

# Conformal Sheets of Thin Film Sensors, Electronics and Energy Harvesters for Structural Monitoring

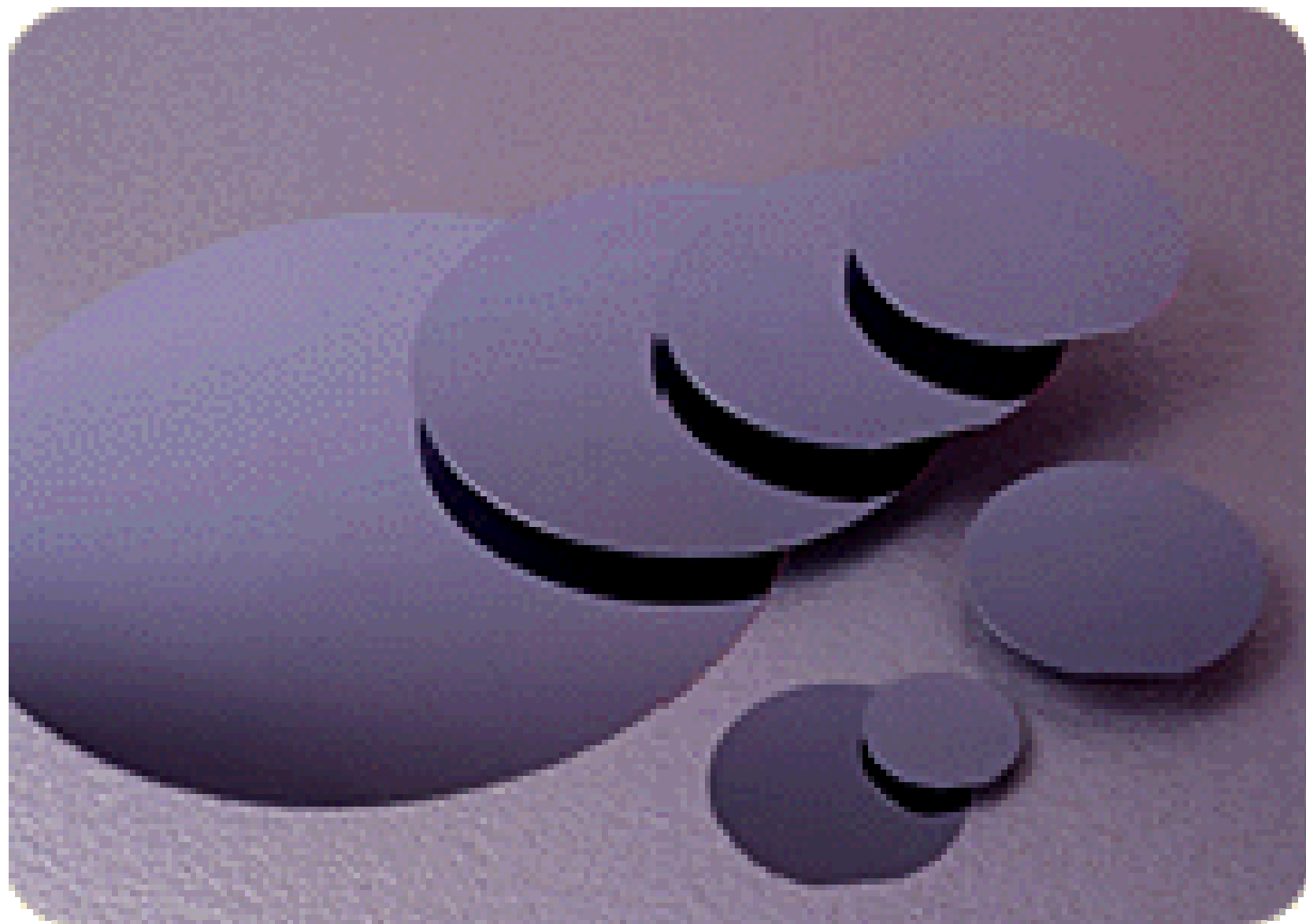
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- Motivation, Perspective
- Materials, Assembly Techniques
- Structural and Human Status Monitoring

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Electrical and Computer Engineering, Bioengineering  
Mechanical Science and Engineering, and Chemistry  
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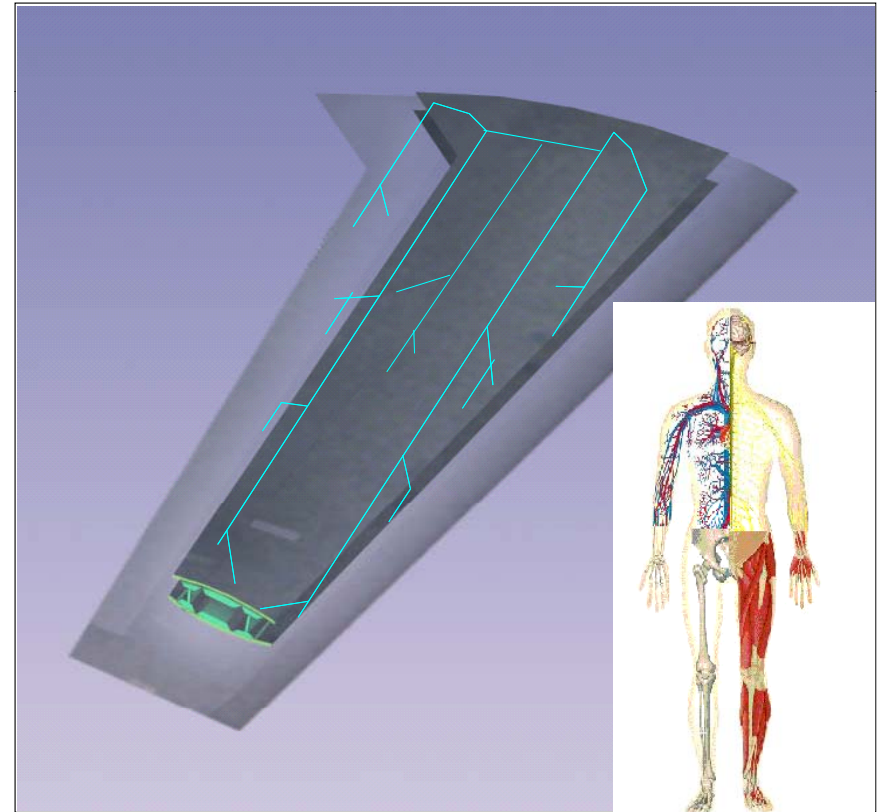
[jrogers@illinois.edu](mailto:jrogers@illinois.edu); (217) 244-4979; <http://rogers.matse.illinois.edu/>

| Report Documentation Page                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                    |                                     |                                                           | Form Approved<br>OMB No. 0704-0188                  |                                 |
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| 14. ABSTRACT                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                    |                                     |                                                           |                                                     |                                 |
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## Structural Health Monitors for Aerospace

### *The Living Airframe – B. Baron/AFRL*



## Macroelectronics for Advanced Medical Systems

### Intelligent, Wireless Medical Sensors



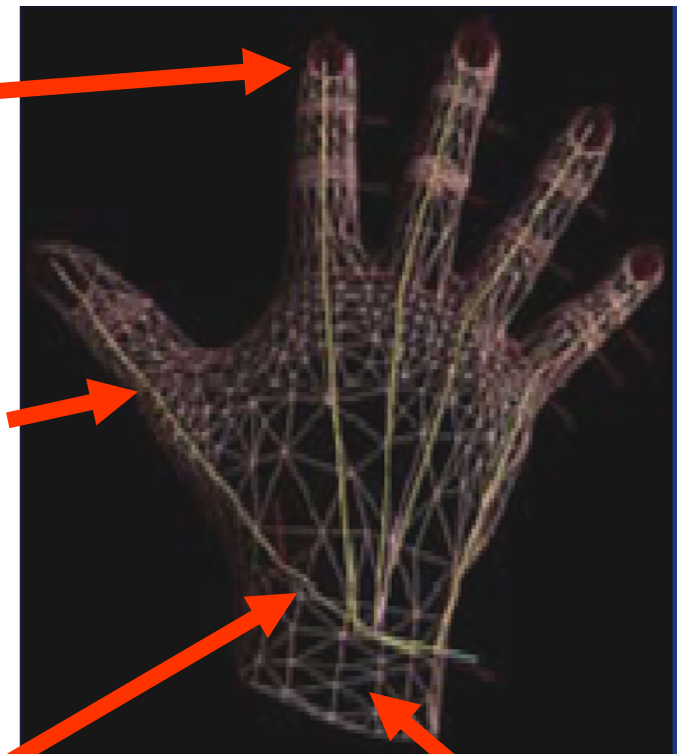
### Smart Surgical Glove

$\mu$ sensors:  
chemical,  
optical,  
thermal

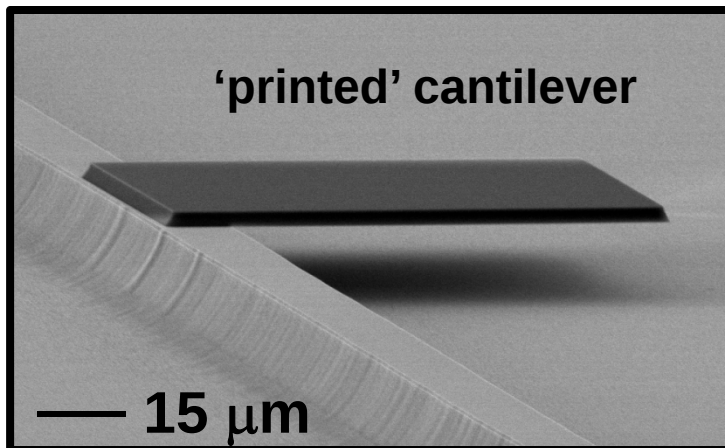
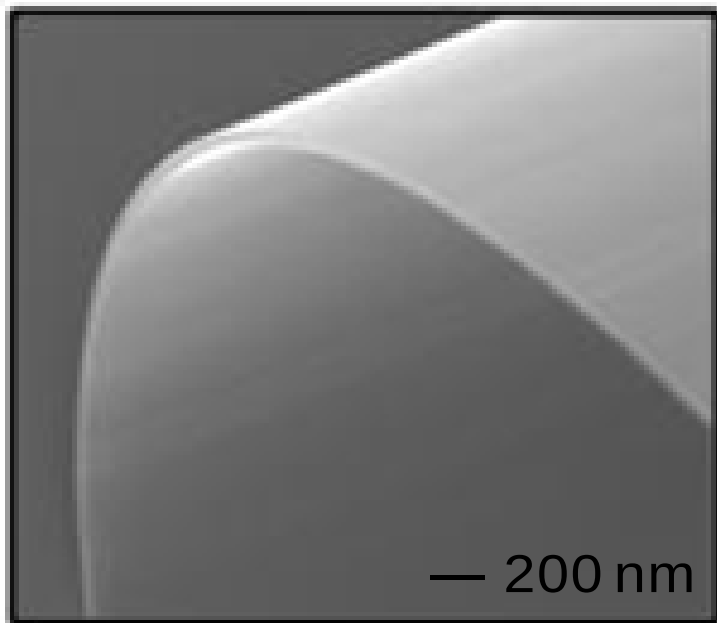
$\mu$ fluidic  
channels

embedded  
integrated circuits

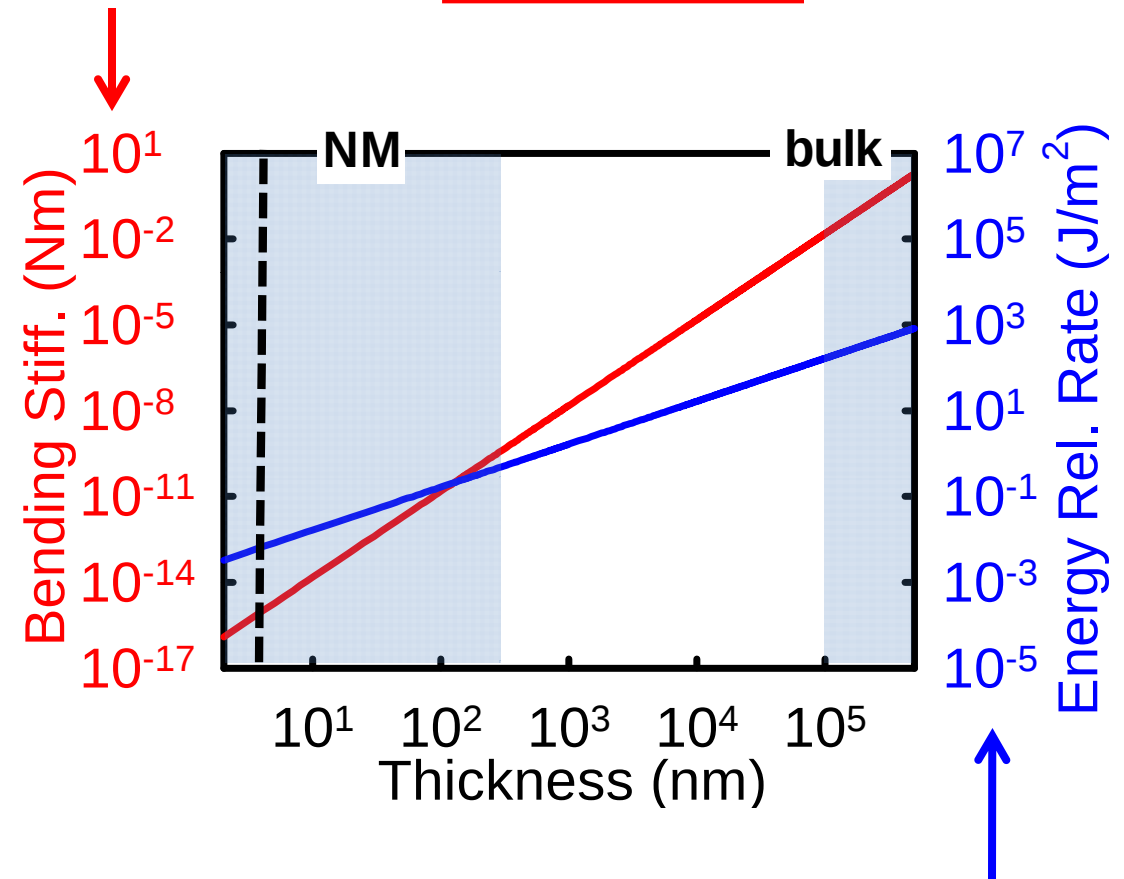
RF transmit/receive



# Mechanics of Silicon *Nano*Membranes



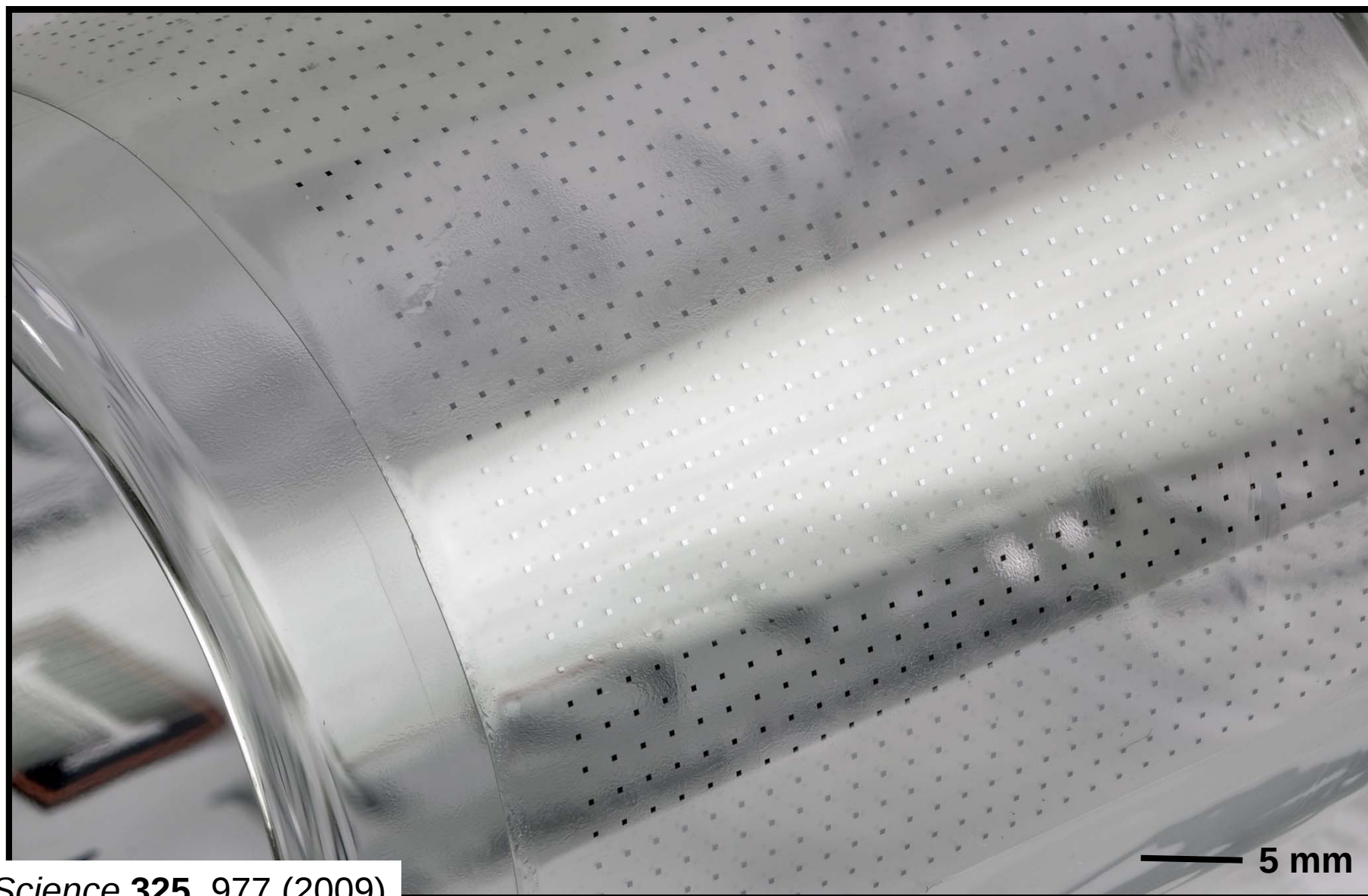
$$EI \sim Eh^3 \quad \text{and} \quad \varepsilon_{peak} \sim h / R$$



$$G \sim h(\alpha_1 - \alpha_2)^2 \Delta T^2$$

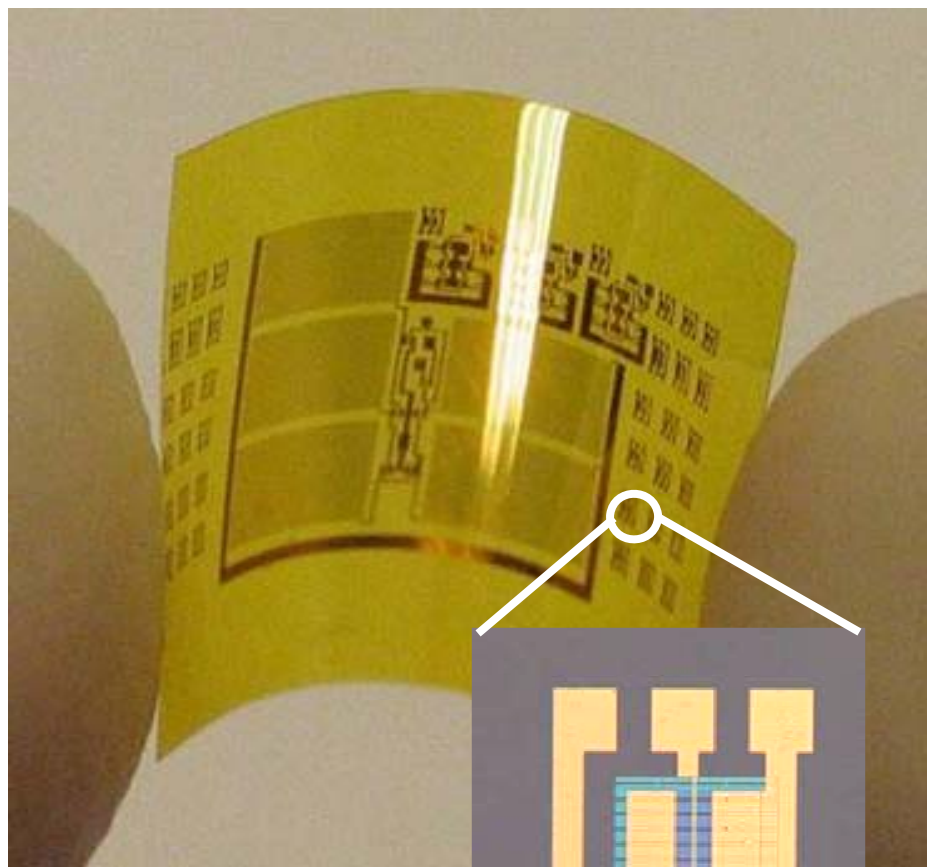
*Nature*, **477**, 45 (2011).

## **GaAs Membranes Printed Onto Plastic (1600; 100% yield)**

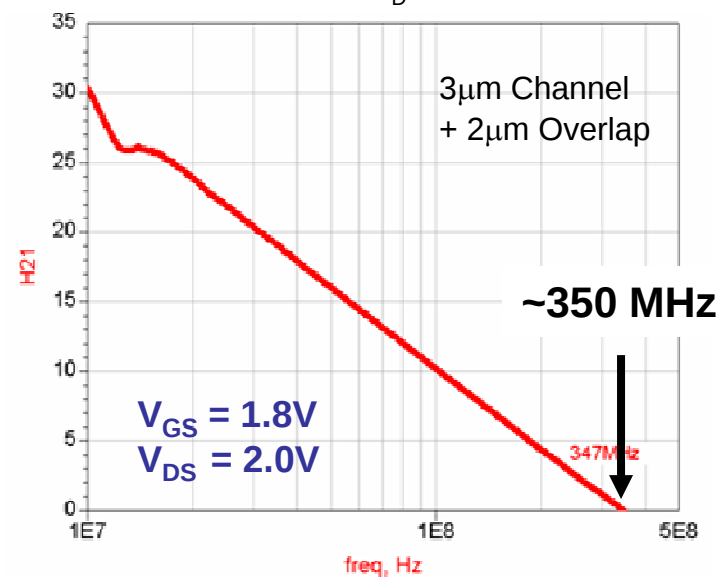
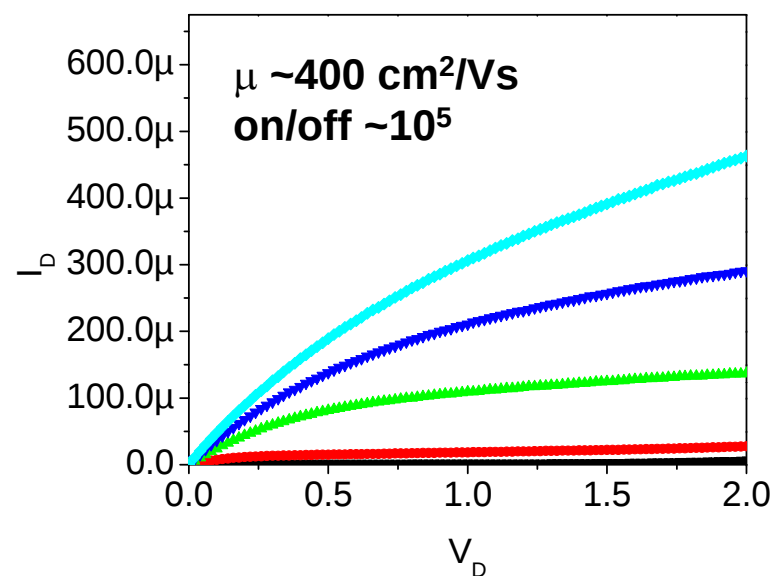


*Science* **325**, 977 (2009)

# Single Crystal Silicon TFTs and Circuits on Plastic

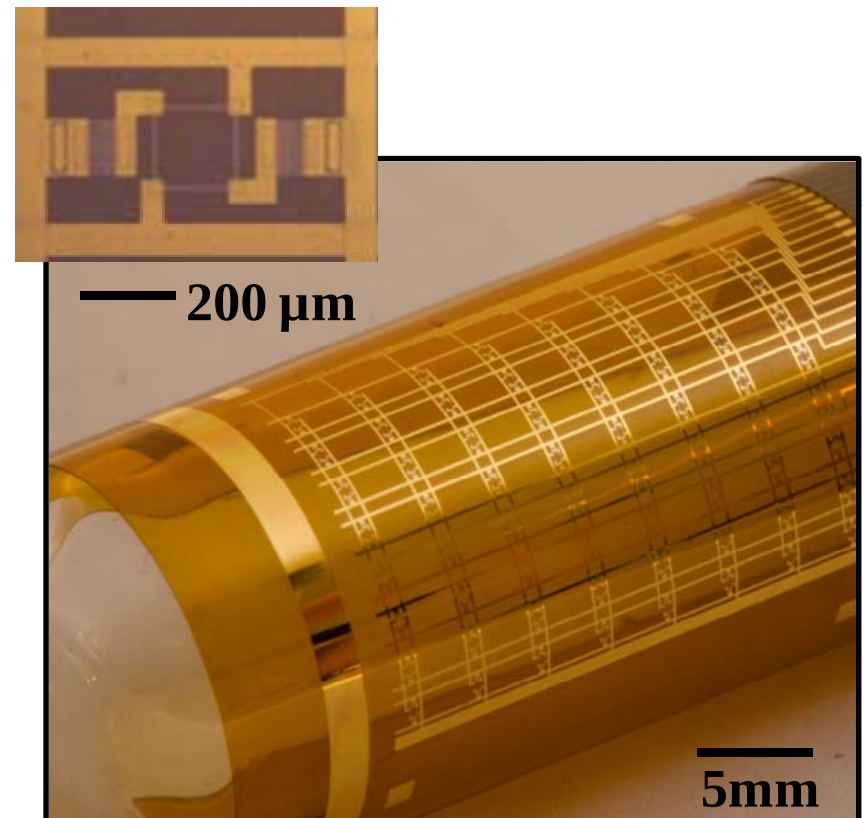
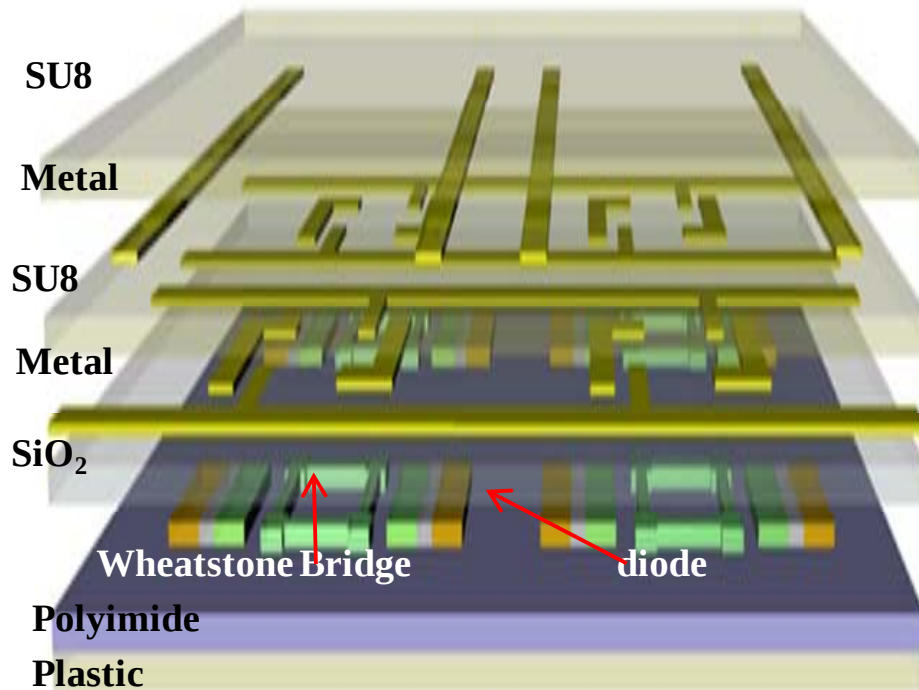


– 10  $\mu\text{m}$

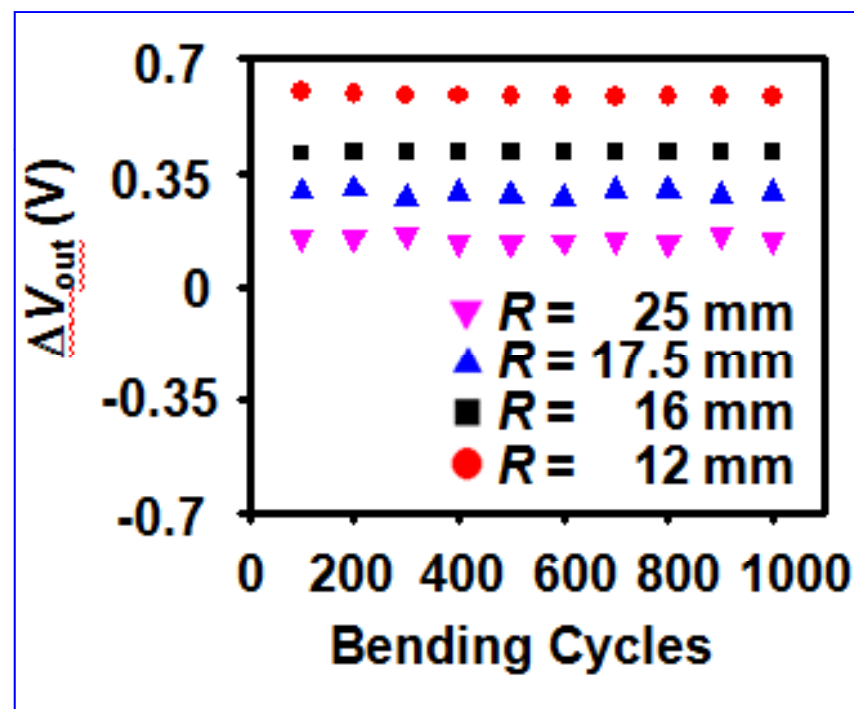
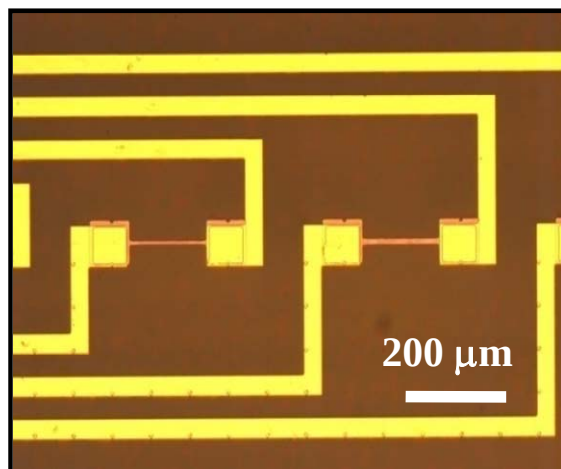
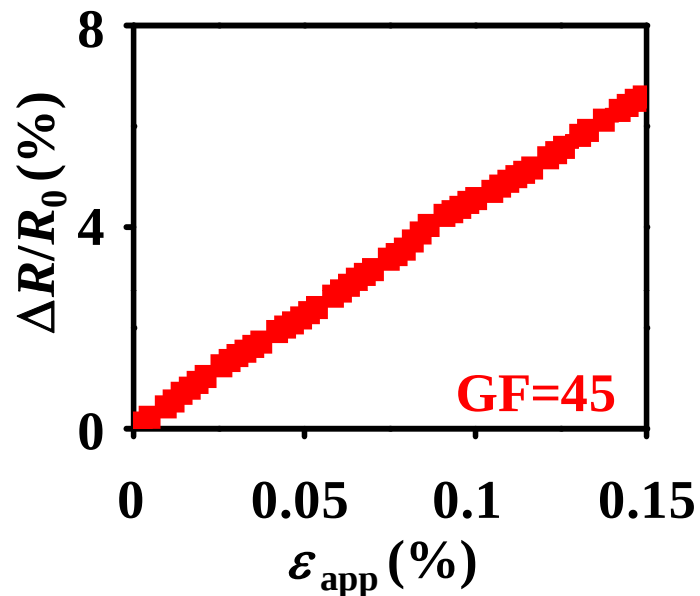


*IEEE Electron Dev. Lett.*, 27(6) 460 (2006).

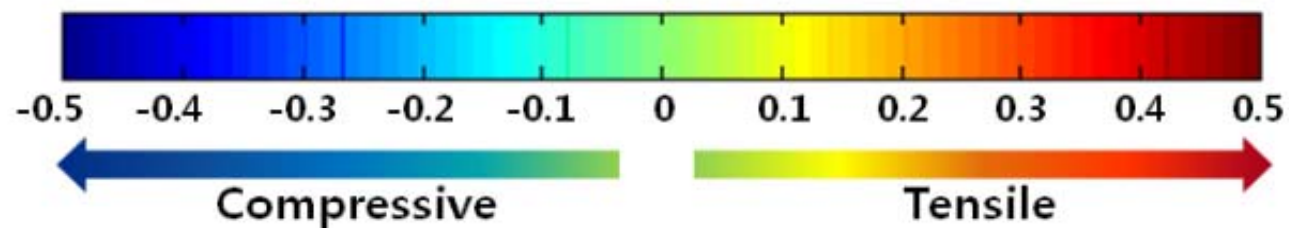
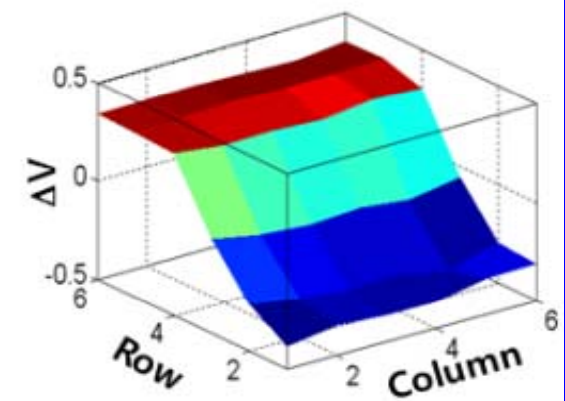
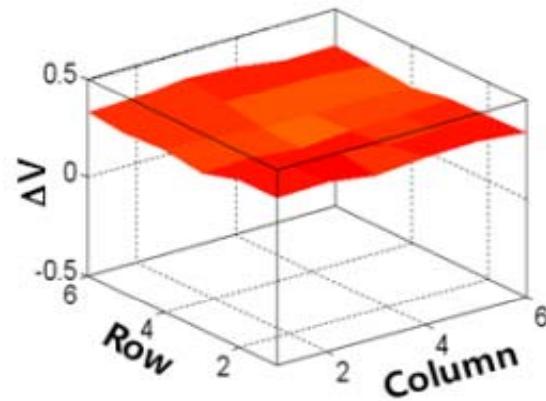
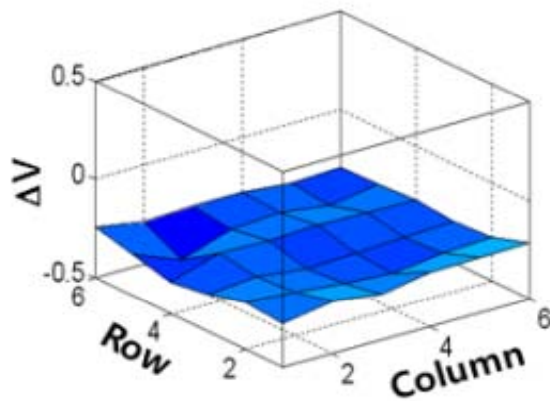
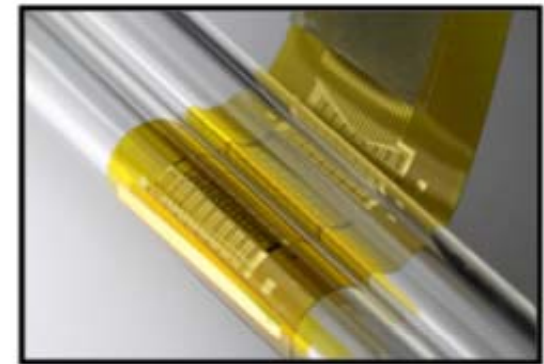
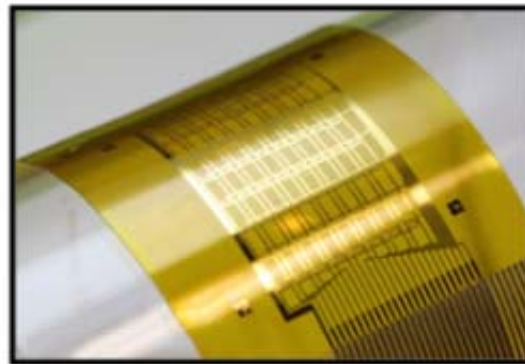
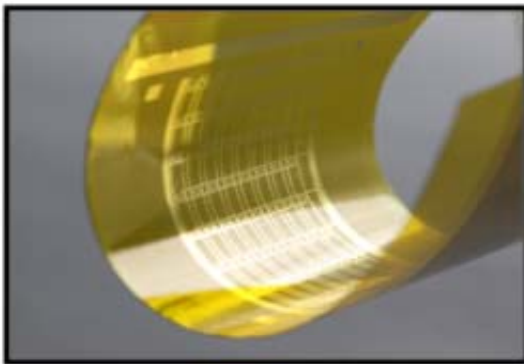
## Flexible, Multiplexed Silicon Strain Gauges



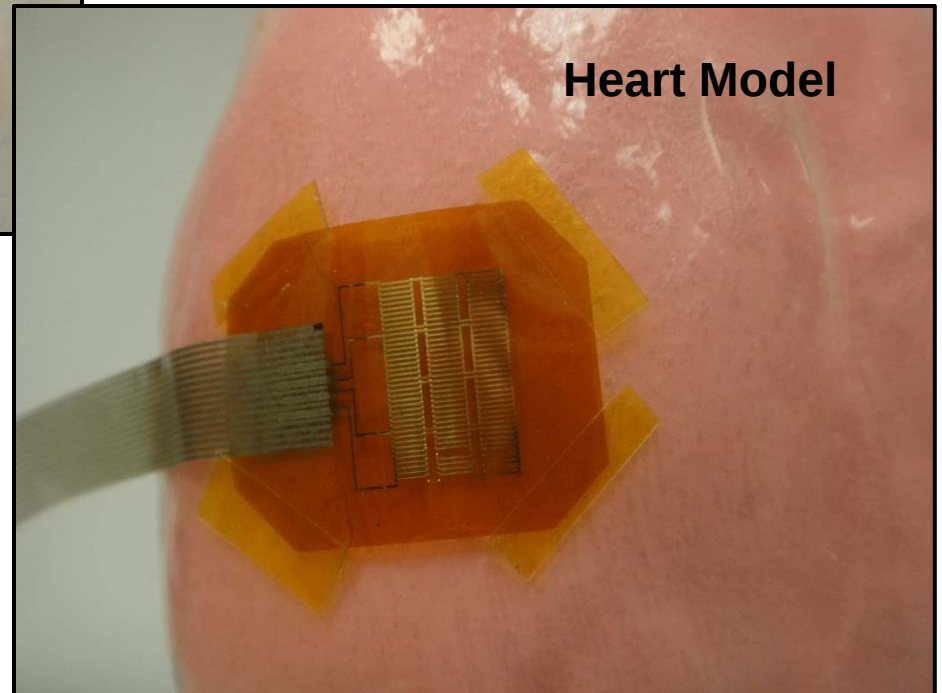
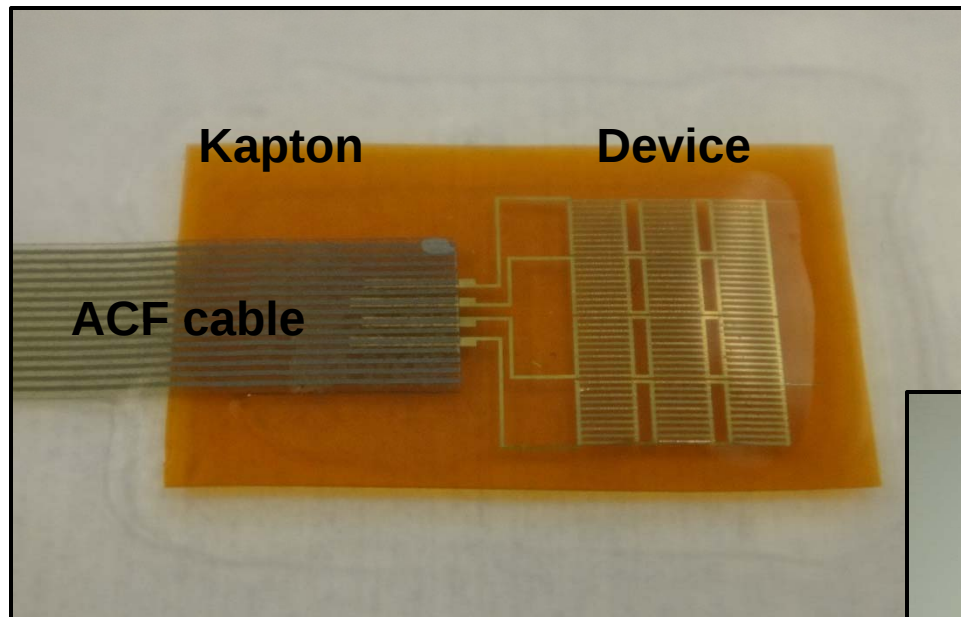
## Flexible Silicon Strain Gauges – Performance



# Strain Mapping with Flexible Silicon Strain Gauges

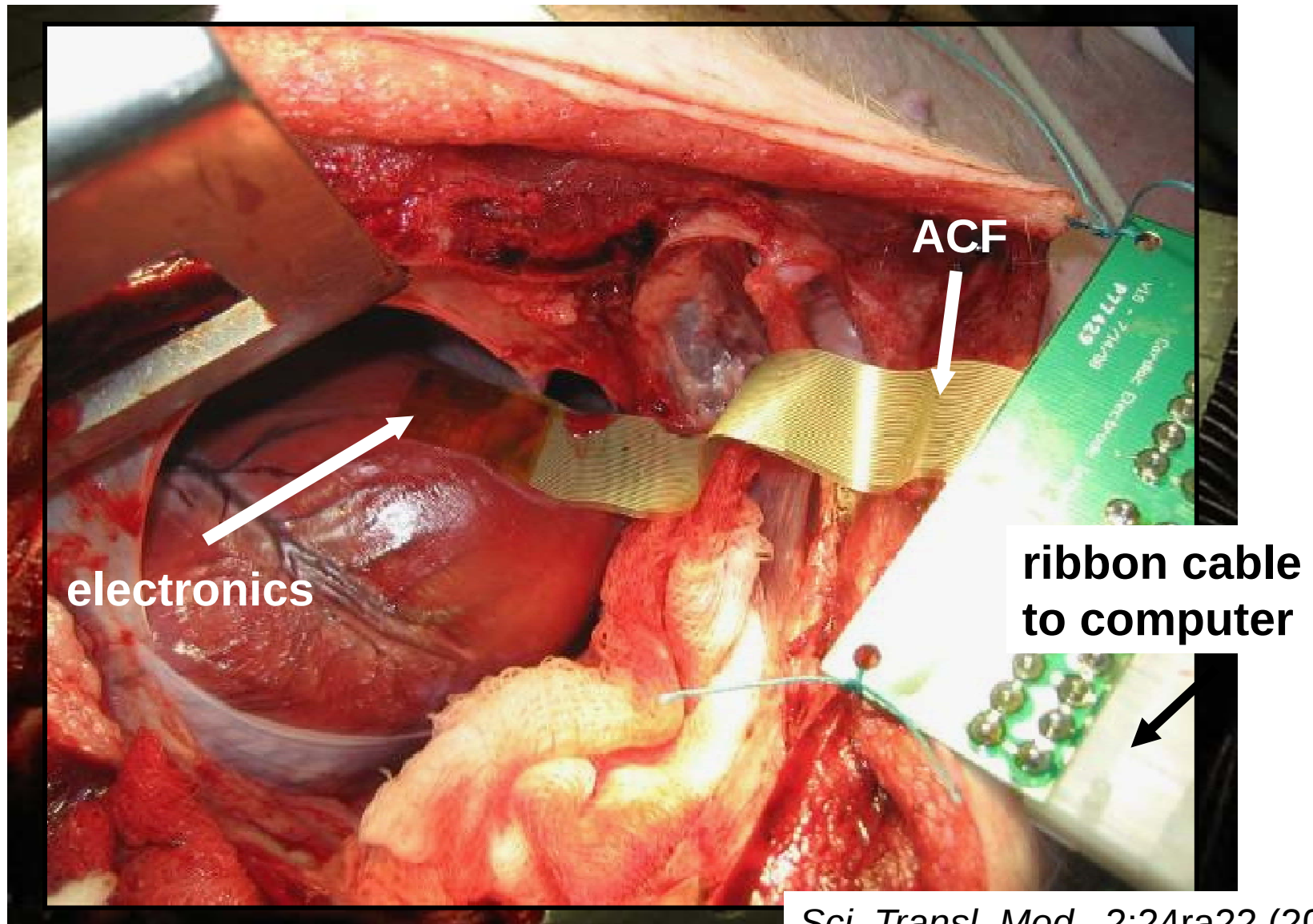


## Energy Harvesting with Flexible PZT Elements



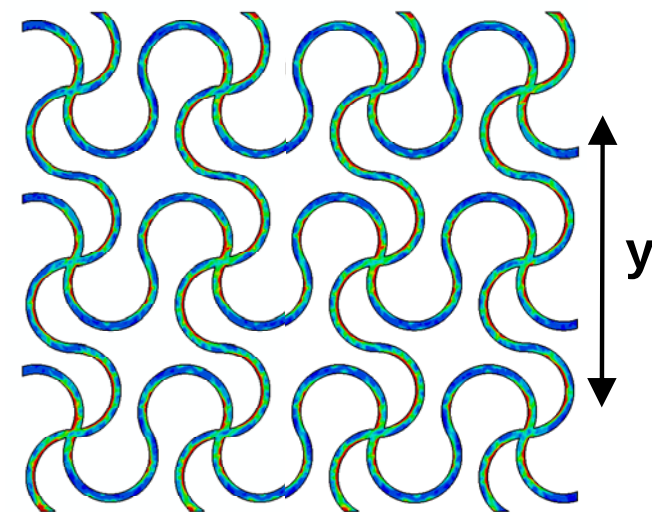
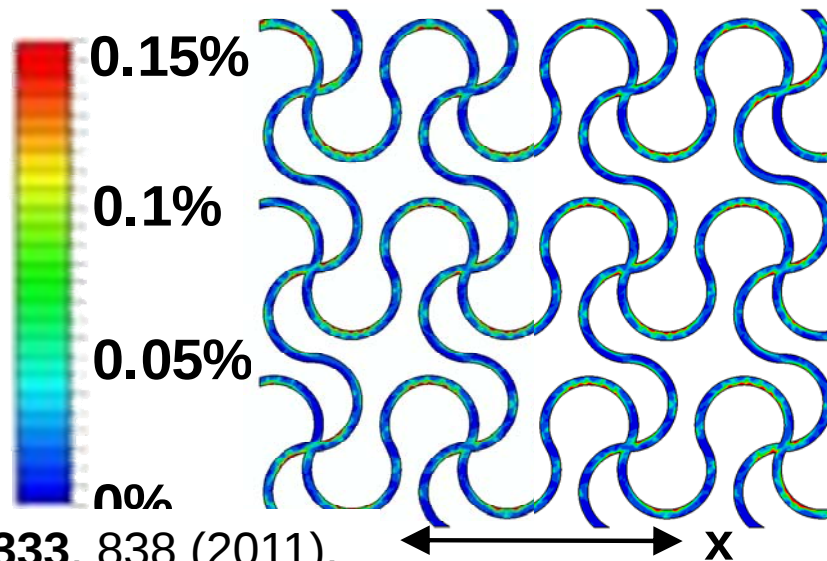
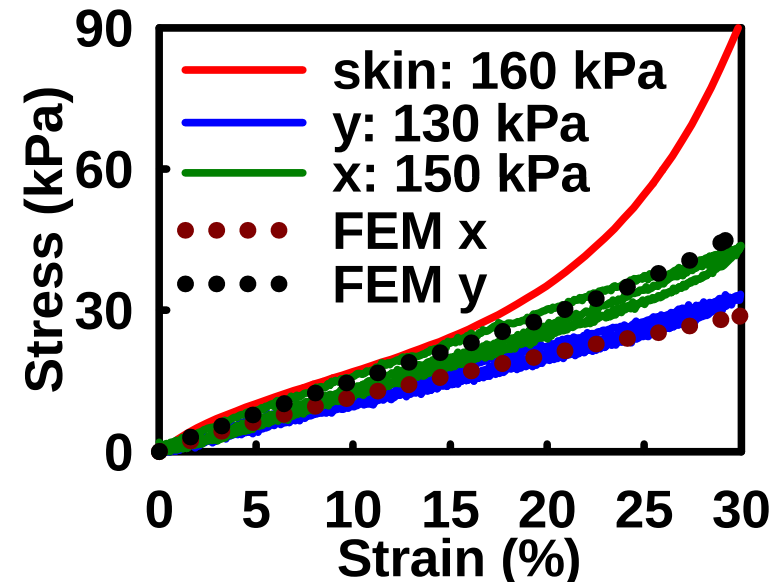
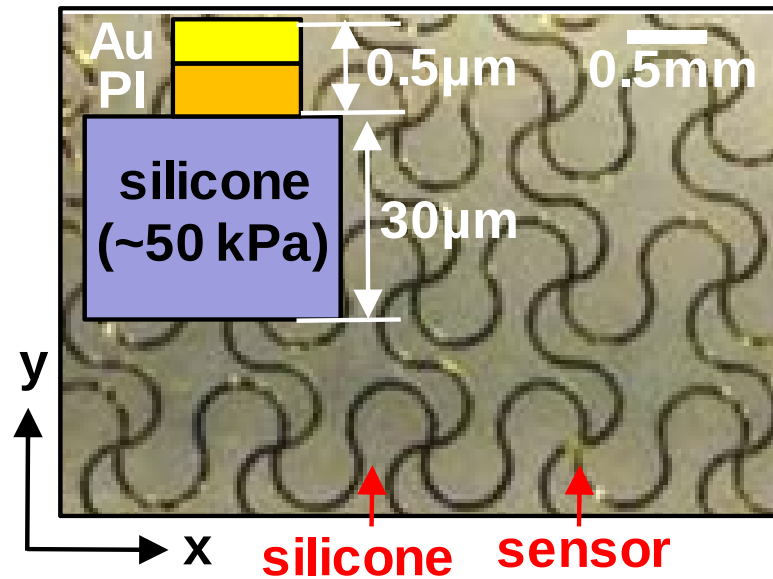
*unpublished*

## Thin, Epicardial Sensing / Harvesting 'Tapes'



*Sci. Transl. Med.*, 2:24ra22 (2010)

# Mechanics in Filamentary Serpentine EES



## Skin-Like Silicon Electronics

### Skin Mounted, Deformed



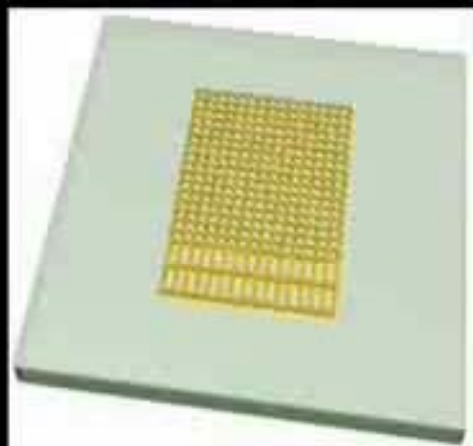
*Science* **333**, 838 (2011).

### Free Standing



— 3 mm

## Dissolving Backing Substrate with Water



transfer to  
ecoflex/PVA

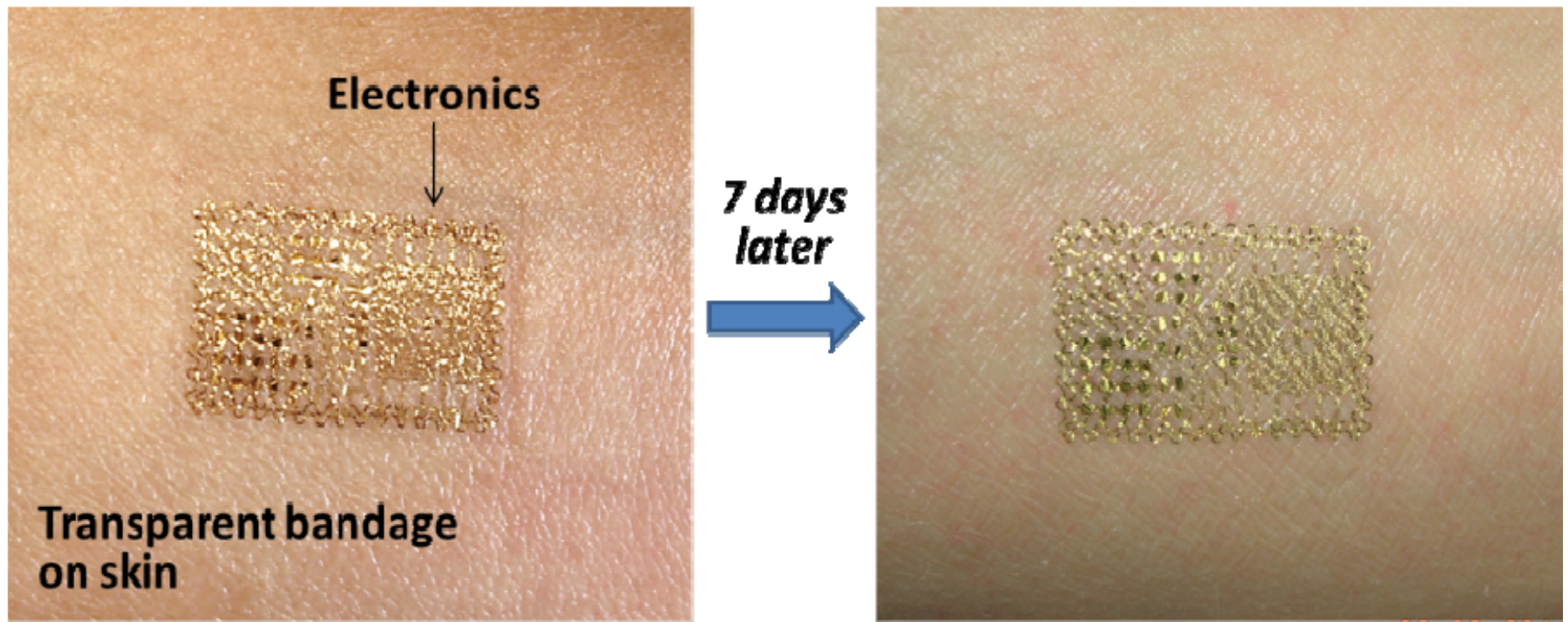


apply to skin



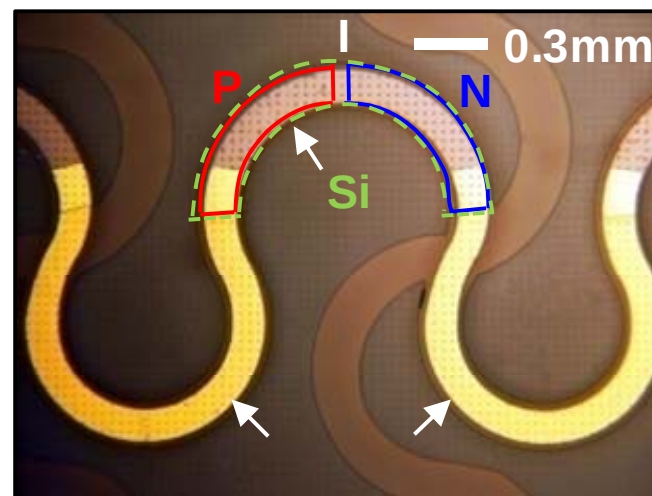
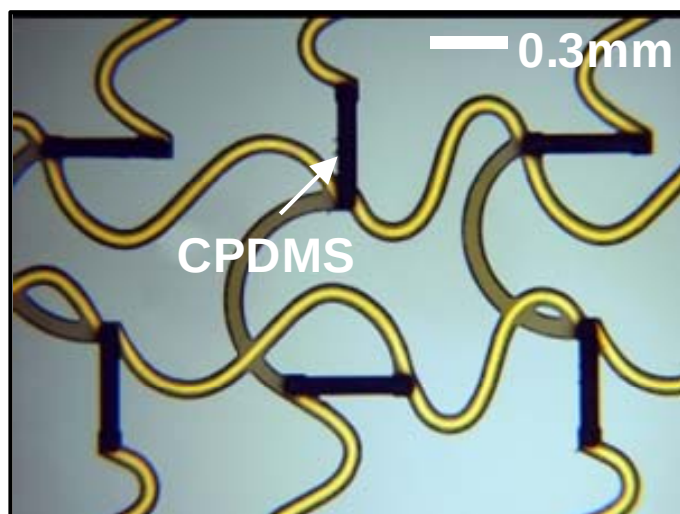
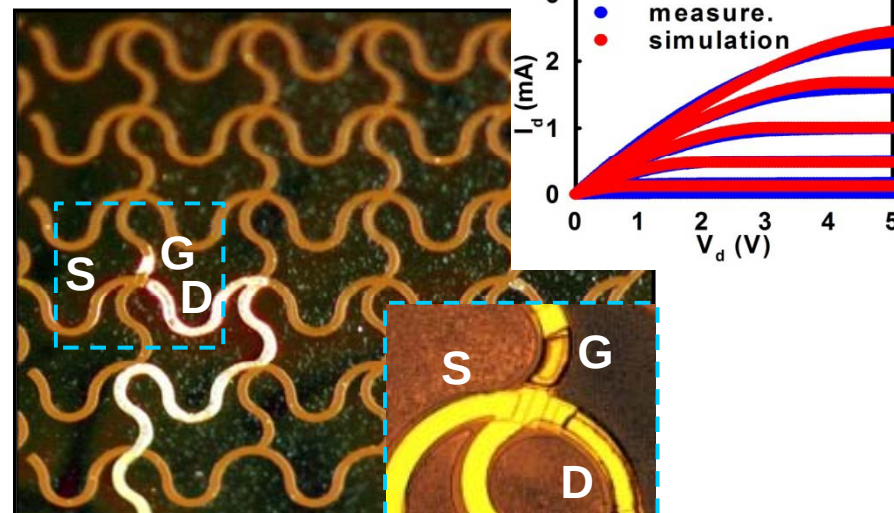
dissolve  
backing PVA

## Wearability of Current FS-EES Devices



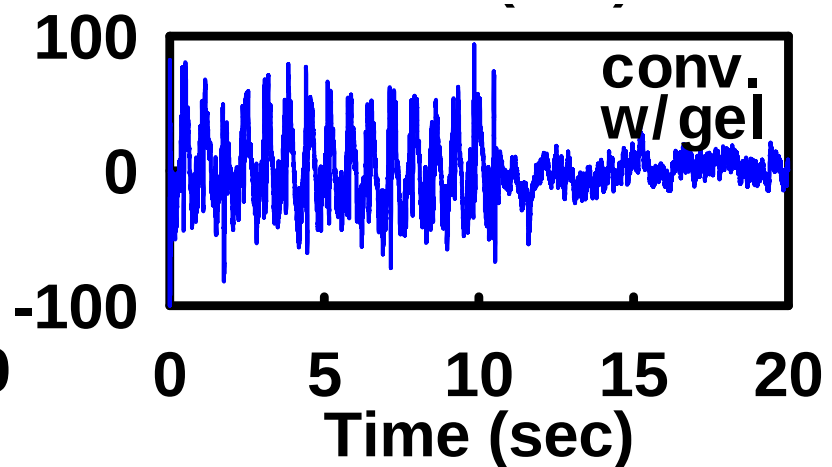
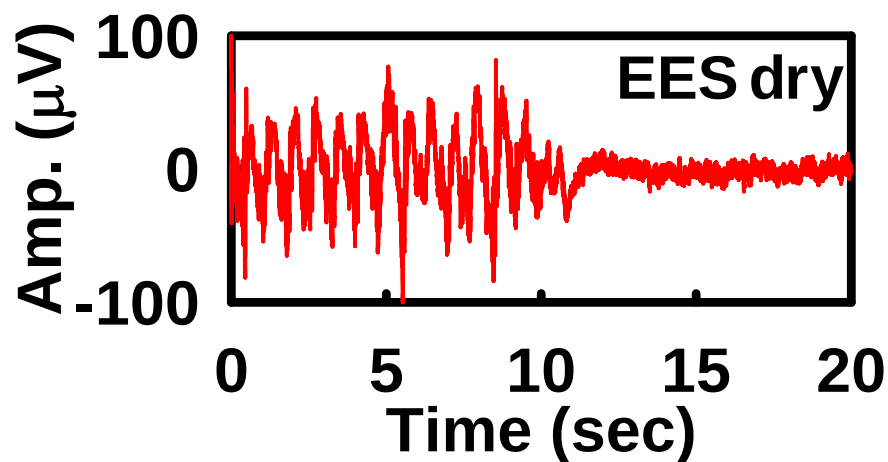
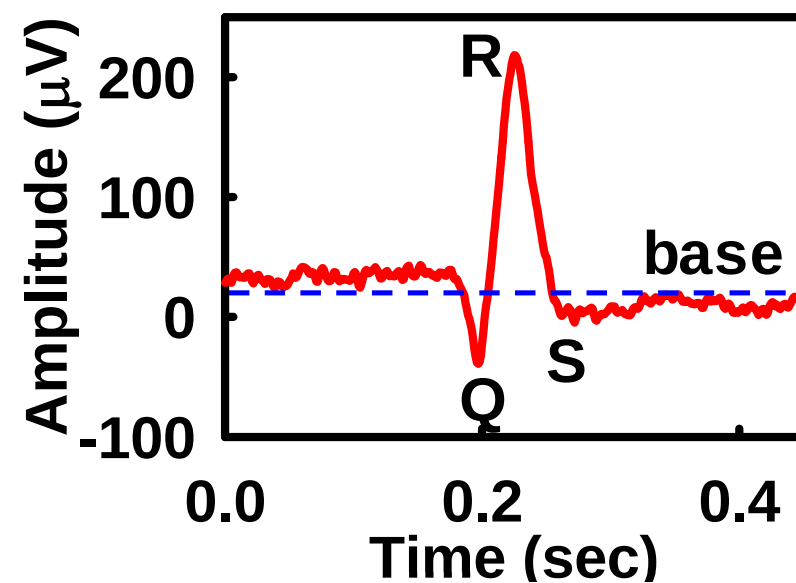
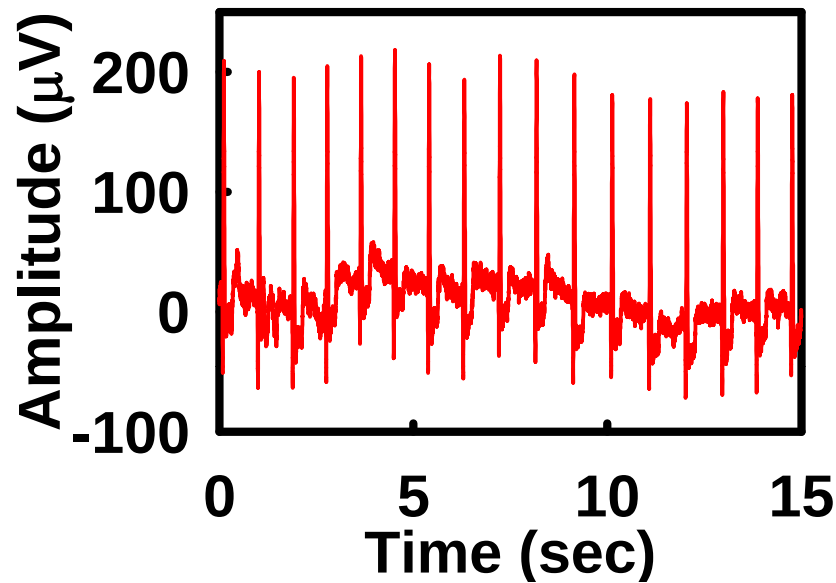
*unpublished*

## 'Epidermal' Electronic Systems – Ex. Devices

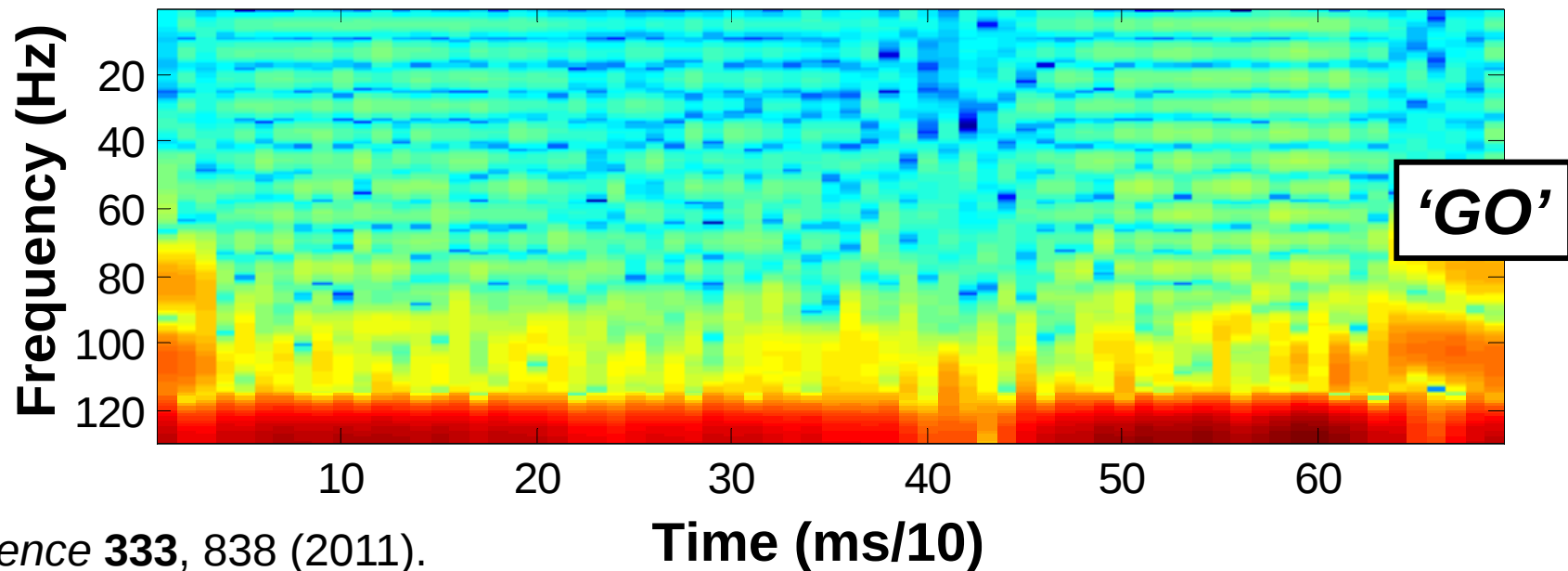
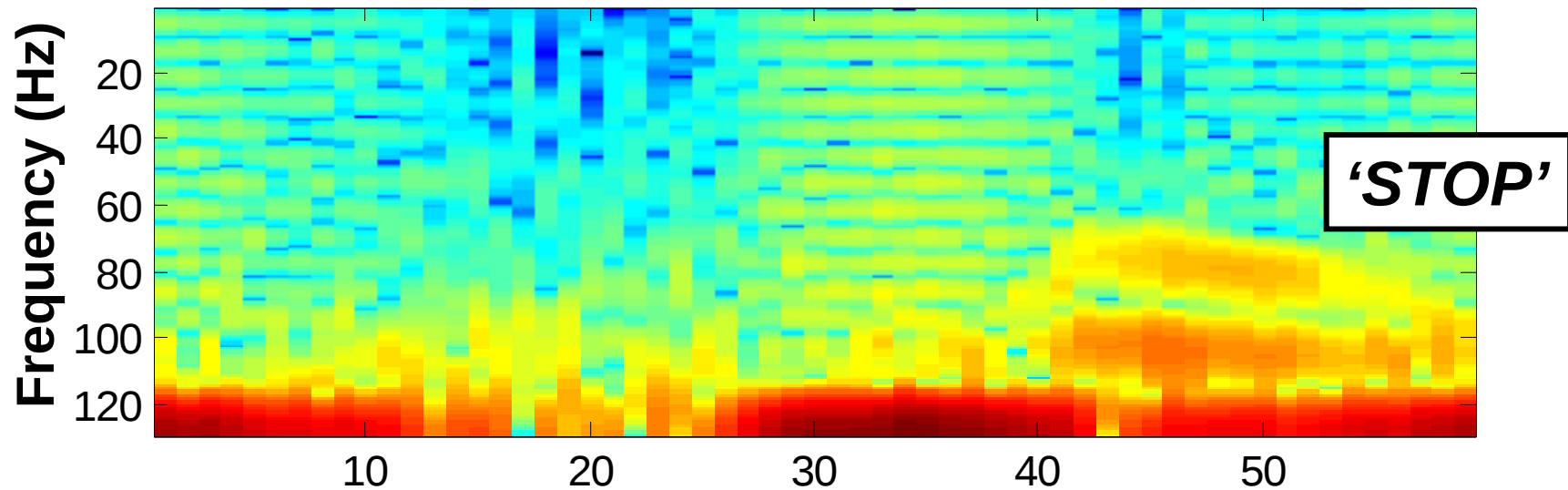


*Science* **333**, 838 (2011).

## Measuring EKG, Forearm EMG via EES (w/ Coleman)



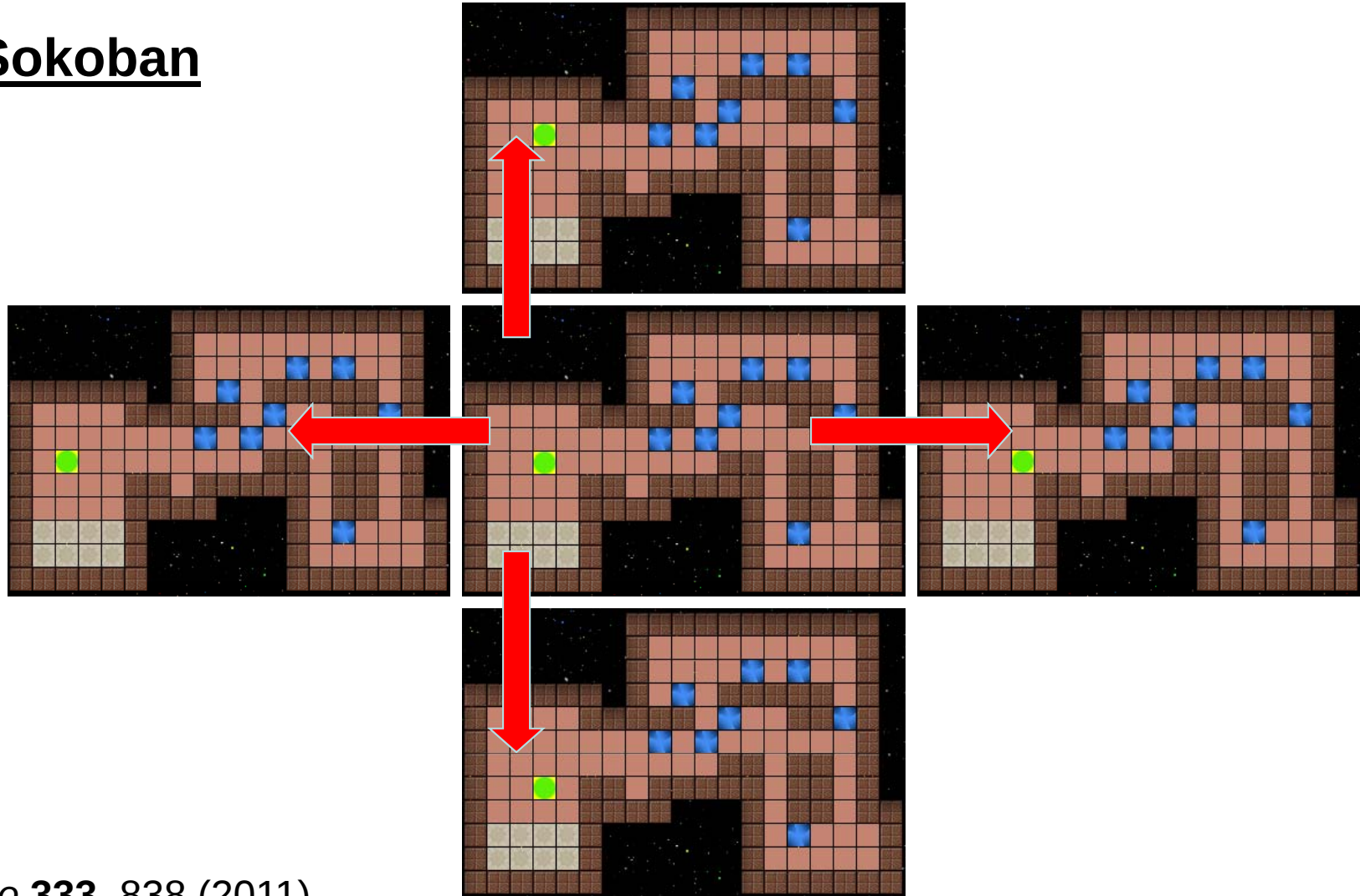
## Measuring Speech via Neck EMG with EES (w/ Coleman)



*Science* **333**, 838 (2011).

# Playing Video Games With An EES Controller (w/ Coleman)

## Sokoban



*Science* **333**, 838 (2011).

## Gestural Control of an RC Helicopter via Epidermal EMG



## Senior Collaborators

---

### Academic

***Prof. Y. Huang (NU) – mechanics***

***Prof. P. Ferreira (UIUC) – manufact.***

***Prof. T. Coleman (UIUC) – EEG, interf.***

***Prof. D.-H. Kim (SNU) – mtl's, chem eng***

### Clinical

***Dr. B. Litt (Penn) – neurology***

***Dr. D. Callans (Penn) – cardiology***

***Dr. M. Slepian (Sarver) – cardiology***

***Dr. J. McDonald (JHU) – rehabilitation***

***Dr. I. Efimov (Wash Univ) -- cardiology***

