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

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

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**Abstract:**

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**Limitation of Abstract:** Same as Report (SAR)

**Number of Pages:** 22
Structural Health Monitors for Aerospace

*The Living Airframe – B. Baron/AFRL*
Intelligent, Wireless Medical Sensors

\( \mu \)sensors: chemical, optical, thermal

\( \mu \)fluidic channels

embedded integrated circuits

RF transmit/receive

Smart Surgical Glove
Mechanics of Silicon NanoMembranes

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

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


‘printed’ cantilever 

\(200 \text{ nm} \)

\(15 \mu \text{m}\)
GaAs Membranes Printed Onto Plastic (1600; 100% yield)

Science 325, 977 (2009)
Single Crystal Silicon TFTs and Circuits on Plastic

$\mu \sim 400 \text{ cm}^2/\text{V} \cdot \text{s}$

on/off $\sim 10^5$

$V_{DS} = 2.0 \text{ V}$

$V_{GS} = 1.8 \text{ V}$

$\mu = 40 \mu \text{m}$

$0.0 \mu \text{m} \quad 100 \mu \text{m} \quad 200 \mu \text{m} \quad 300 \mu \text{m} \quad 400 \mu \text{m}$

$V_D$

$\text{freq, Hz}$

$1 \times 10^7 \quad 1 \times 10^8 \quad 5 \times 10^8$

$347 \text{ MHz}$

$\sim 350 \text{ MHz}$

$3 \mu \text{m} \text{ Channel} + 2 \mu \text{m Overlap}$

Flexible, Multiplexed Silicon Strain Gauges

Flexible Silicon Strain Gauges – Performance

\[ \frac{\Delta R}{R_0} (\%) \]

\[ \varepsilon_{\text{app}} (\%) \]

GF = 45

Strain Mapping with Flexible Silicon Strain Gauges
Energy Harvesting with Flexible PZT Elements

unpublished
Thin, Epicardial Sensing / Harvesting ‘Tapes’

Mechanics in Filamentary Serpentine EES

Skin-Like Silicon Electronics

Skin Mounted, Deformed

Free Standing

Dissolving Backing Substrate with Water

1. transfer to ecoflex/PVA
2. apply to skin
3. dissolve backing PVA

Wearability of Current FS-EES Devices

Transparent bandage on skin

Electronics

7 days later

unpublished
‘Epidermal’ Electronic Systems – Ex. Devices

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

[Graphs showing EKG and EMG data with comparison between EES dry and with gel]

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

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

Sokoban

Gestural Control of an RC Helicopter via Epidermal EMG

Take off
Senior Collaborators

**Academic**

Prof. Y. Huang (NU) – mechanics
Prof. P. Ferreira (UIUC) – manufact.
Prof. T. Coleman (UIUC) – EEG, interf.
Prof. D.-H. Kim (SNU) – mtls, 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