Bound Water** (PIs: Yagoobi and Tilley – WPI)
- Smart Drying Enabled by Multi-Source Data Fusion and **Machine Learning** (PIs: Shao – UIUC and Narra – WPI)
- An Investigation of the Role of Area, Scale, and Hierarchical **Surface Topography** in Wetting and Drying of Stochastically Patterned Surfaces (PIs: Daniello and Brown) – (NSF REU)

Transfer of Technology

- Enhancement of Heat and Mass Transfer with Innovative Impinging Jet Nozzles (PI: Yagoobi – WPI)

CARD USDA Project

- **Project Title**: Innovative Food Dehydration Technologies for Improving Product Quality, Energy Efficiency, and Sustainability
- **Principal Investigator**: H. Feng (University of Illinois)
- **Co-Principal Investigators**: J. Yagoobi (WPI), N. Engeseth and I. Ahmad (University of Illinois), Mark Lippi (CARD)

CARD DOE Project

- **Project Title**: Novel Energy-Efficient Drying Technologies for Food, Pulp and Paper, and other Energy Intensive Manufacturing Industries
- **Principal Investigator**: J. Yagoobi (WPI)
- **Co-Principal Investigators**: Feng (UIUC), Liu (WPI), Narra (WPI), Petkie (WPI), Ahmad (UIUC), Nam (UIUC), Salapaka (UIUC), Shao (UIUC), Patel (ORNL), Nawaz (ORNL), Lippi (CARD), and Turpin (APPTI)

CARD DOE Project – Partners

PEPSICO

appti

HERSHEY
THE HERSHEY COMPANY

Mondelēz International
SNACKING MADE RIGHT

Ingredion

READING BAKERY SYSTEMS

FUTURECEUTICALS

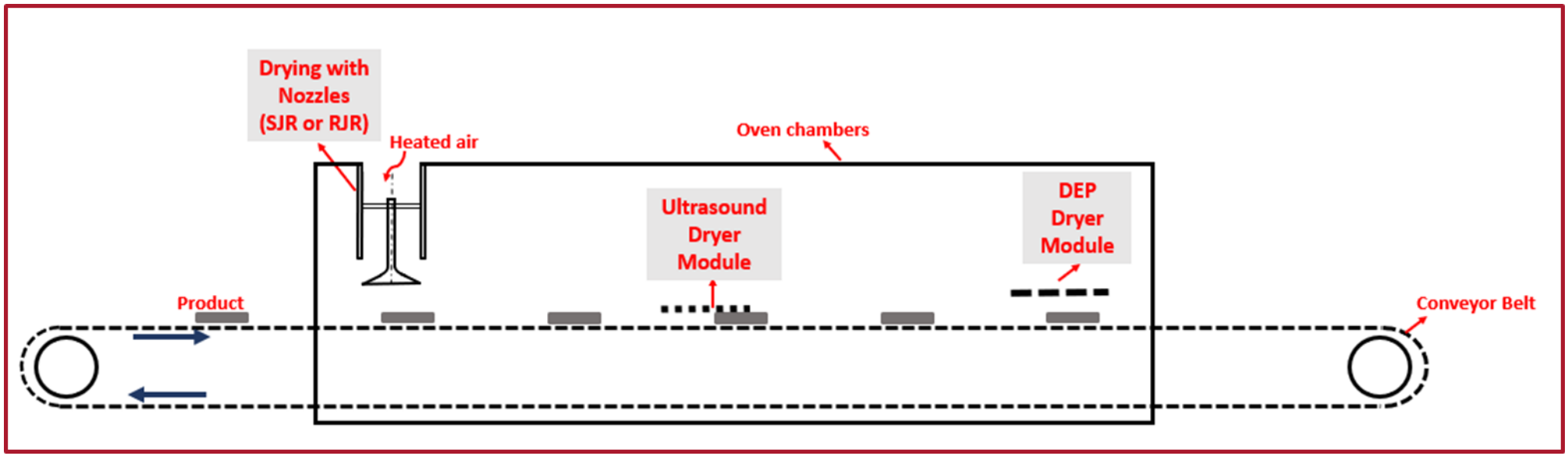
US ARMY NATICK SOLDIER RD&E CENTER

Project Summary

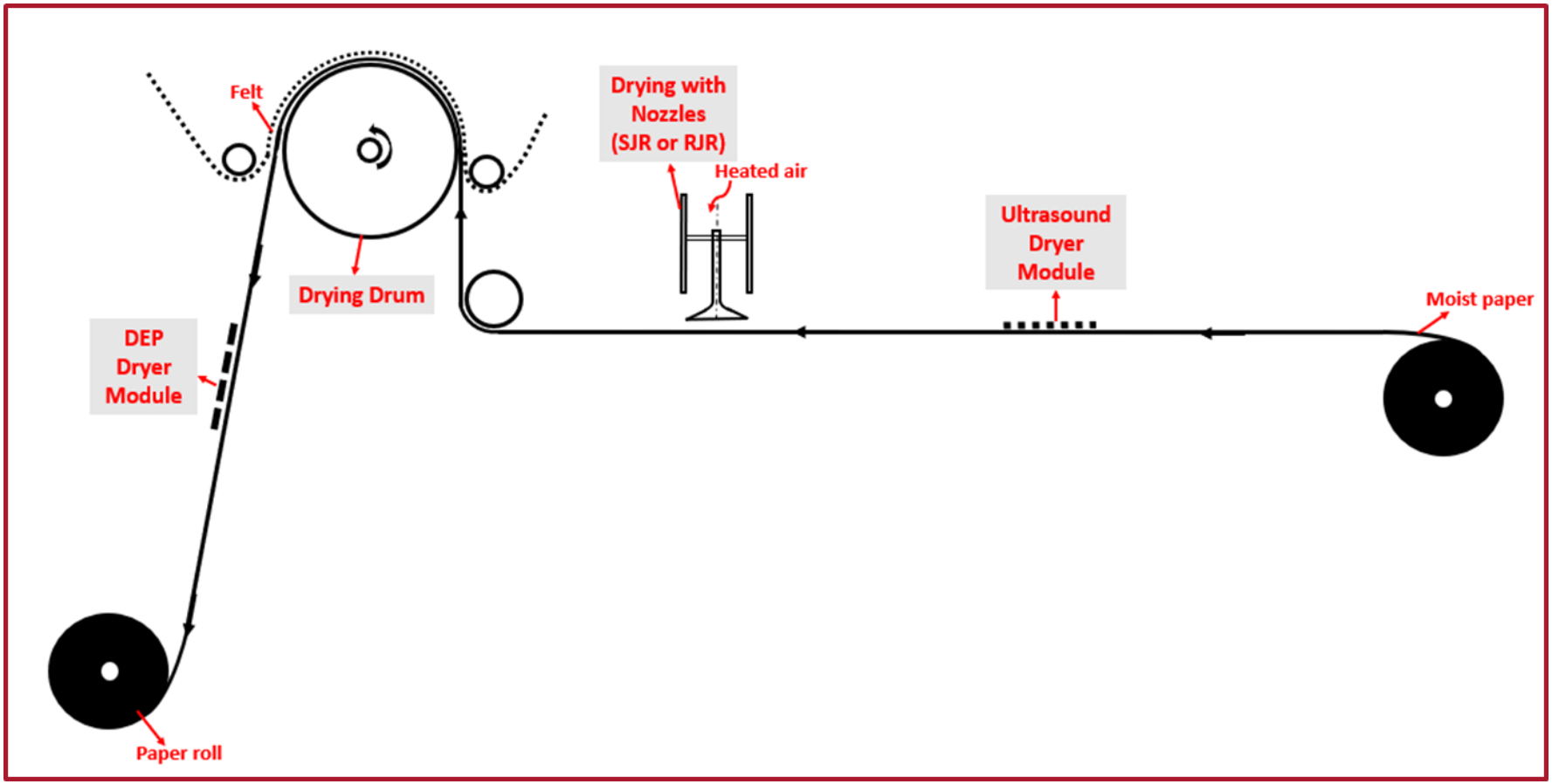
- Conduct applied R&D building on basic science funded by CARD. Three technologies pursued to deliver up to 25% energy efficiency increase:
  - Di-electrophoresis
  - Ultrasonic
  - Slot Jet Reattachment Nozzles
- Scale high performing drying technologies
- Integrate advanced sensors and AI for optimal process control and up to 10% additional energy efficiency
- Test and evaluate pilot line in partnership with industry

Smart Dryer/Oven – Video Presentation

Project Testbed 1



Project Testbed 2

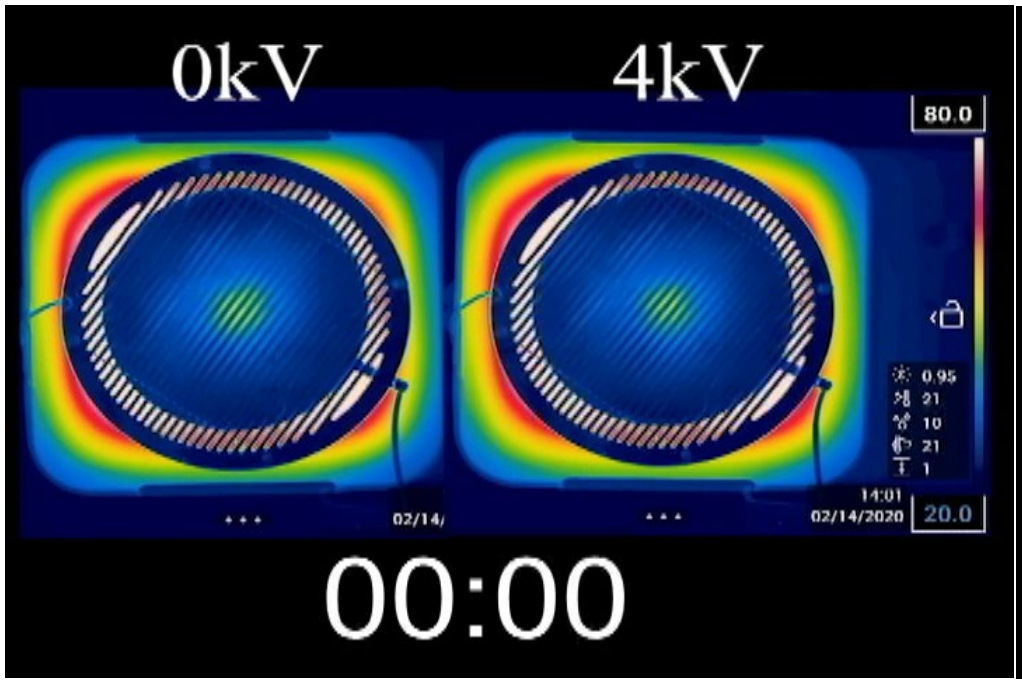


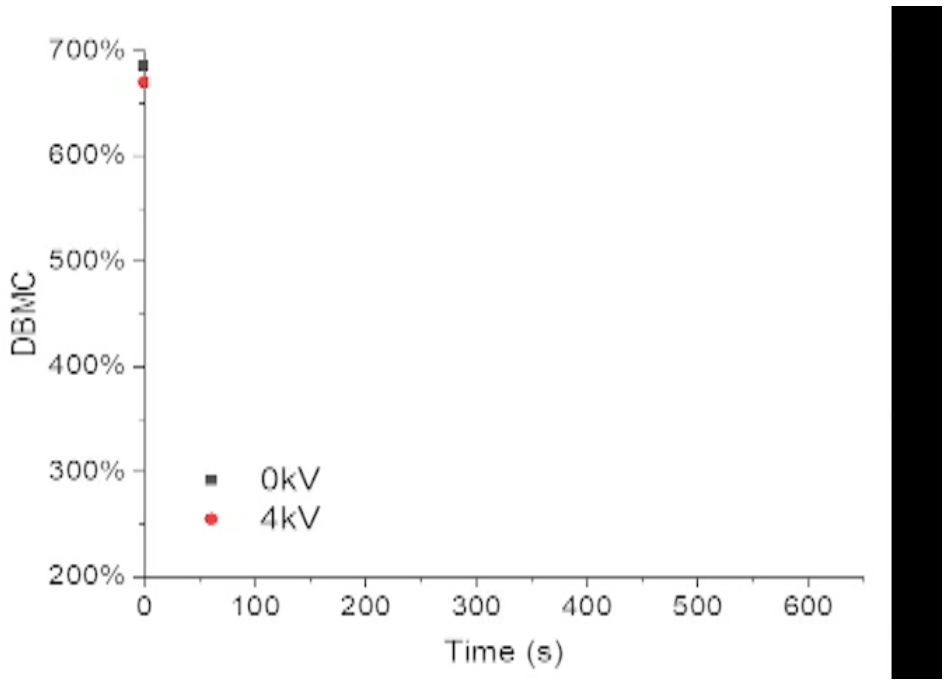
DEP Assisted Drying Technology

Yagoobi, J. and Yang, M., “Electrohydrodynamic Drying of Moist Porous Materials”, provisional patent issued in September 2020.

Task 1.2 – Visualization of Surface Temperature and DBMC in the Presence of DEP Mechanism

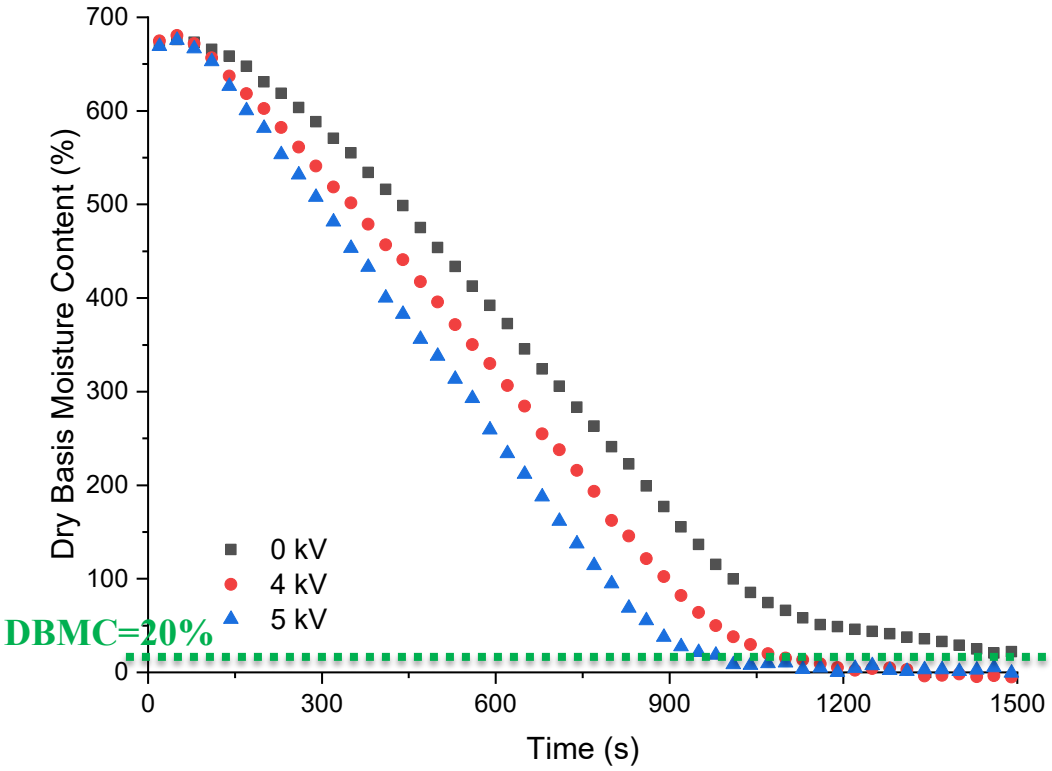
$$Dry\ basis\ moisture\ content\ (DBMC) = \frac{instantaneous\ weight\ of\ water(g)}{bone\ dried\ weight\ of\ sample(g)} \times 100\%$$



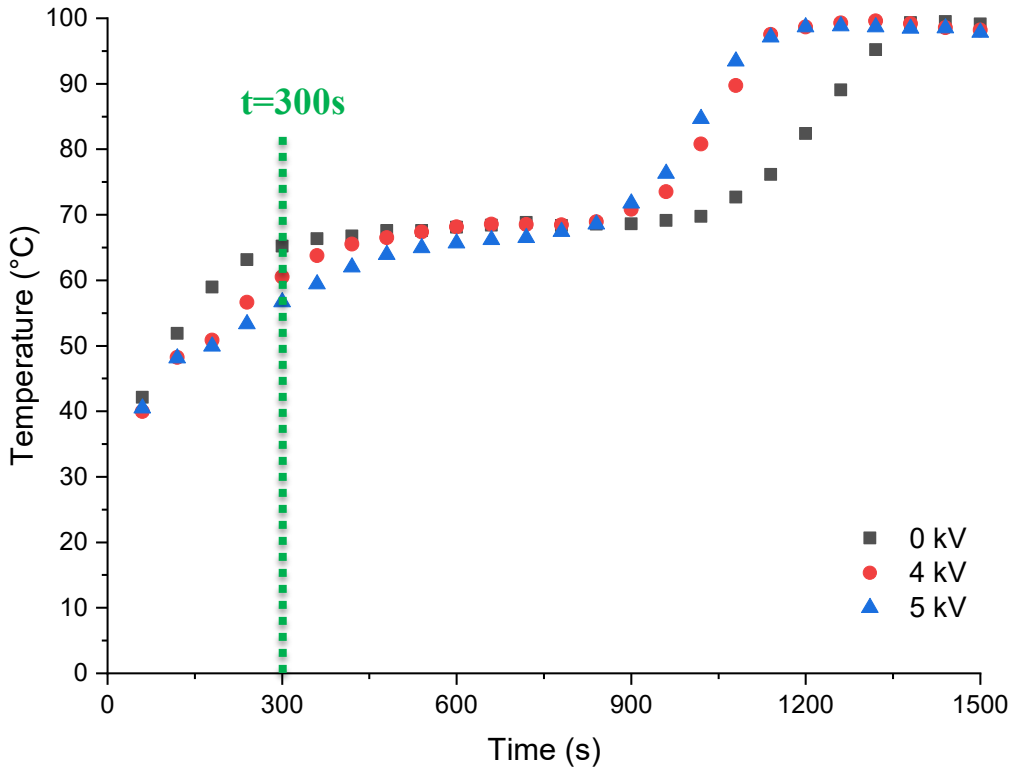


Comparison of surface temperature (Left) and DBMC (Right) evolution with hand-sheet paper sample

Task 1.2 – Comparison of DBMC and Surface Temperature



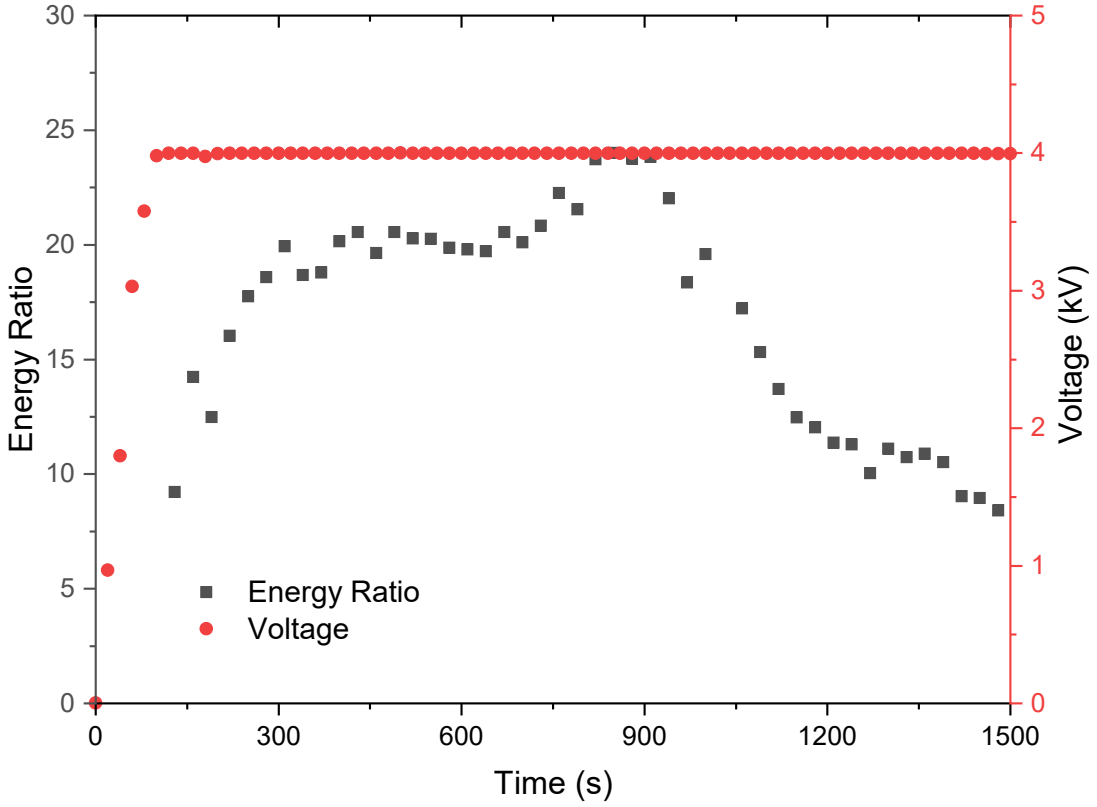
Drying curves under various applied potentials



Area averaged sample surface temperature evolution under select applied potentials

- In the presence of DEP mechanism, the drying time required to reach DBMC of 20% was reduced by 33% (1470s for 0kV case vs. 970s for 5 kV case).
- In the presence of DEP mechanism, the surface temperature of hand-sheet paper was reduced by 10 °C at t=300s (65°C for 0kV case vs. 55°C for 5 kV case).

Tasks 1.2 & 1.3 – Energy Efficiency of DEP Mechanism (Cont'd)



Energy ratio as a function of drying time with applied potential of 4 kV

Energy Ratio

$$= \frac{Enhanced\ evaporation\ energy}{Accumulated\ input\ electric\ energy} = \frac{(m_1 - m_2) * h_{fg}}{\int_0^t V(t)I(t)dt}$$

m_1: The instant weight of sample under regular drying (g)

m_2: The instant weight of sample under DEP drying (g)

h_{fg}: Latent heat of evaporation (j/g)

V: Applied voltage (V)

I: Current (A)

The DEP mechanism achieves high energy efficiency.

CARD - Collaboration

CARD is eager to collaborate with others to make the drying processes energy efficient, with reduced carbon footprint, improved product quality, and increased throughput.

Fundamental (low TRL) and applied research is needed.

CARD/WPI to host IDS 2020

22nd International Drying Symposium

June 28, 2020 to July 1, 2020

175 technical papers accepted for oral and poster presentations.

Many thanks to CARD members for reviewing the IDS papers.

Due to pandemic, the IDS 2020 postponed to the year 2021.

IDS 2021 will take place at WPI campus from June 26 through June 29, 2022.

CA

22nd International Drying Symposium

June 28, 2020 to July 1, 2020

Next CARD Semi-Annual IAB Meeting @ UIUC

- May 20 and 21, 2021

For more information contact:

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