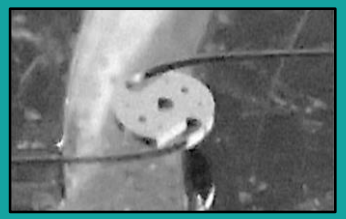
جامعة الملك عبدالله
للعلوم والتقنية
King Abdullah University of
Science and Technology

COMSOL
CONFERENCE
2015 GRENOBLE

# SIMULATION OF A TETHER STRUCTURE FOR ULTRA-STRETCHABLE MONOLITHIC SILICON FABRIC

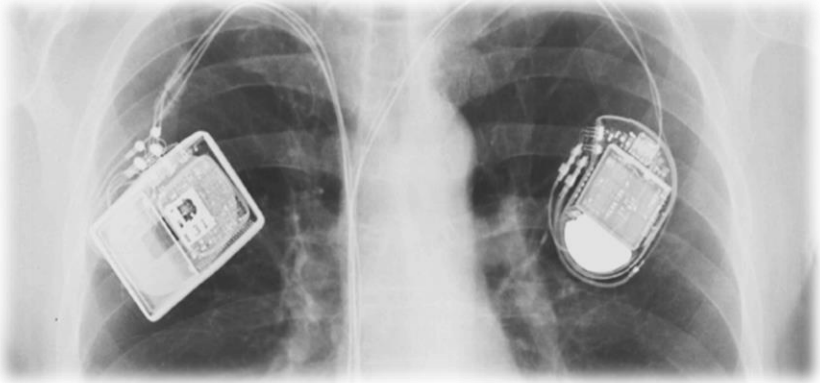
*PRESENTED BY ARPYS AREVALO*

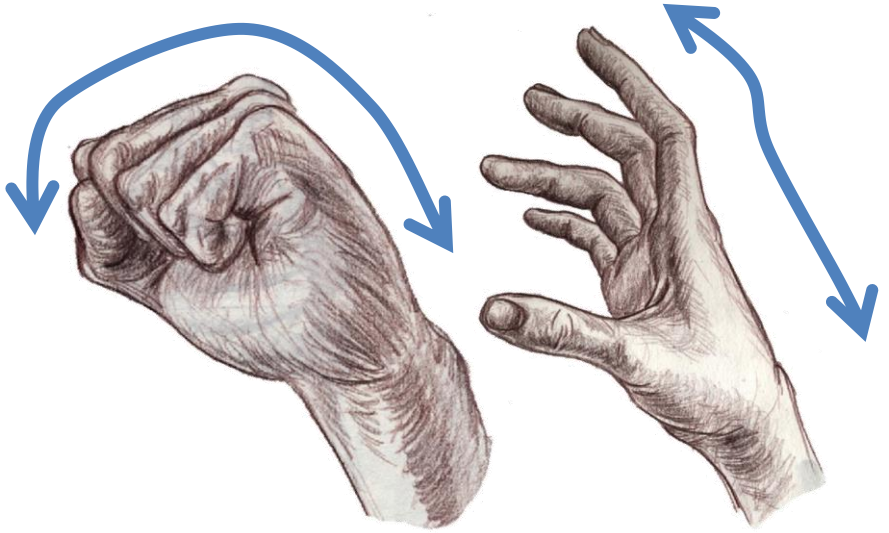


Stretching the boundaries of inorganic materials

# MOTIVATION

*"Advancing electronic systems for wearable & bio-integrated applications"*





➔ *Compliance to asymmetric shapes*

➔ *Adaptable, mobile, shape-shifting*

# Current Approaches

## Inorganic Substrates

"Electrically advanced but mechanically limited"

**Thinning technologies**

- Back-grinding /Polishing

***Limitations:***

- Roughness, Strain, Thickness
  → Constrain applications
- Material wastage

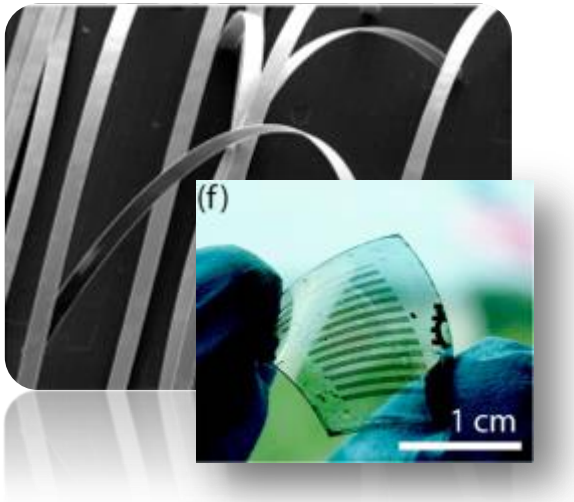
## Organic Substrates

*"Mechanically attractive but*

- ✓ Cost-effective solutions
- *Low mobility* - Poor performance
- *Incompatibility* with high thermal budget processes

## Hybrid Approach

"A point in between"

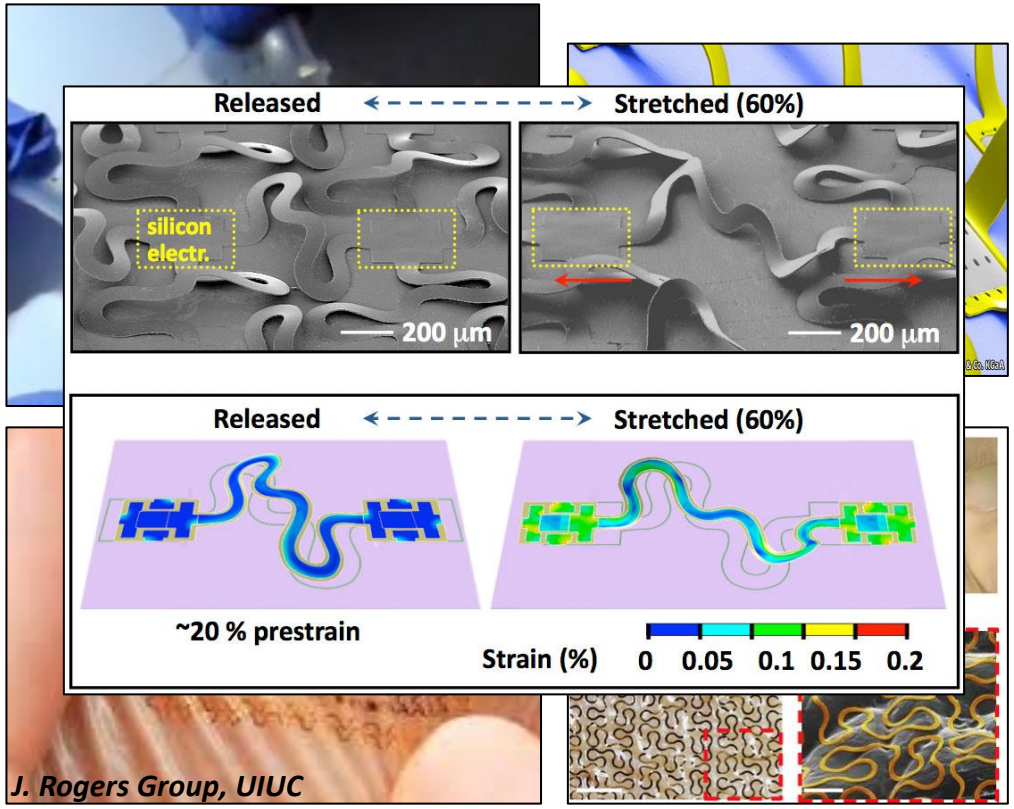



- ✓ Good efficiency and flexibility
- + Costly, + Complex, - Performance

# Hybrid Approach

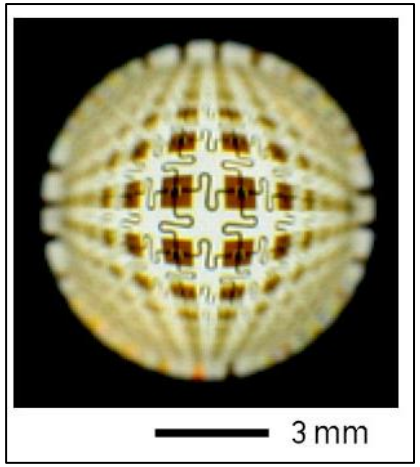
**Transfer printing technology**

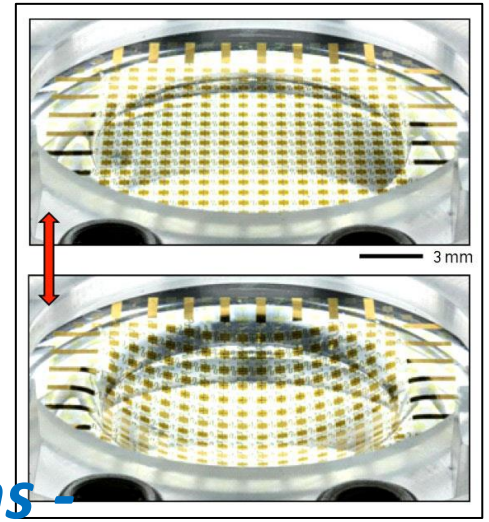
*Integration of inorganic and polymeric materials*




http://rogers.matse.illinois.edu/

**Shape-shifting Demonstration**



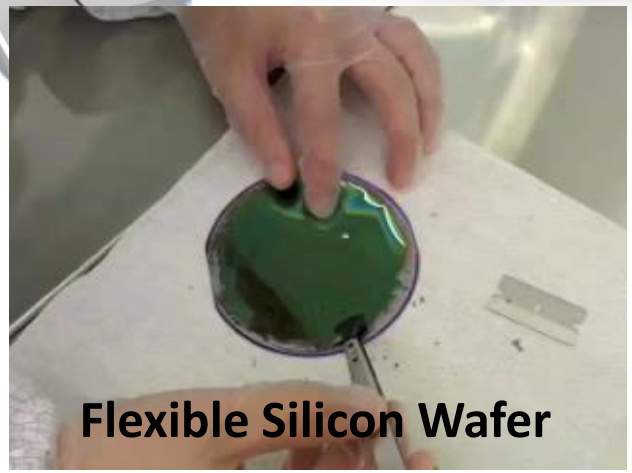



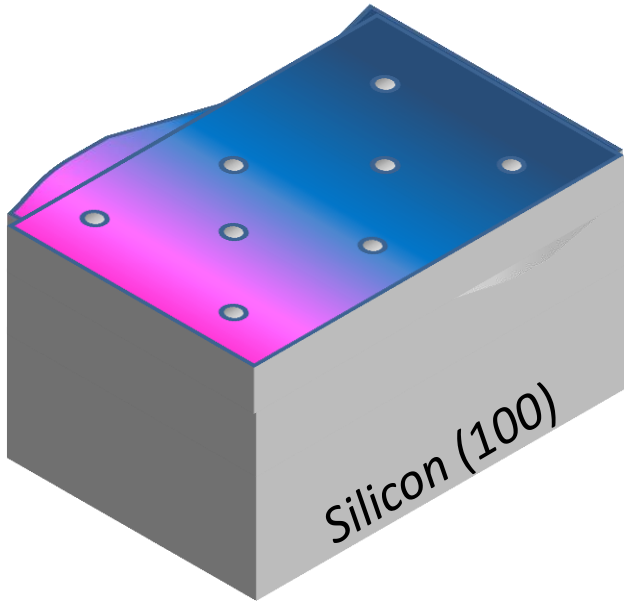

***- Power of Structural Modifications -***

# Transformational Electronics
## - A different Approach -

*Flexible devices of the future*





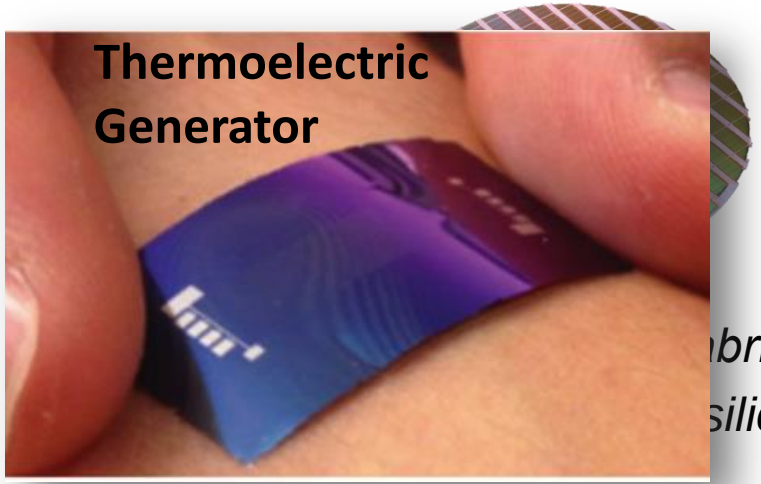



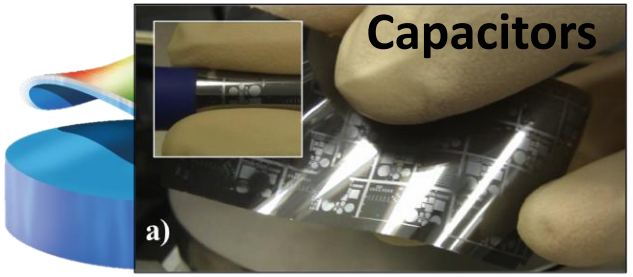

*Flexural Rigidity*

$$D = \frac{Et^3}{12\left(1 - \nu^2\right)}$$

*E*: Young's modulus
*v*: Poisson's ratio
*t*: Thickness

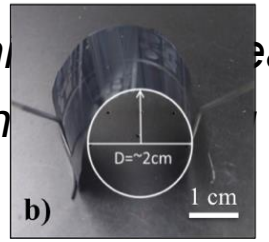
# Demonstrations




*brication techni*

*silicon with high*



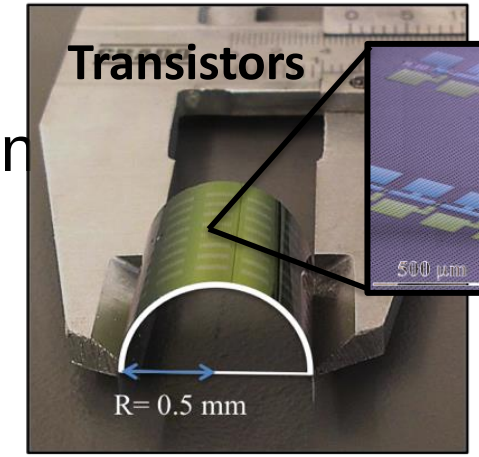


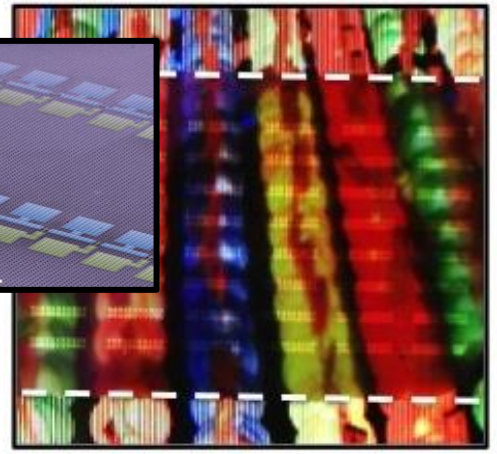
✓ High electrical performance


den

lity

*y*

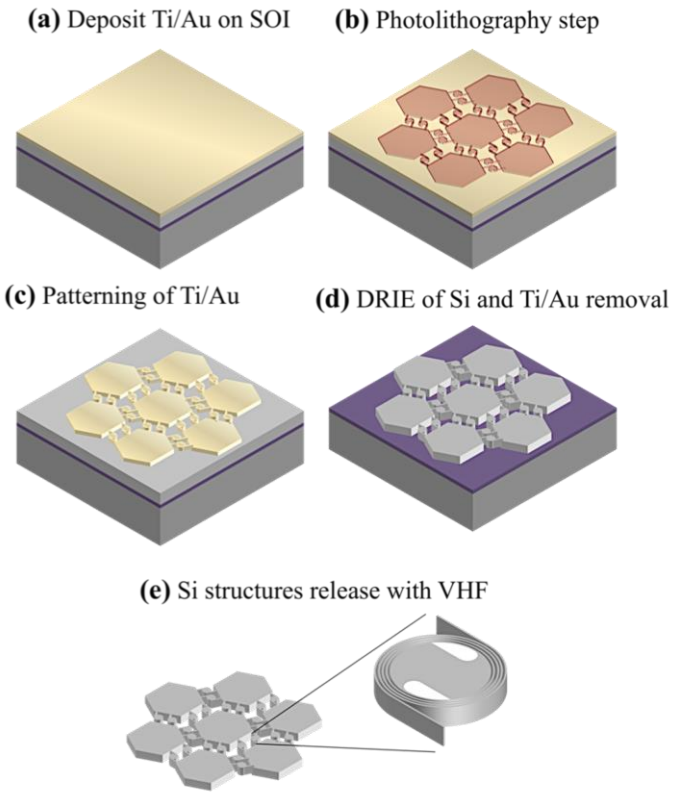


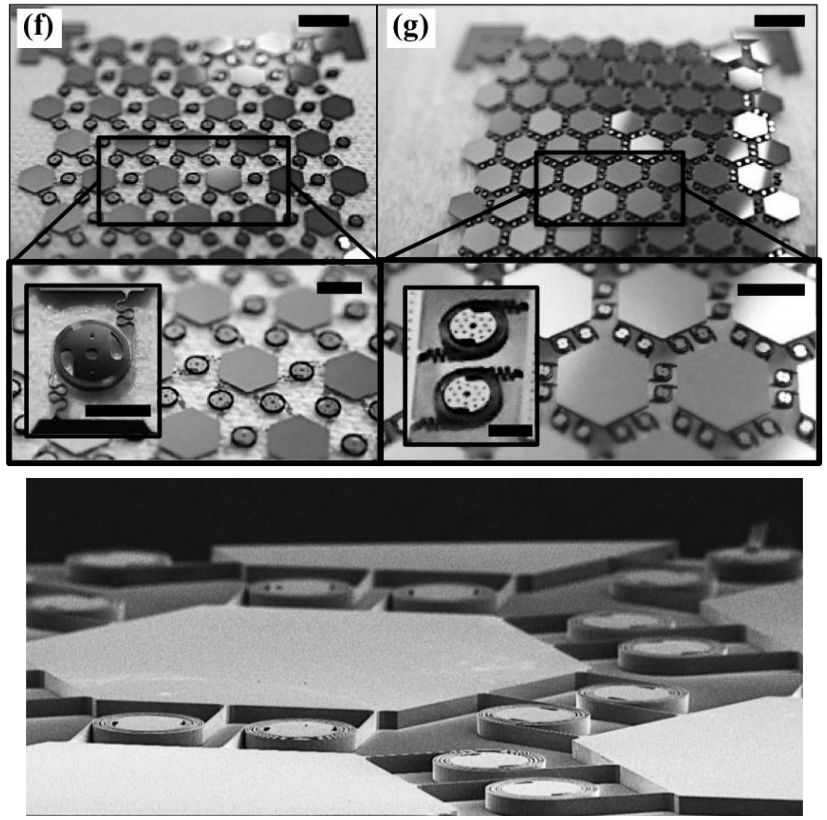



# Stretchable Electronics
## - A Different Concept -

J. P. Rojas *et al.*, Appl. Phys. Lett., 105(15), 154101 (2014)

**- Structural modifications to achieve stretchability in rigid materials -**



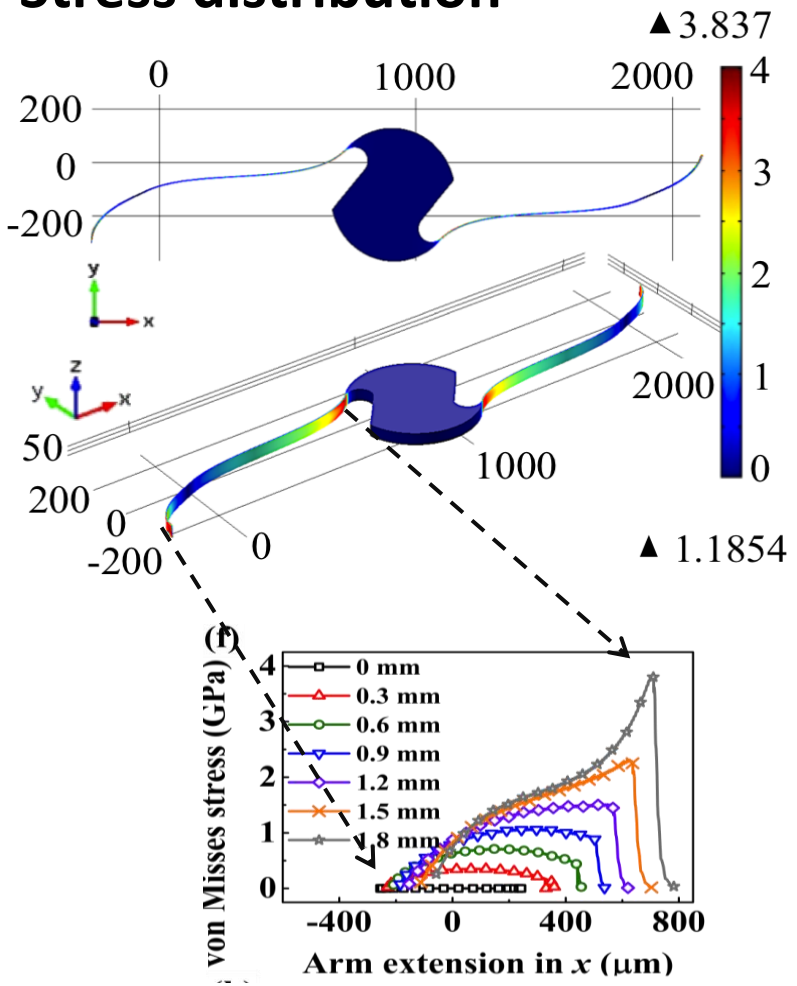




**Double spiral design to achieve more than 1000% stretchability**

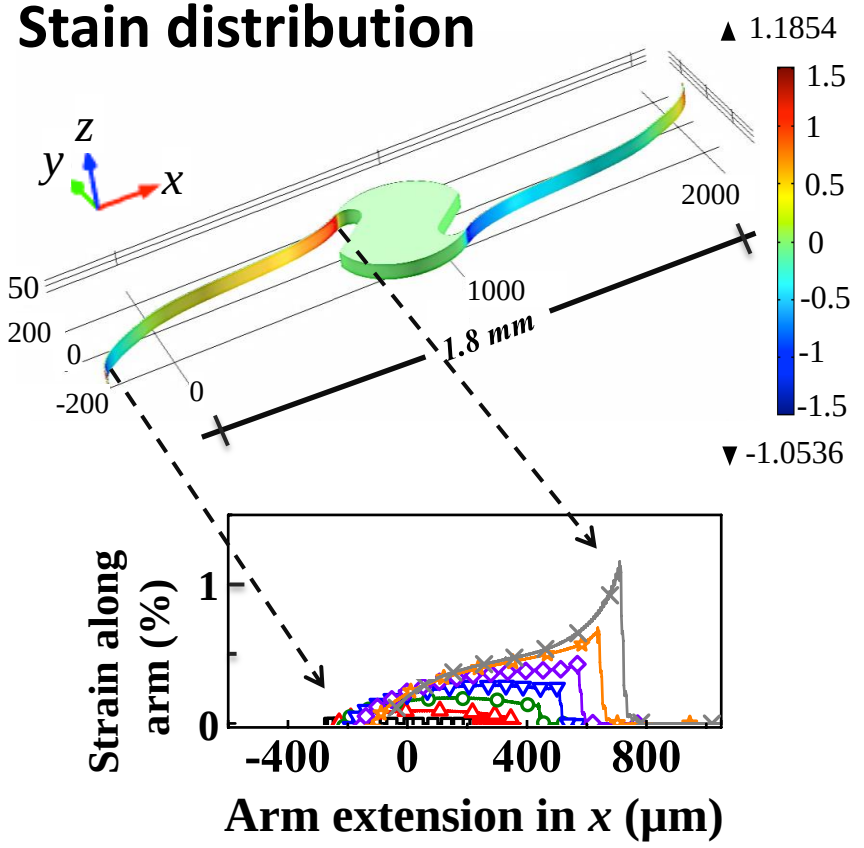
# Stretchable Silicon: Finite element simulation

J. P. Rojas *et al.*, Appl. Phys. Lett., 105(15), 154101 (2014)

## Stress distribution




## Stain distribution



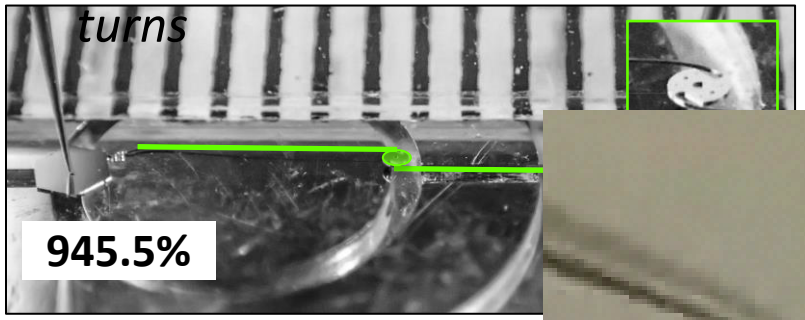

$$e_{MAX} = w/2R = 1\% \Rightarrow R = 50w$$

# Stretchable Silicon: Experimental Results

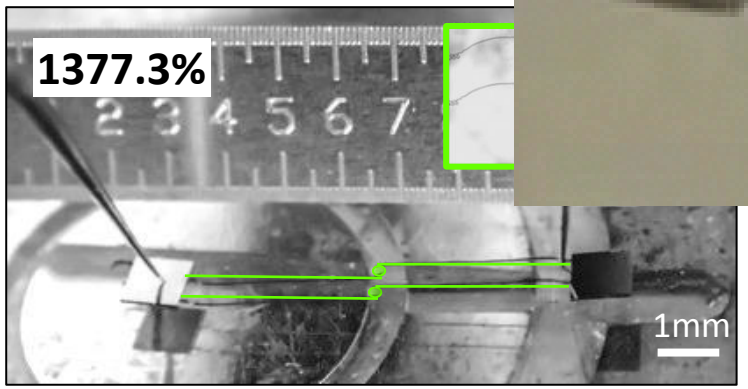
J. P. Rojas *et al.*, Appl. Phys. Lett., 105(15), 154101 (2014)

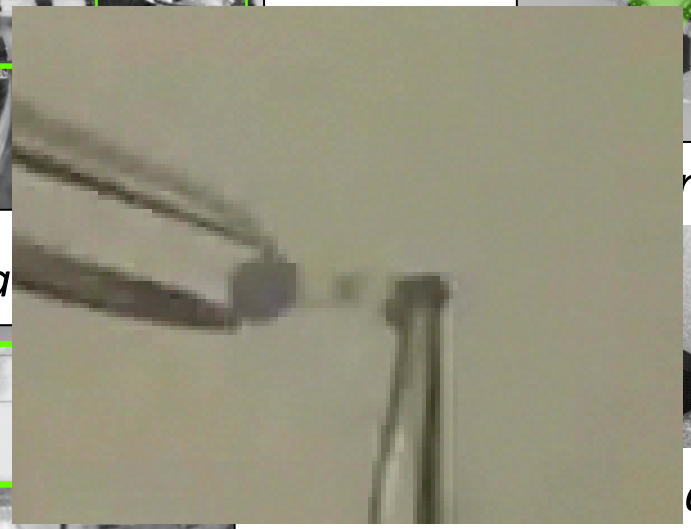
## Length extension test

*Single 5 µm-wide arm; 3 turns*



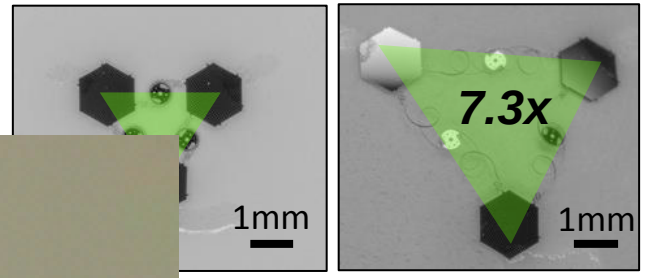

*Double 2 µm-arm spira*



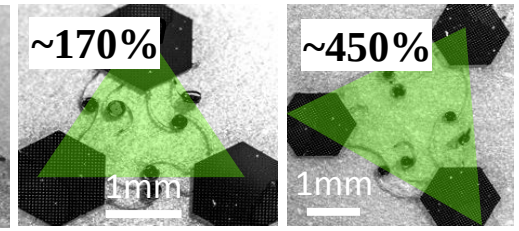



## Area expansion tests

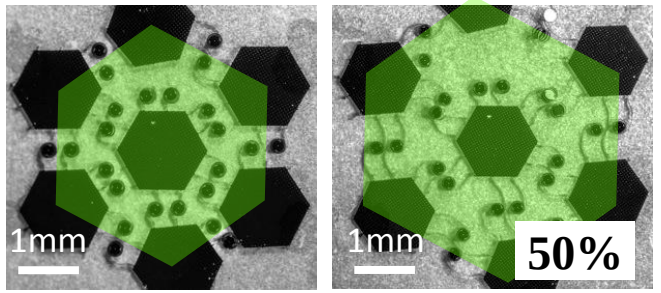
*3 hexagons array; Single 5 µm-arm*




*ns array; Double 2 µm-*



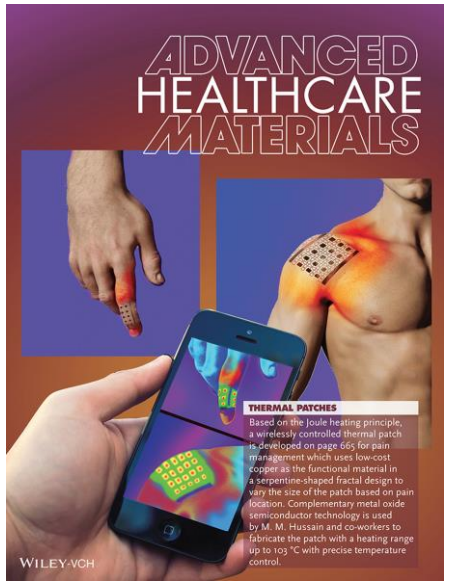

*array; Double 2 µm-arm*

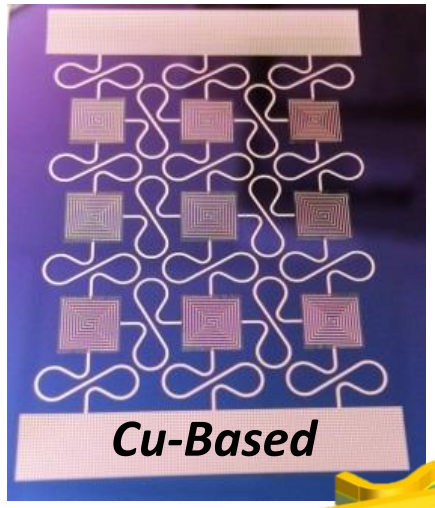


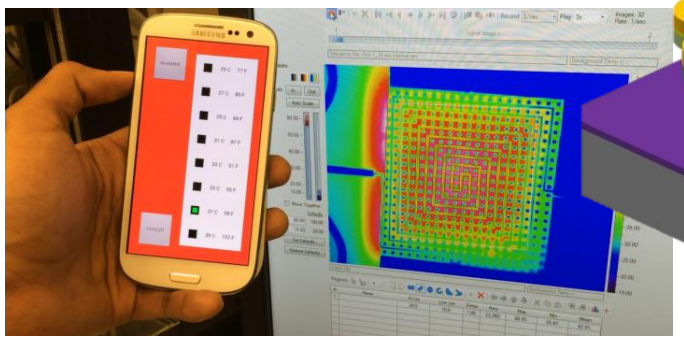
# Ultra-Stretchable Smart Patch for Thermotherapy

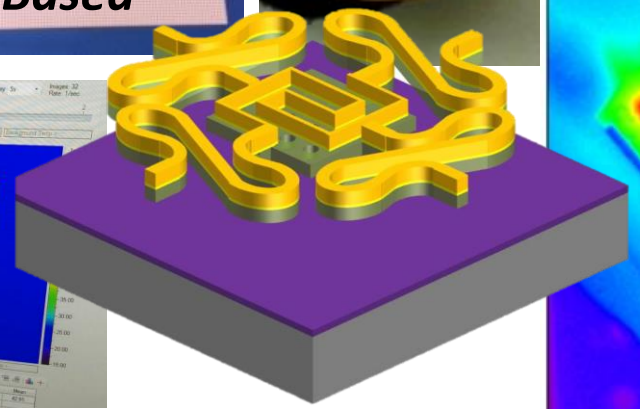
A. M. Hussain *et al.*, Adv. Healthcare Mater., DOI: 10.1002/adhm.201400647 (2014)

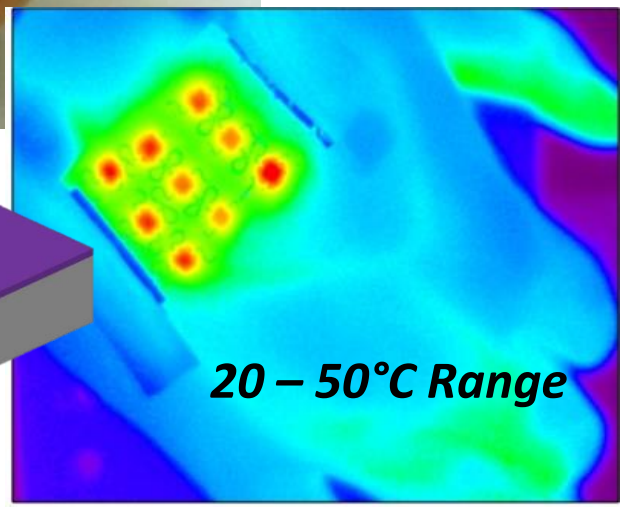
***800% stretchability***








***Wirelessly control thorough Smartphone***

# Conclusions and Future Work

- Silicon remains still the best material choice for high-performing electronics
- Structural designs allow to expand mechanical properties of materials (even rigid materials such Silicon can become flexible and stretchable)

➢ Explore and model new geometries and shapes (combinations, bio-inspired)

➢ Incorporate this novel structures with devices and systems for new-frontier electronics.

جامعة الملك عبدالله
للعلوم والتقنية
King Abdullah University of
Science and Technology

COMSOL
CONFERENCE
2015 GRENOBLE

# Thank you!

Any Questions?