Machine Knittable Yarns for Interactive Pressure Sensing Textiles

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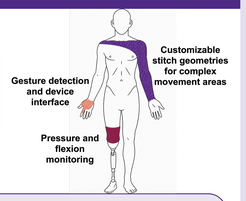
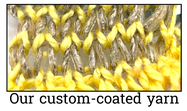
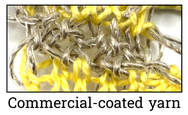
Introduction

- Knitting is ideal for E-textile devices and wearables as it enables mechanically dynamic fabrics at the stitch-level and can be manufactured by programmable machines.





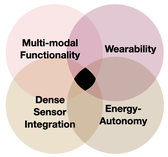
Our custom-coated yarn



Commercial-coated yarn

- High-density, knitted tactile sensors need individual yarns to be flexible and insulated to remain electrically isolated, addressable, and functional.
- Commercially-insulated conductive yarns are not suitable for machine knitting.

- This project develops a low-cost, tunable dip-coating process that produces custom insulated conductive yarns optimized for knitting.
- Electromechanical characterizations validate machine knittability and insulation performance, while applications show promise towards dense, energy efficient sensing.



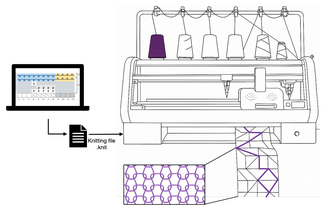
Expanding Accessibility

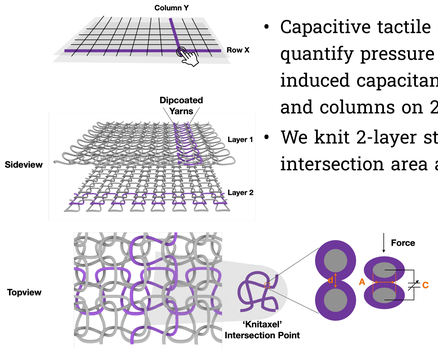
- Simple and inexpensive fabrication of functional yarn contributes to customizable, ubiquitous knitted sensors.
- Yarn knittability shown on Kniterate Digital Knitting Machine, which is up to **10x** cheaper than standard, industrial machines.

Scalable · Manufacturable · Low Cost · Low Barrier

Knitting and Sensing Approach

- Knitting using the Kniterate® digital knitting machine, a 7 gauge flatbed machine.
- Programmable knit structure enables control over fabric mechanical behavior and sensor geometry.





- Capacitive tactile sensors locate and quantify pressure by measuring force-induced capacitance change between rows and columns on 2 perpendicular layers.
- We knit 2-layer structures and define each intersection area as a **knitaxel**.
- Force on a knitaxel causes measurable capacitance change.

$$C = \frac{\epsilon A}{d}$$

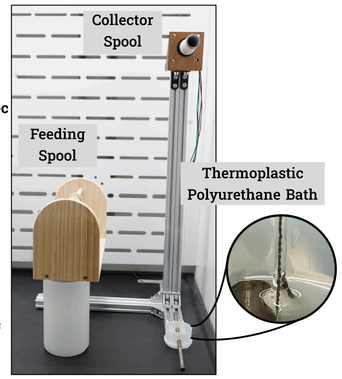
ϵ = Dielectric permittivity
A = Area of electrode overlap
d = Distance between electrodes

Results

Fabrication Technique

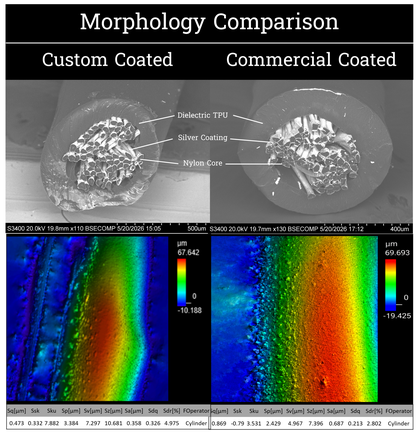
Design Parameters

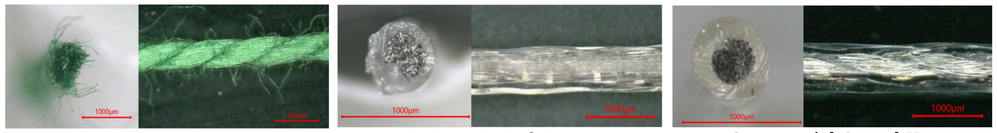
Withdrawal speed	2.5 mm/sec
Drying Time	~20 hours
Bath Angle	90°
Solution Viscosity	31.1 Pa/sec



Morphology Comparison

Custom Coated · Commercial Coated



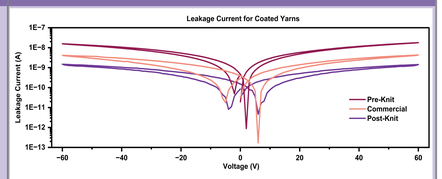
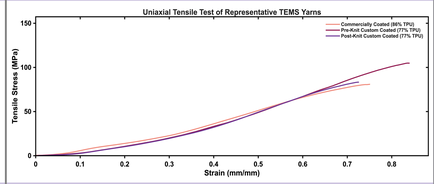
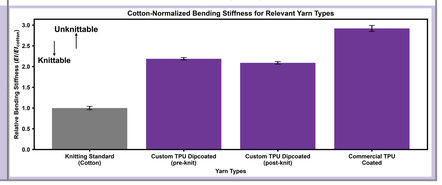


Cotton Yarn · Custom Coated Yarn · Commercial Coated Yarn

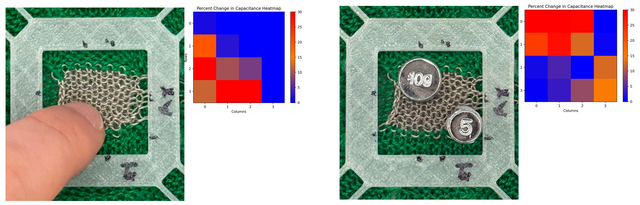
Electromechanical Characterization

Comparing electromechanical data between:

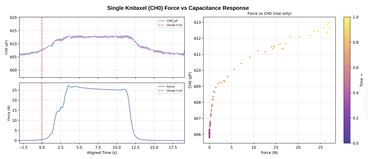
A. **Shieldex (Commercial Coated) yarns:** "industry standard" TPU-insulated yarns
B. **Pre-Knit yarns:** custom-coated yarns before knitting
C. **Post-Knit yarns:** custom-coated yarns from deconstructed-knitted samples

Characteristic	Collection Method	Impact on Functionality	Data
Leakage Current (A)	Voltage Sweep from -60V to 60V using an ambient probe station and source-measure unit	Low leakage ensures safe, efficient sensor operation	
Tensile Strength (MPa)	220N Uniaxial Tensile Tester	Strong yarns maintain mechanical durability during knitting	
Bending Stiffness (Normalized against cotton yarn)	Hanging Pear Loop Test	Proper stiffness preserves flexibility and sensor performance	

Current Applications



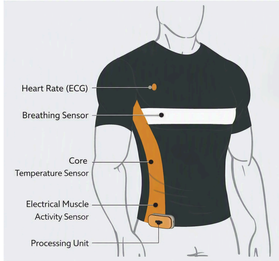
- High density multi-touch detection (~50 knitaxels/cm^2).
- Knitted, 2-layer capacitive pressure sensors exhibit high precision at the knitaxel level (<100mN sensitivity).
- Device performance is suitable for multi-touch and touch gesture input interfaces.

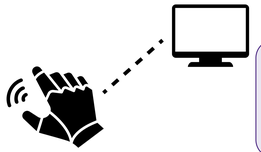


Future Work

- Expand gesture recognition in knitted wearables for gestural inputs and enriched communication in human-human interactions.

- Extend dipcoating process to other materials that enable triboelectric nanogenerators (TENG) at a yarn-level and energy-efficient hierarchical sensing.
- Utilize TENG-Capacitive hybrid fabrics for health monitoring, prosthetics support, and athletic wearables.





- Improve sensor density and tactile response for enhanced robotic dexterity and perception in computer-computer interactions.

Commercially available insulated yarns are not optimized for machine knitting. **Using a custom fabrication process, we've produced insulated yarns optimized for knitted sensing interfaces.** Our yarns show >20% less bending stiffness as well as similar tensile behavior and electrical insulation compared to an industry standard. Our knitted tactile sensors achieved 50 knitaxels/cm^2 density and <100 mN pressure sensitivity.

Acknowledgements

The authors extend their gratitude and appreciation towards the following: Elizabeth Griffin, Koushik Medhi, Hayden Williams, and Ashley Gonzalez for assistance with SEM imaging. The Northwestern University Atomic and Nanoscale Characterization Experimental Center (NUANCE), Micro/Nano Fabrication Facility (NUFAB), Materials Characterization and Imaging Facility (MatCI), and Central Laboratory for Materials Mechanical Properties (CLaMMP) for their material property testing facilities. David Ventre and Lucia Stein-Montalvo for their support with mechanical testing. Andres Turullols for help with capacitive sensing applications. Catherine Ding, Sanjana Subramaniam, and Jian Cao for foundational discussions on dip coating. Ansys Inc for their generous funding support.

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