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Realizing Rugged and Conformable Printed Devices via In-Mold-Electronics

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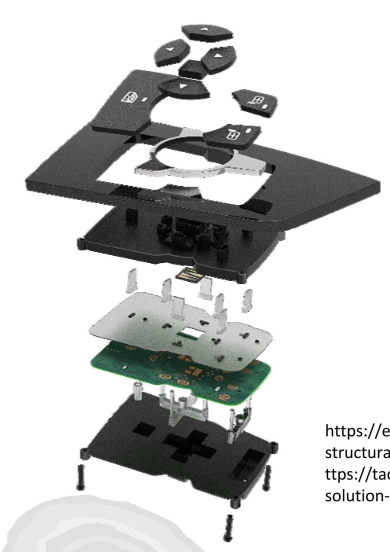
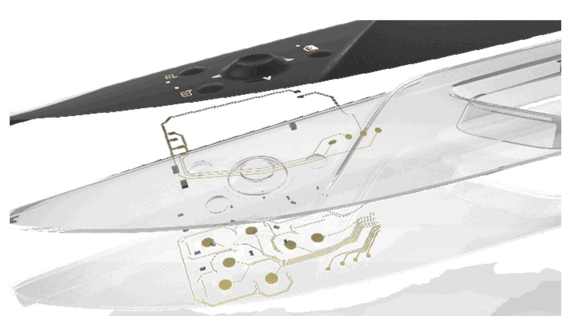
Purpose

By combining stretchable/moldable materials with tolerant electronic inks, printed electronics can be directly molded into structural parts. In-mold electronics (IME) is one such emerging technology whereby flexible conductive inks are printed onto moldable substrates. IME allows for the creation of circuits that are much thinner and lighter than traditional circuit boards, buttons, and wiring, with considerably more design freedom. IME circuits can also be more robust than traditional buttons and wiring because there are fewer moving parts and other failure points. The purpose of this project was to design and make IME demonstrators to showcase and characterize AML's IME capabilities.





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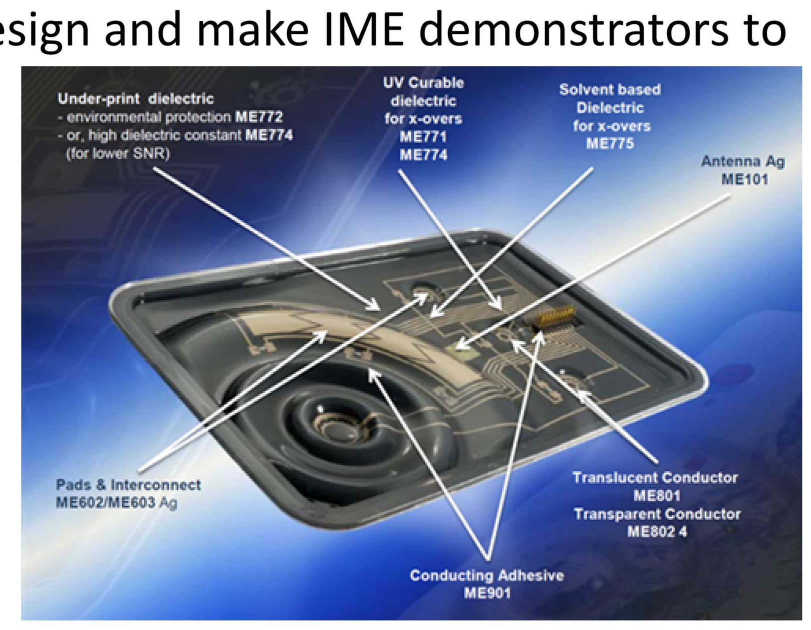
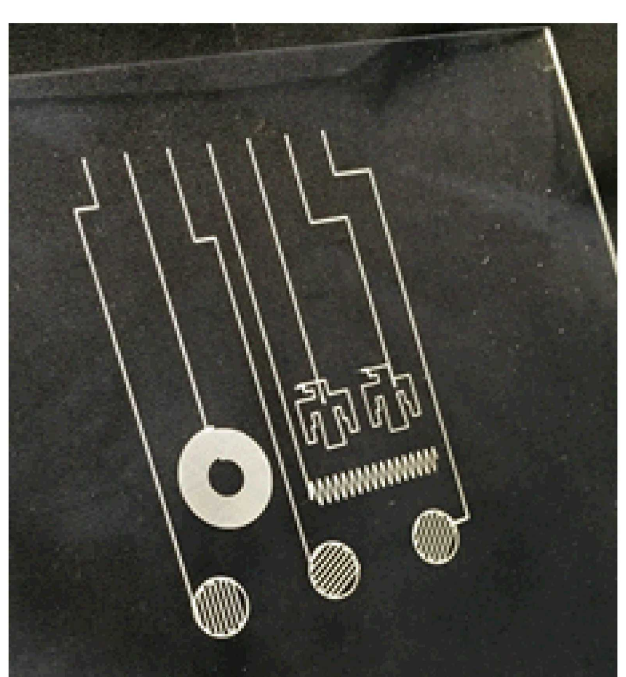


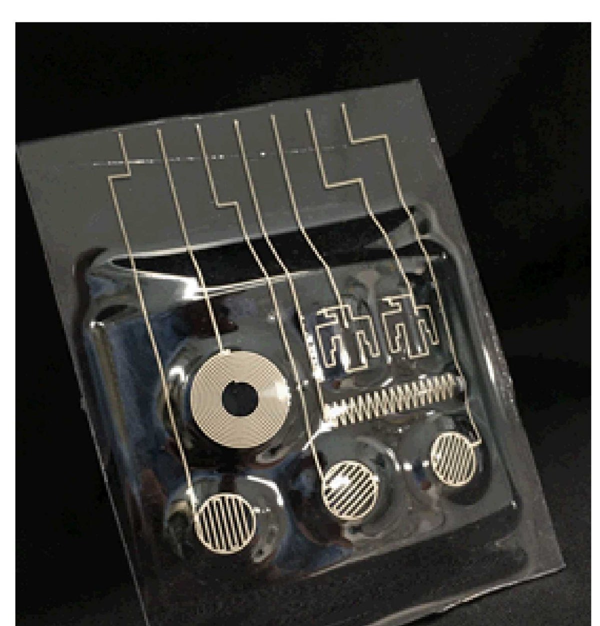
Dupont's suite of IME inks (shown above) include Ag and transparent conductors (for RF and interconnects) and dielectrics (for crossovers).

Approach

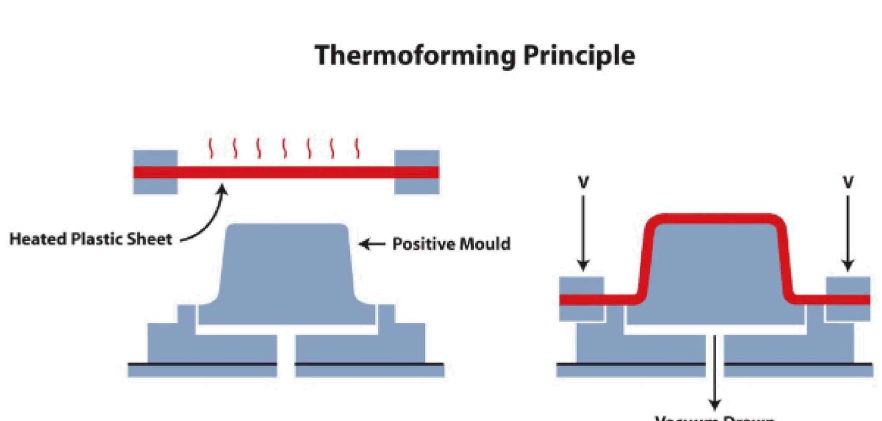


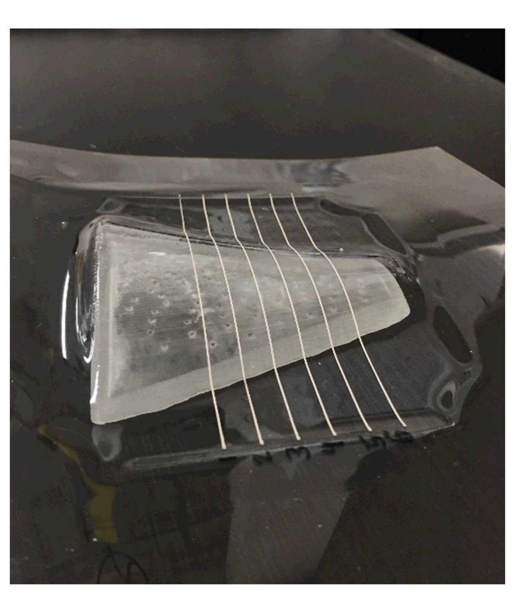
1. Print Ag (ME101) on PET G substrate using nScript microdispensor.

2. Vacuum form (120C) against 3D printed mold (above).



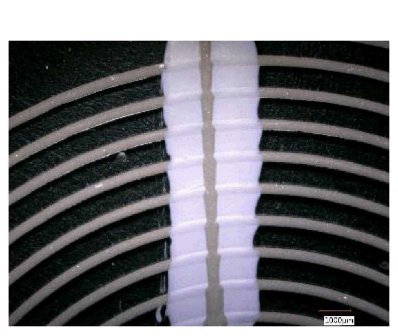
3. Test conductivity, print crossovers, encapsulate and pin out.





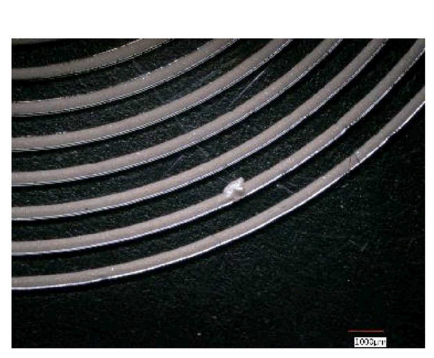
Printed trace characterization

We designed and successfully printed capacitive touch and near-field communication (NFC) demonstrator circuits. These circuits were printed using a direct-write machine and DuPont's flexible conductive and dielectric inks onto polyethylene terephthalate glycol (PETG) or polycarbonate substrates, which were then thermoformed over various stereolithography (SLA) printed molds.



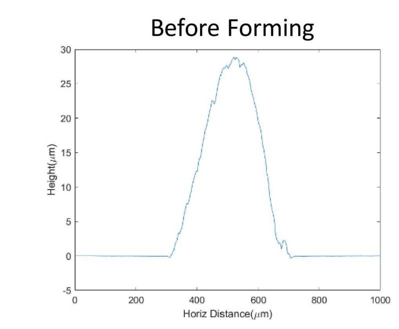
Dielectric crossover

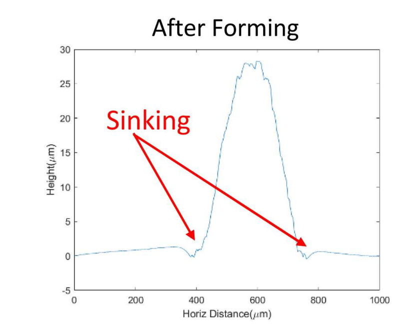
LED attached using conductive adhesive

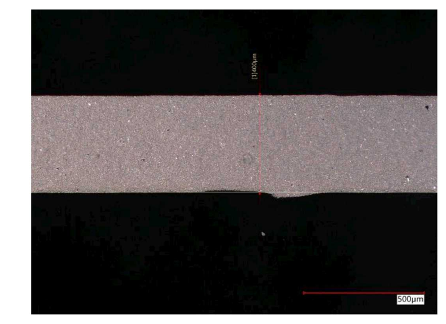


Trace repaired with conductive adhesive

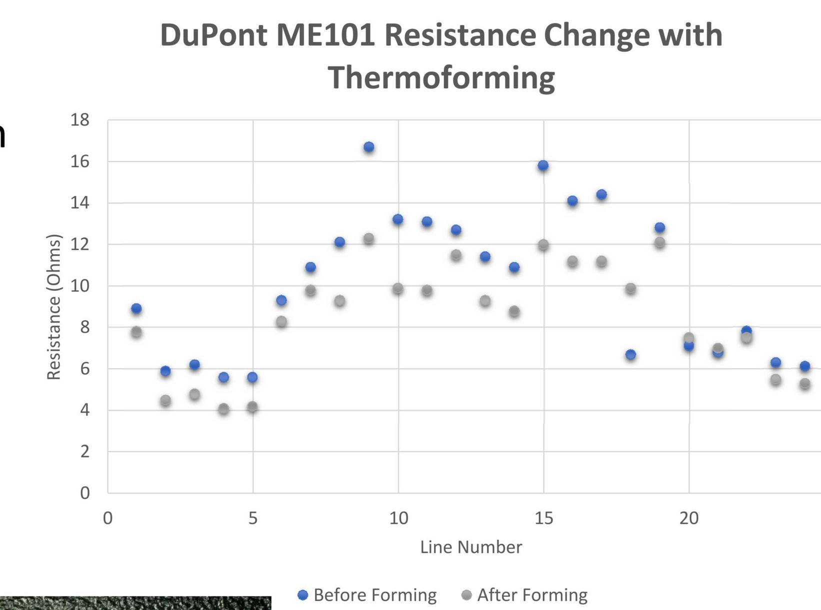
Results



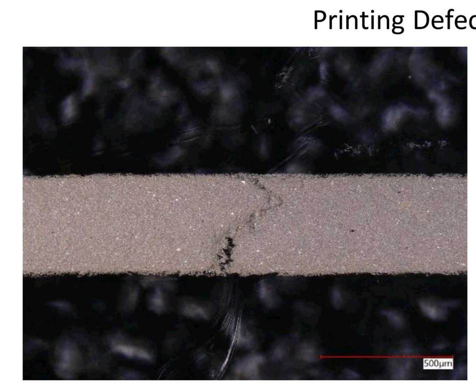


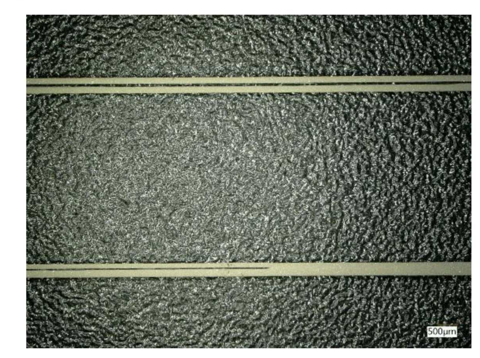


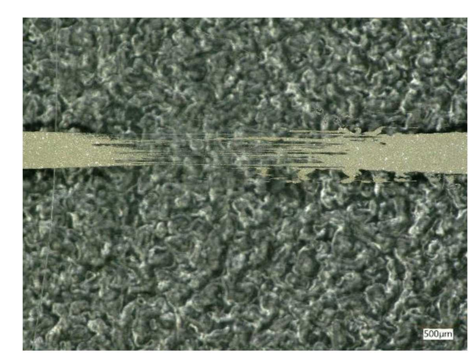
Resistances varied due to unintended printing variation and defects. Resistance tended to decrease with any heating, including thermoforming.

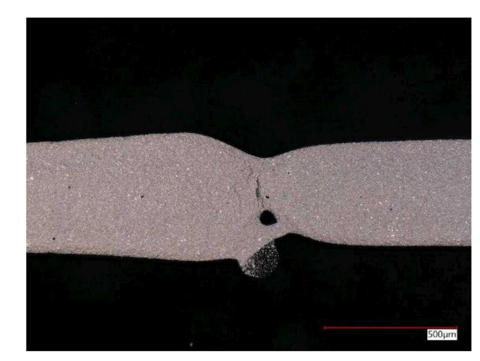


Printing Defects

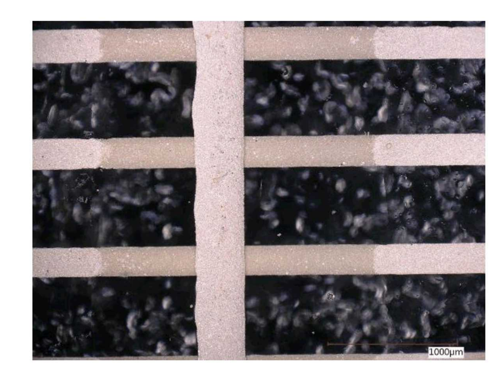






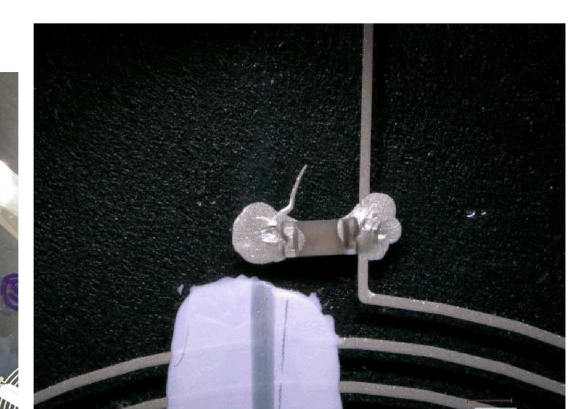


Cracking during thermoforming

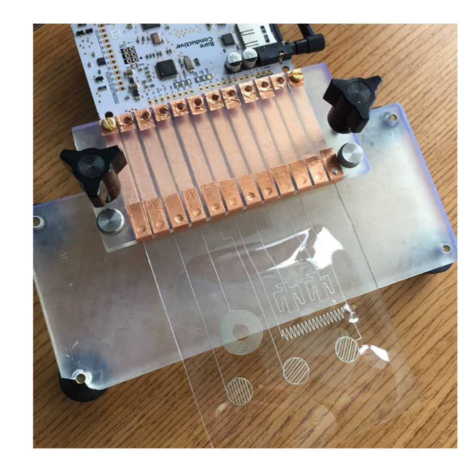


Epoxy dielectric crossover

NFC device demonstrator



Transparent conductive crossover

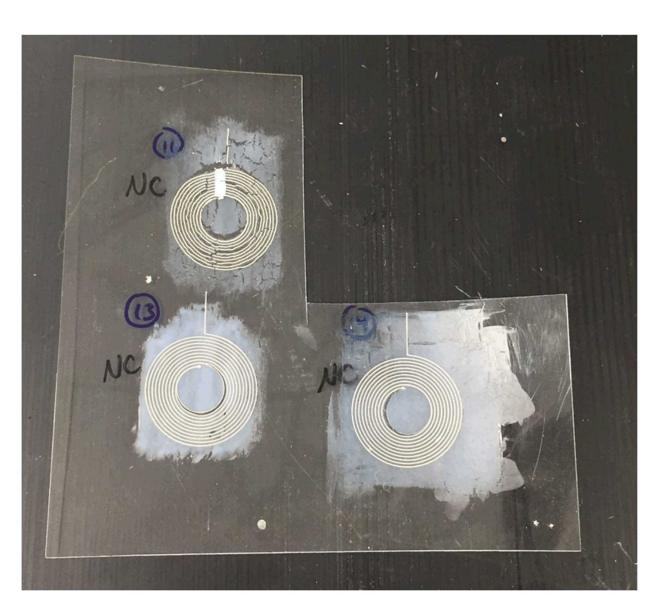


Capacitive touch device demonstrator

Significant findings included considerable variation in dimension and resistance of traces with this printing method as well as a decrease in the resistance of traces after heat-curing or thermoforming. Of note, traces equal to or smaller than 400 μm wide and 30 μm tall were less likely to crack than larger traces.

	PETG	Polycarbonate	Polystyrene
Glass Transition Temp	80°C	147°C	100°C
Sticks when heated?	Yes	No	No
Bubbles?	No	Yes	No
Formable with oven?	Yes	No	No
Conductive lines crack when forming?	No	Yes	No
Best Temp for Forming	120°C	180°C	

Future Research



Figuring out a suitable encapsulant for durability of IME devices

We are currently working on further characterization and troubleshooting for this method of creating IME at the AML, as well as additional demonstrators.

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