Modelling reliable electrical conductors for e-textile circuits on polyamide filaments.

E-Textiles 2019: International Conference on the Challenges, Opportunities, Innovations and Applications in Electronic Textiles

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Overview

» Early forms of conductors and problems

» Conductors in the research domain

» State of the art e-textile conductors

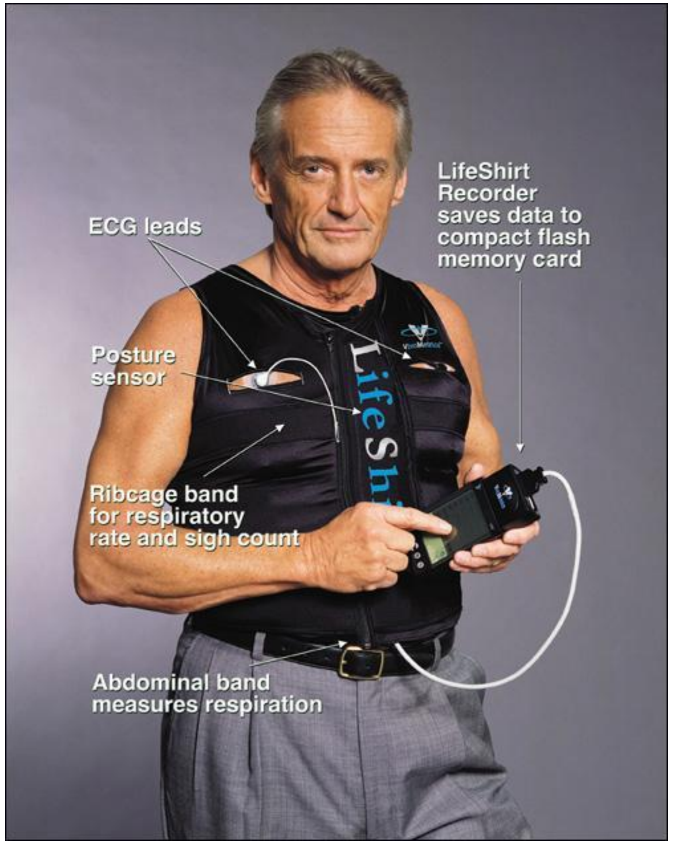
» CBT model of filament circuit

» Bending Results

» Effect of encapsulation on NA and stiffness

» Conclusion

Early forms of e-textile conductors



a. The Lifeshirt by Vivometrics (2001)

b. ICD+suit by Levi and Phillips Electronics (2003)

c. Solar powered SCOTT eVest (2004)

Problems of early prototypes

» E-textiles

  » Integrated wires are very bulky

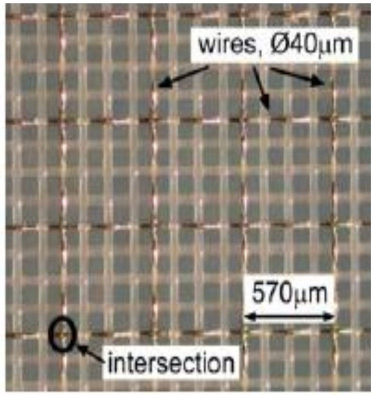
  » Enclosed conventional portable electronics into pockets within the textile.

  » Can be uncomfortable to wear over extended periods due to the rigidity and accumulative weights of enclosed electronics.

  » Can lack desired fashion or aesthetics

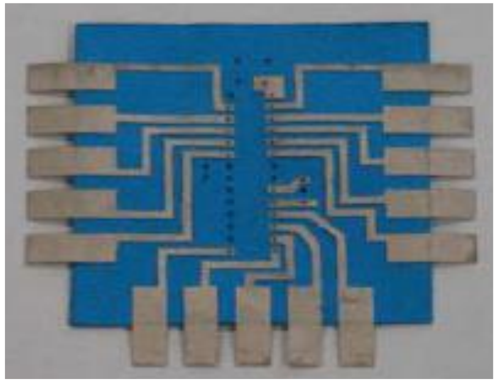
  » Electronics need to be detached before washing

E-textile conductors in the research domain

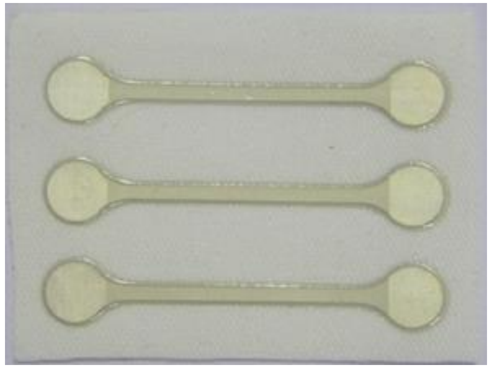


Thin enamelled copper wires

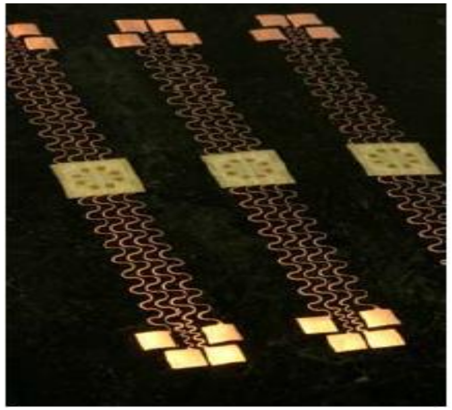
Embroidered silver coated threads



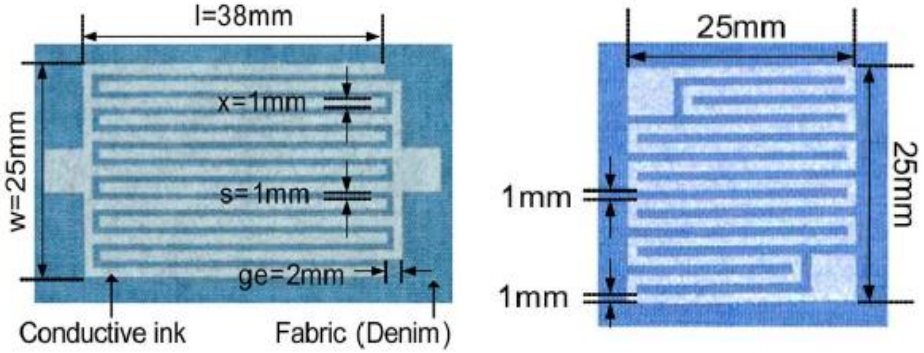
Heated transferred conductive fabrics



Screen printed silver inks and Polyurethane encapsulation



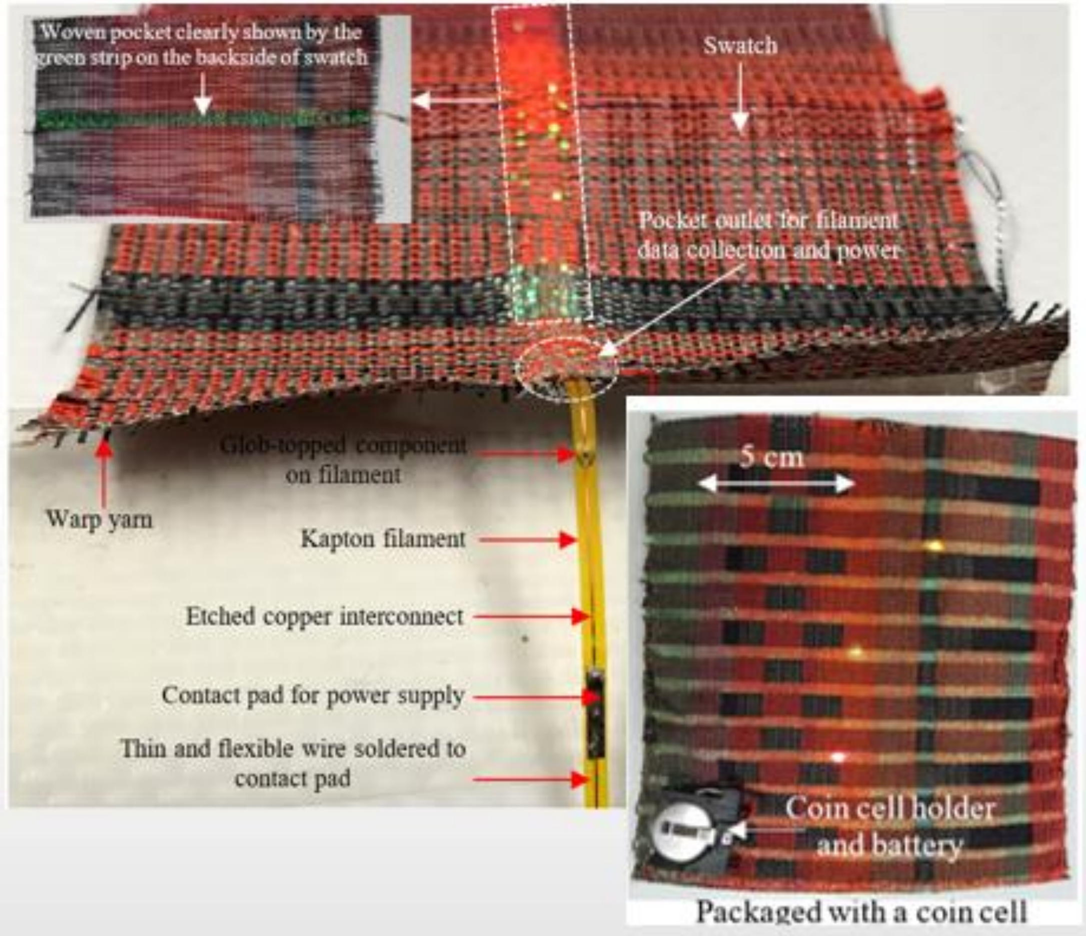
Stretchable interconnects from STELLA project



Screen printed capacitor and resistor

State of the art e-textile at UoS

» Wearable e-textiles with filament circuits
  » Knitting or weaving of electronic filament circuits ((< 2mm wide) into fabrics during manufacture
  » Improves wearability of emerging fabrics after electronic integration
  » reliable process for manufacturing e-textiles of different garment sizes
  » Post integration, prototypes survive up to 45 wash cycles and more than 1500 bending cycles



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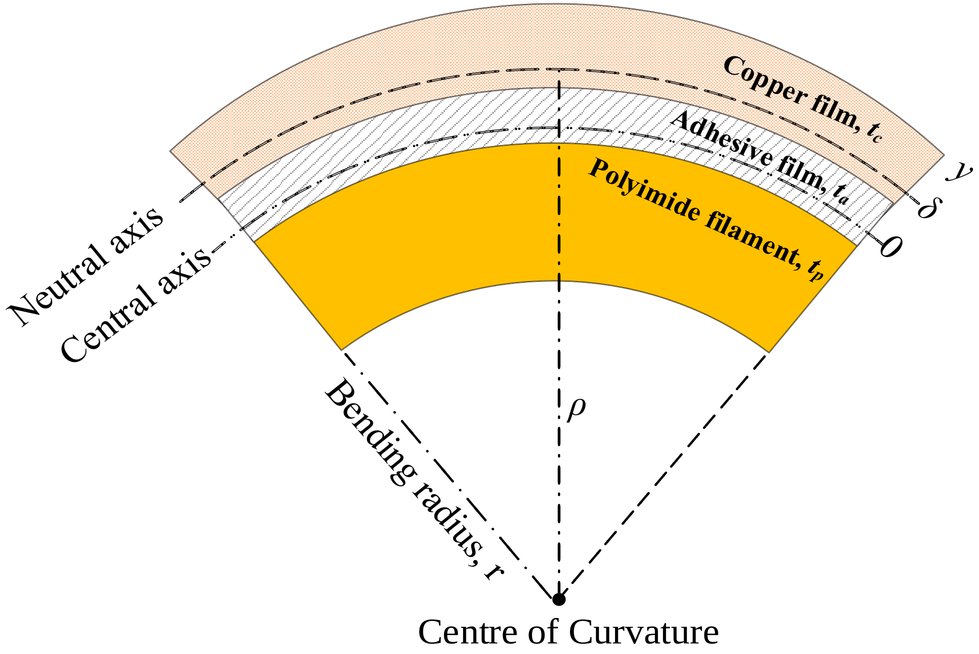
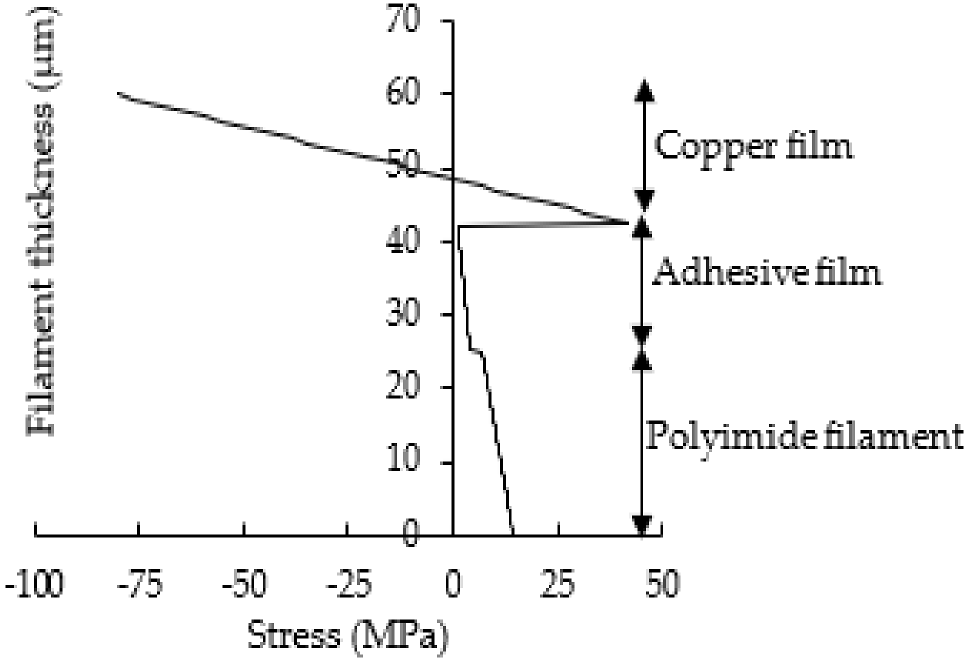
Classic model of the filament





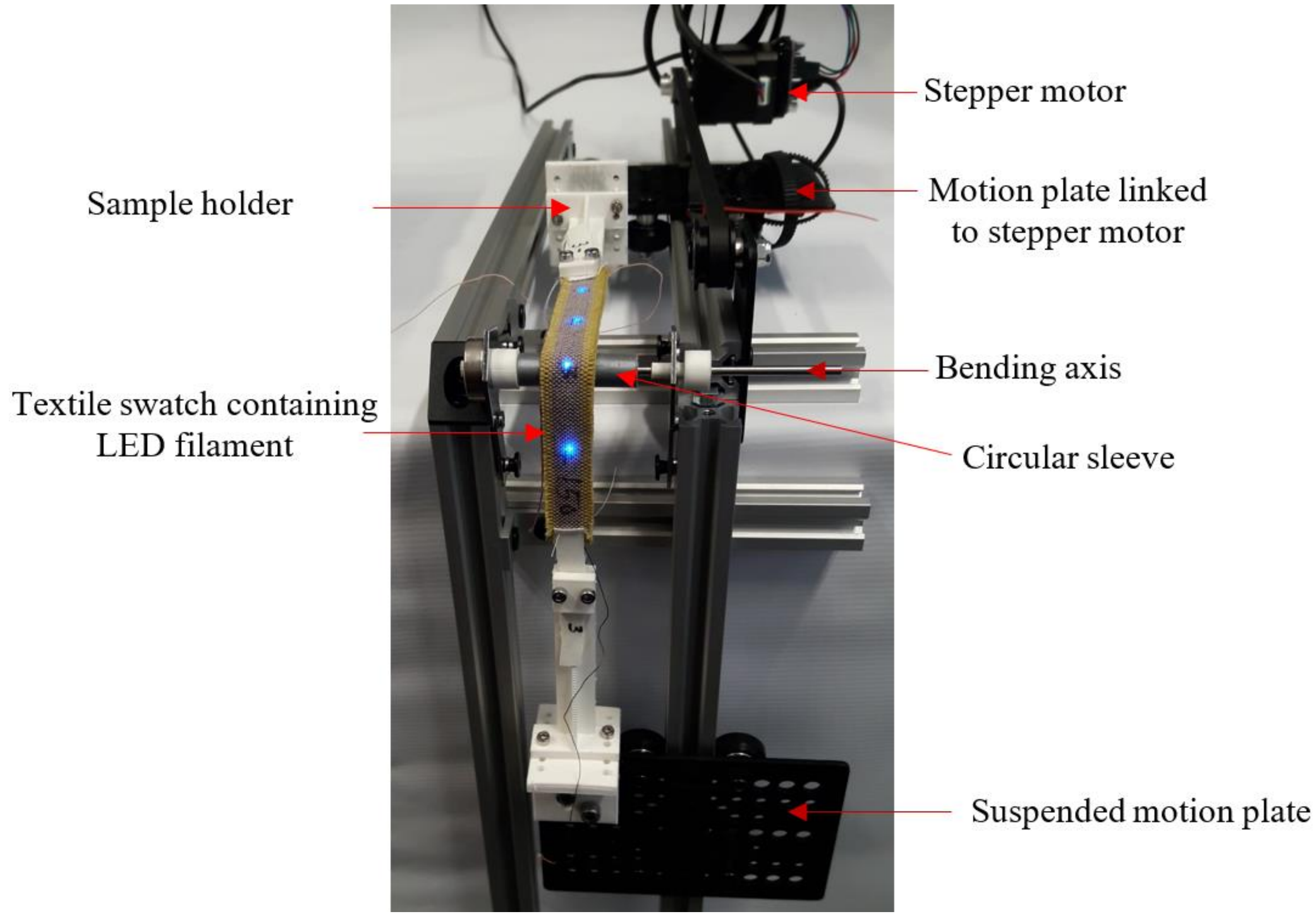
Materials	Thickness, t (µm)	Width, x (mm)	Elastic Modulus E (GPa)
Apical Polyimide	25	2	3
Thermoplastic Adhesive	17	0.2	1.8
Copper	18	0.2	70

$$NA = \frac{\sum_{i=1}^{n} E_i x_i t_i \left(2\sum_{j=1}^{i} t_j - t_i\right)}{2\sum_{i=1}^{n} E_i x_i t_i} = 48.5\ \mu m$$

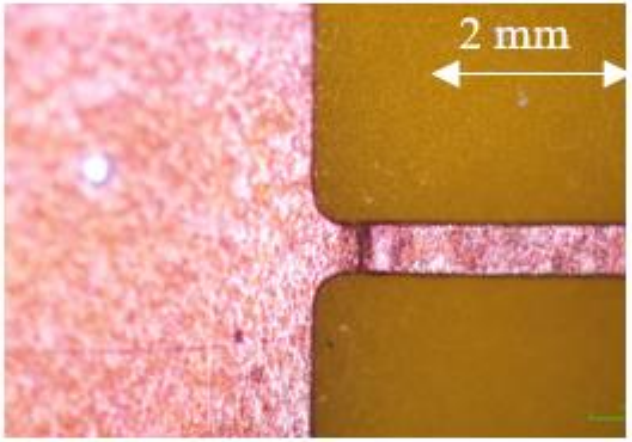
$$Stress, \sigma = E\,\frac{y-\delta}{\rho}$$

» NA is inside copper layer

Results from bending

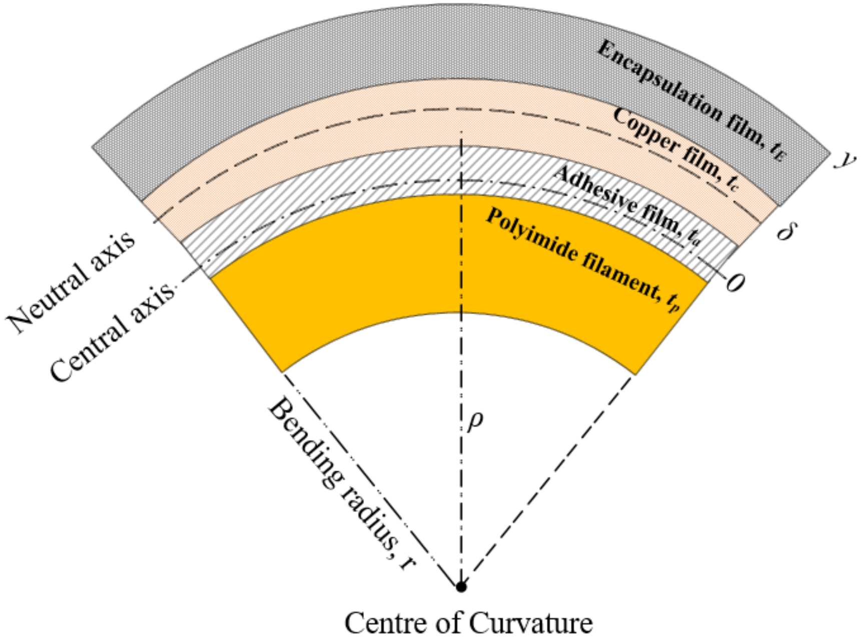


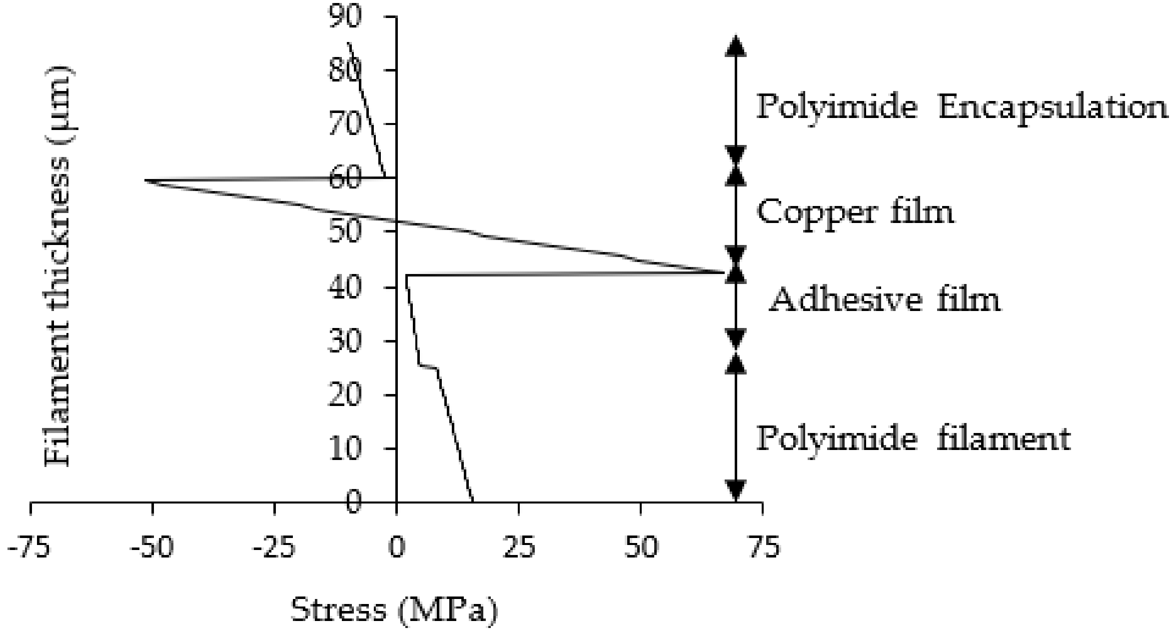
Cracking of copper film



Buckling of copper film

Effect of encapsulation on the NA

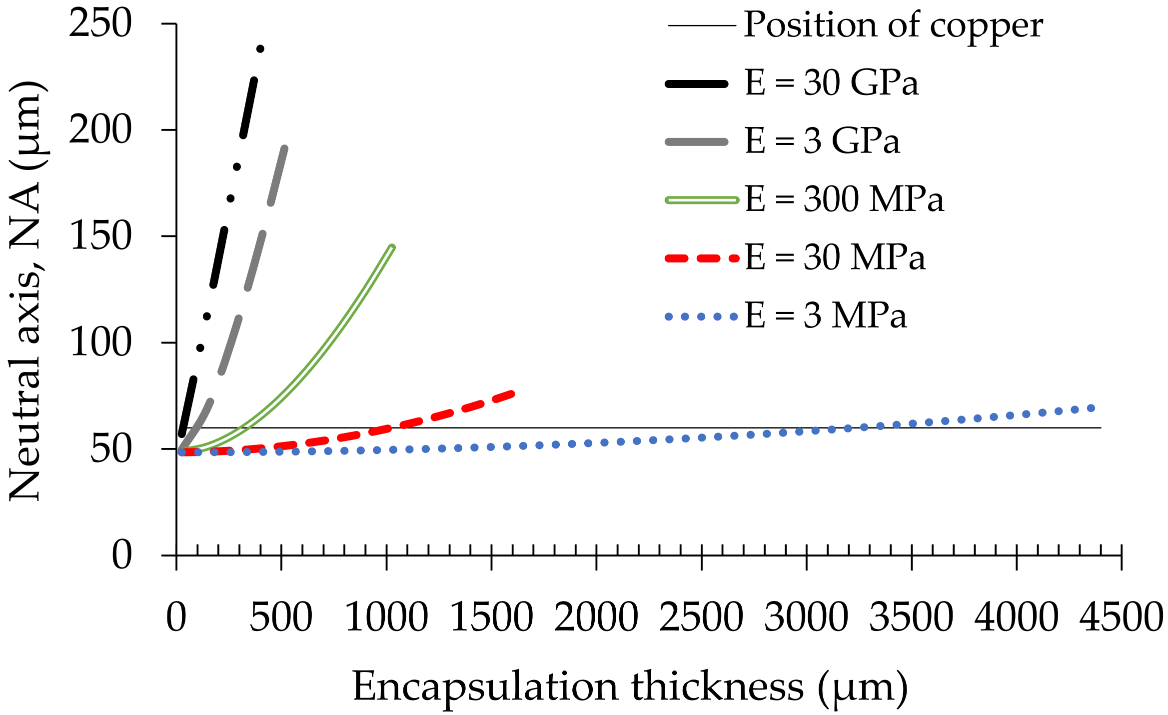


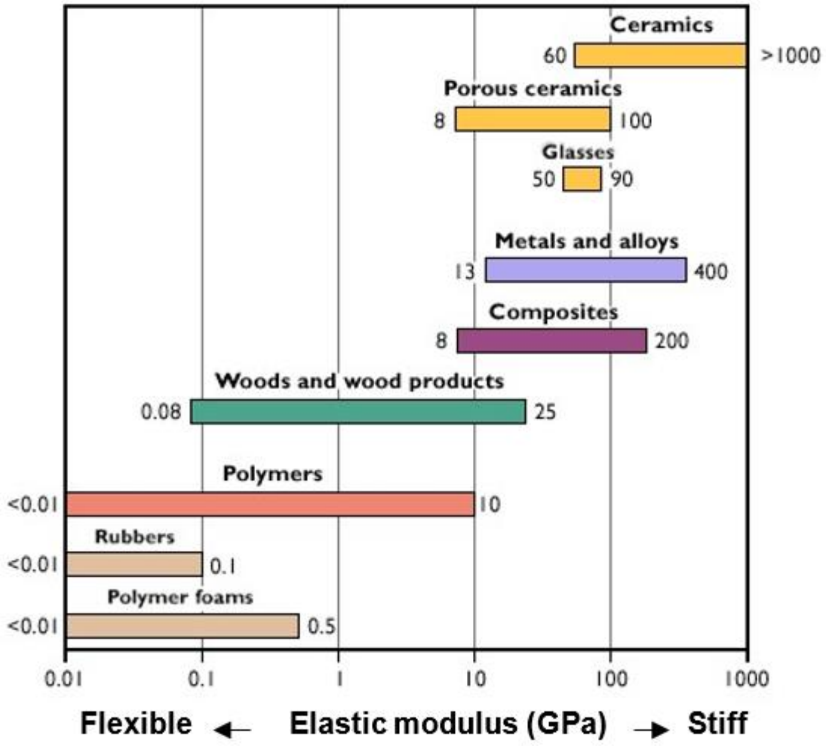


» Encapsulation only shifts the position of NA within the copper layer

» The stress is uniformly distributed within the copper film

Encapsulation thickness and Modulus





- Encapsulation thickness reduces with the increase in elastic modulus
- Elastomers (*3 MPa ≤ E ≤ 300 MPa*) are not suitable for tuning the NA position due to the high thickness requirement.
- At lower thicknesses (≤ 100 μm), elastomers physically protect the copper film from abrasion or moisture without any change in the filament stiffness and the NA position

Effect of encapsulation on filament stiffness

Materials	Thickness, t (µm)	Width, x (mm)	Elastic Modulus E (GPa)	Filament Stiffness, nNm^2 Before Encapsulation	Filament Stiffness, nNm^2 After Encapsulation
Apical Polyimide	25	2	3		
Thermoplastic Adhesive	17	0.2	1.8		
Copper	18	0.2	70		
Encapsulation materials[1]					
PEEK	35	2	3.8		41.9
Mylar	40	2	3.1		47.8
Thermoplastic polyurethane (VPT 9074)[2]	8000	2	0.001	14.8	8548
Apical Polyimide	40	2	3		46.8

[1] The reported thickness shifts the NA to the center of the copper film. [2]Supplied by Covestro

$$Stiffness = \frac{1}{12}\sum_{i}^{n} E_i x_i t_i^3$$

» Filament stiffness triples with materials such as Polymide (E = 3 GPa)

» Elastomers increases stiffness significantly (up to 8000 times)

Conclusions

» Encapsulations are necessary for enhancing the durability of filament circuits

» For polyimide filaments containing 18 µm thick copper films, the encapsulation material improves durability by ensuring the induced stress is uniformly distributed within the copper. It does not position the entire film on the NA

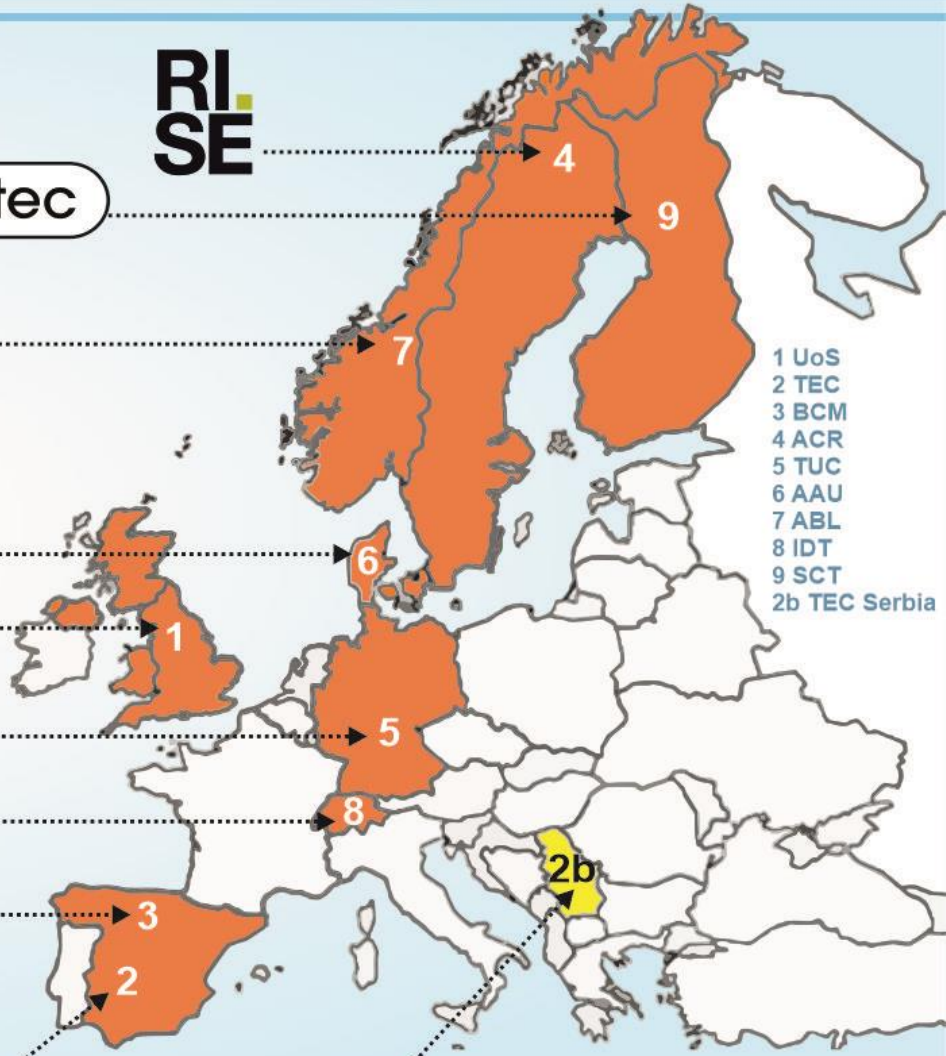
» The entire copper film can be positioned on or close to the NA where the stress is minimum by reducing its thickness significantly (≤ 1µm).

» In both cases, the same encapsulation thickness is required, and the stiffness of the encapsulated filament is up to three times the value before encapsulation

» Encapsulants such as PEEK, polyamide and mylar (E ≈ 3 GPa), a thickness of 40 µm is enough to place the copper film on the NA the filament or e-textiles

Thank you

Wearplex Project partners



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