five things you should know about

PowerFelt

Why would you want to know anything about PowerFelt?

This is important because our lifestyles are changing – mobile, free, individual, but connected…

SO, what are the five things ***you*** should know about PowerFelt?

1

the **human body** gives off 130 watts of heat energy.

the accumulated heat generated by **a platoon of soldiers** in the field is ~ 6.5 kilowatts, whereas, the power carried by that platoon in the form of batteries is ~ 1.5 kilowatts.

a **semi truck**; 99.2 megawatts,

a **144 mm gun** barrel; 4 watts,

an **F15 engine** cowling; 350 gigawatts.

the act of **simply walking** typically generates 10 to 12 Watts of kinetic power

The waste heat/vibration all around us is staggering, it is mobile, it is personal, and it is free.

Big is good? Consider Mr. Small and Mr. Smart
They both want to be green…

Mr. Small has chosen a high performance TEG made from BiTe

Mr. Smart has chosen a covering for the whole car

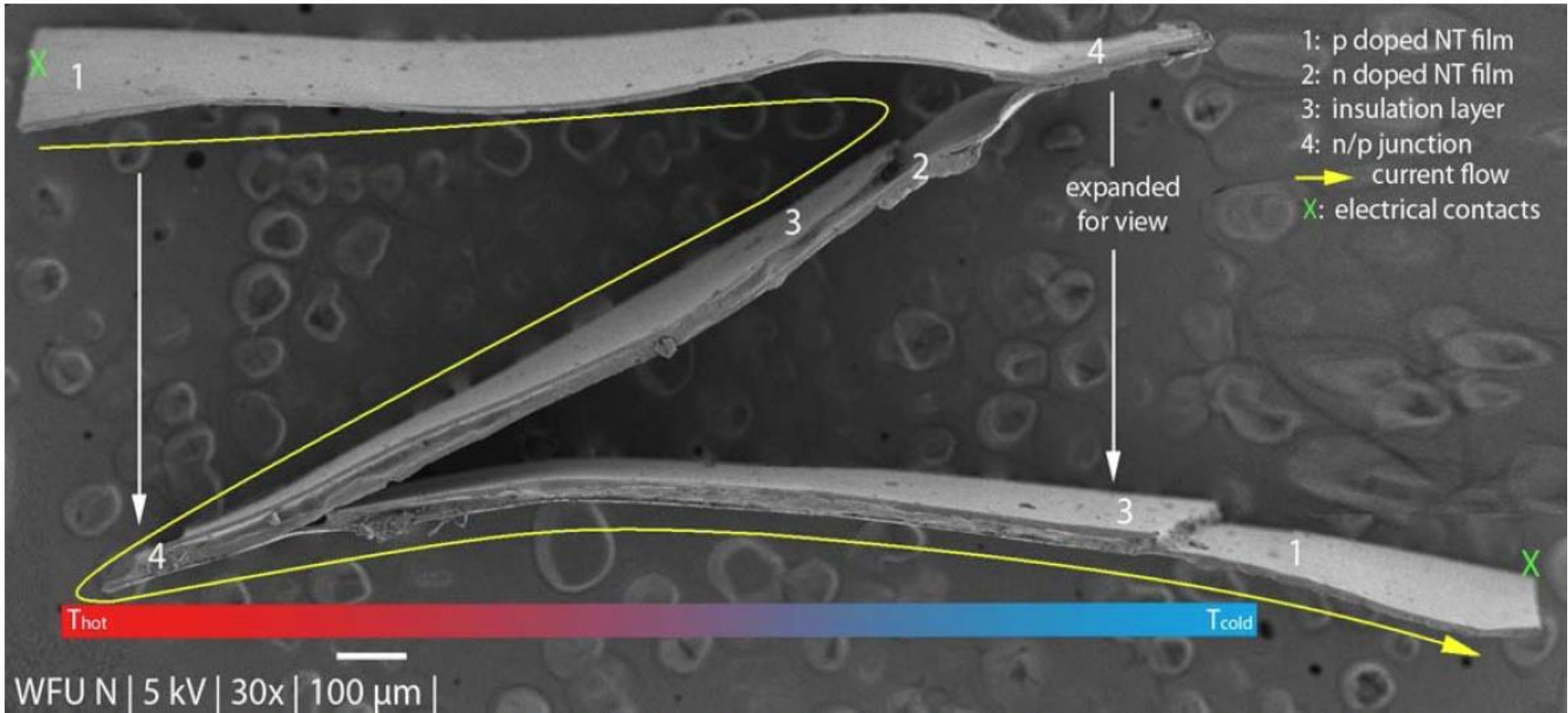
The BiTe is 10X more efficient but it covers 1000X less area. Mr. Smart gets 100x more power…

2

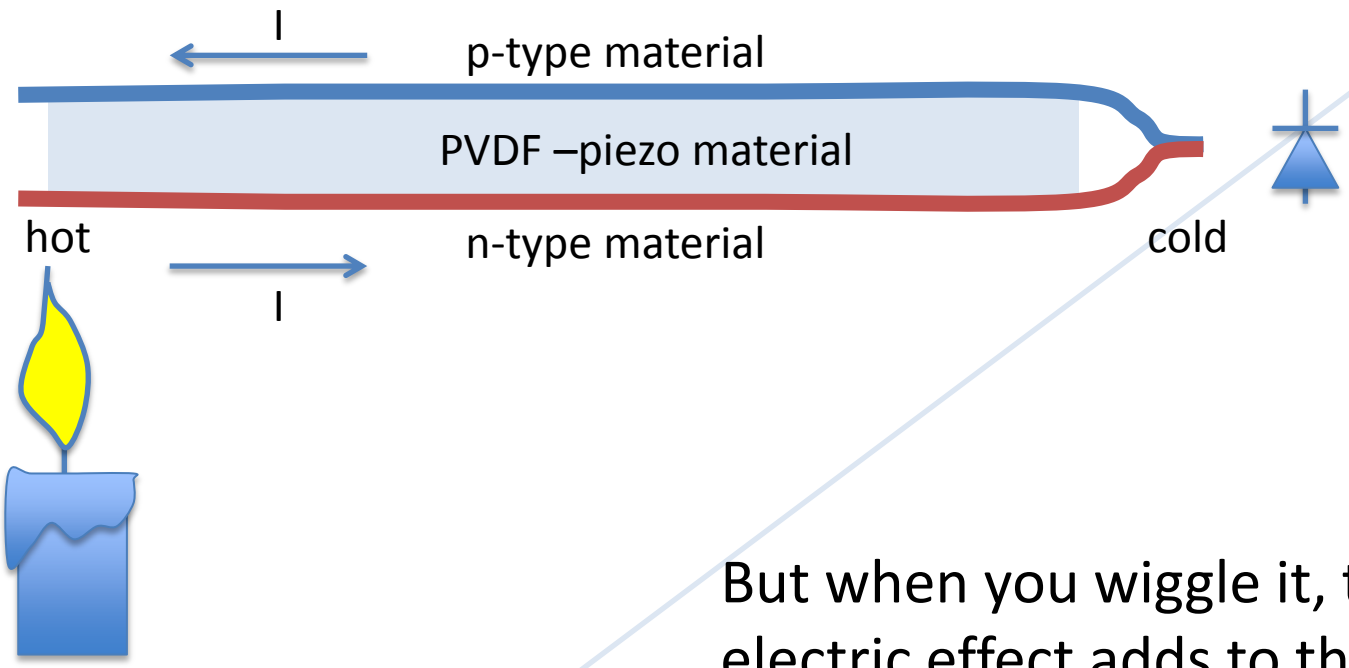
PowerFelt is the world's first thermo-piezo-electric generator (T-PEG): it makes power from thermal sources as well as kinetic sources…

The basic building blocks (the threads) of PowerFelt combine two energy scavenging modalities…

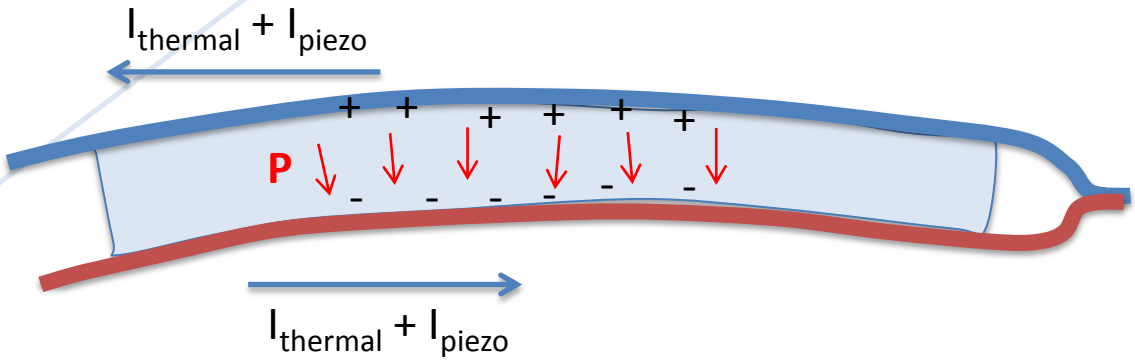
Hewitt *et al.*, *Applied Physics Letters*, **2011**, 98, 183110.



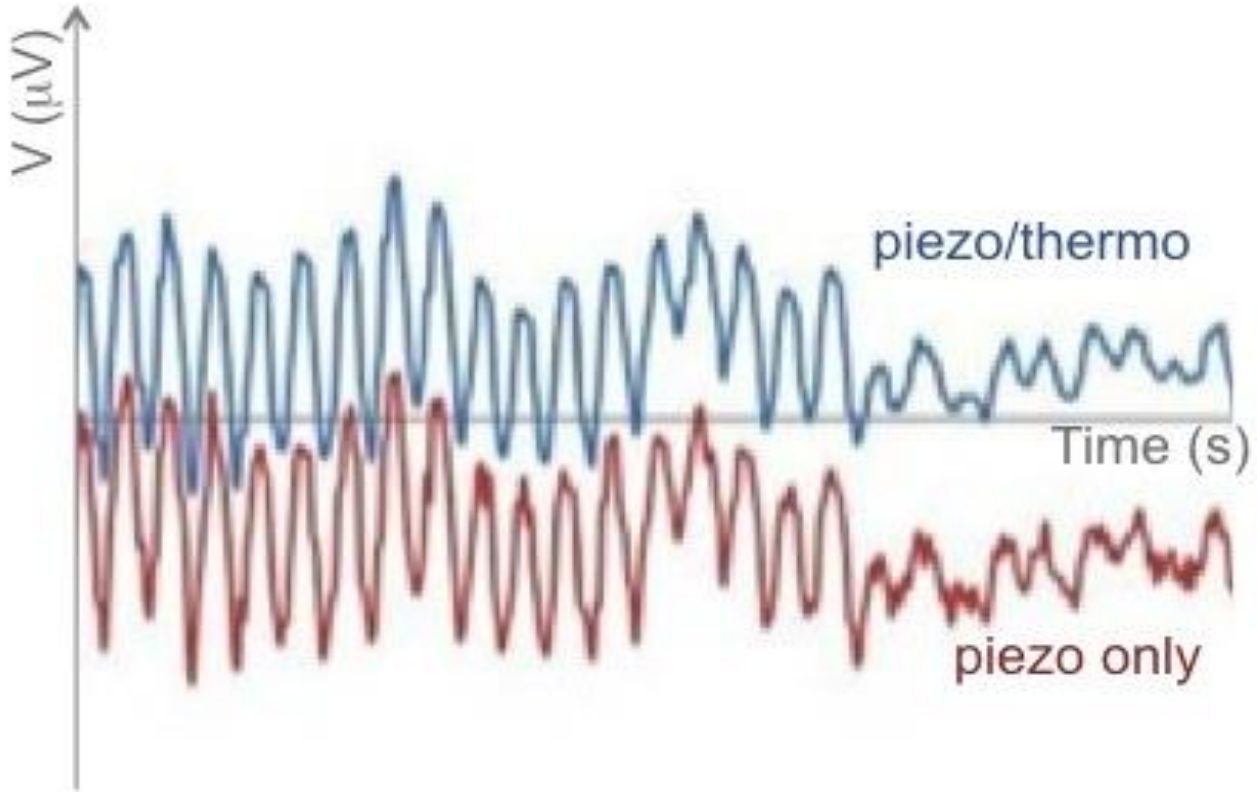
Thermopower collection is based on the Seebeck effect…



But when you wiggle it, the piezo-electric effect adds to the power…

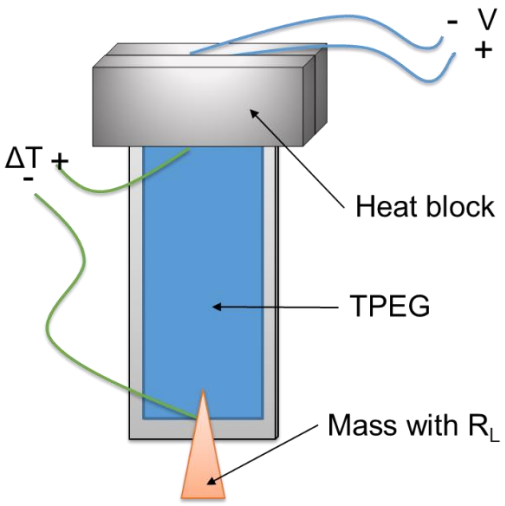


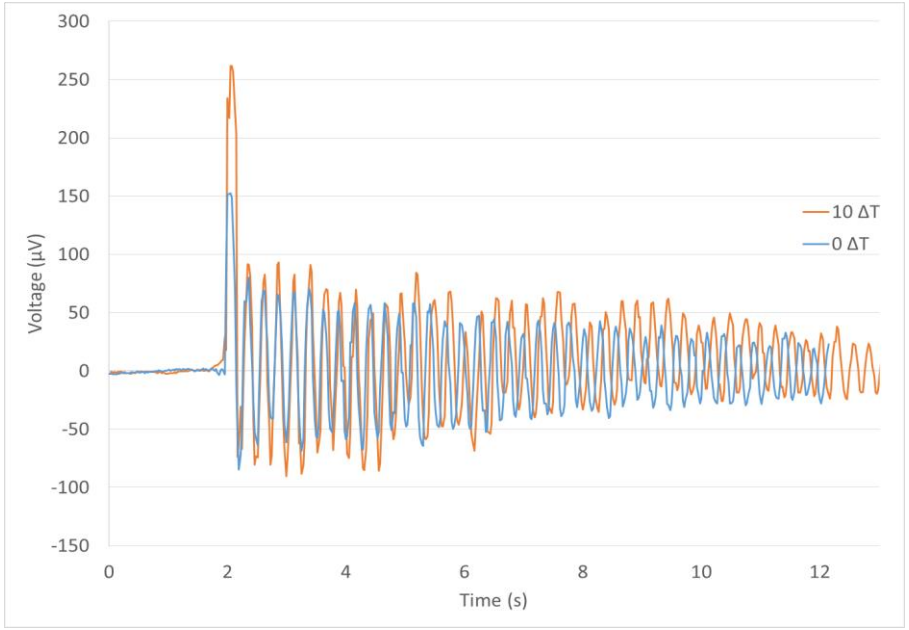
The result is thermal and kinetic energy scavenging…

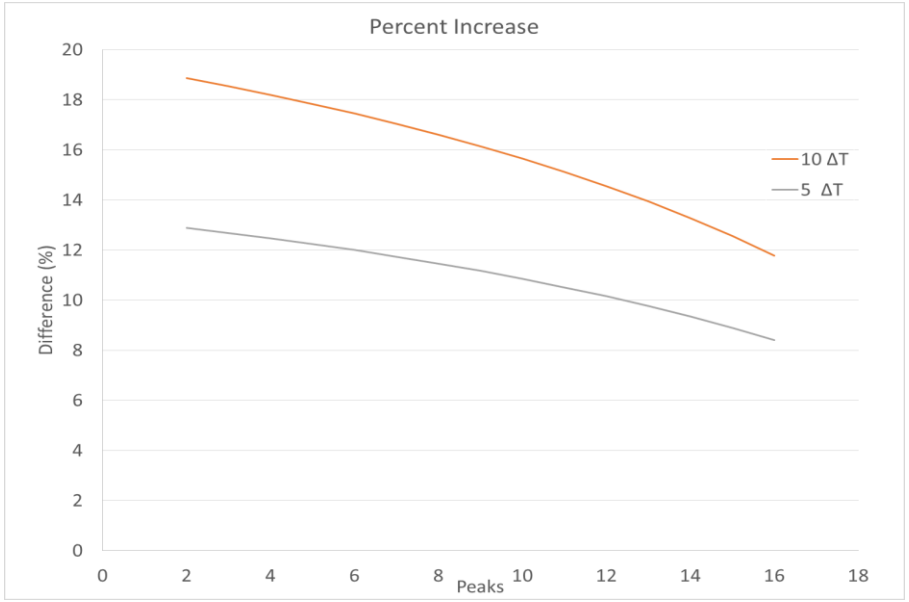


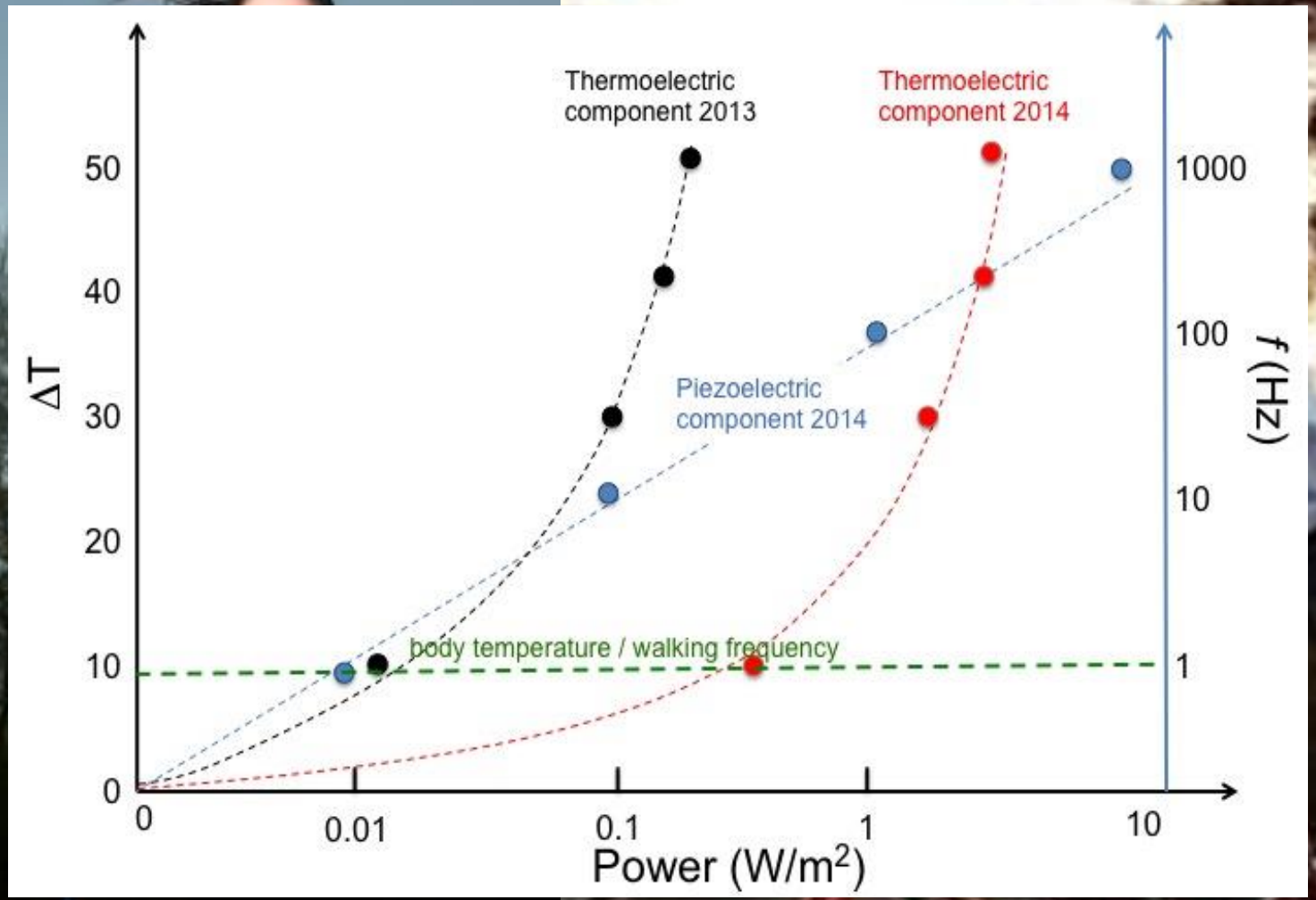
TPEG Model

$$V_{total} = \underbrace{(d + \alpha_{piezo}\Delta T)\sigma}_{\text{Kinetic}} + \underbrace{\alpha_{thermo}\Delta T}_{\text{Static}}$$





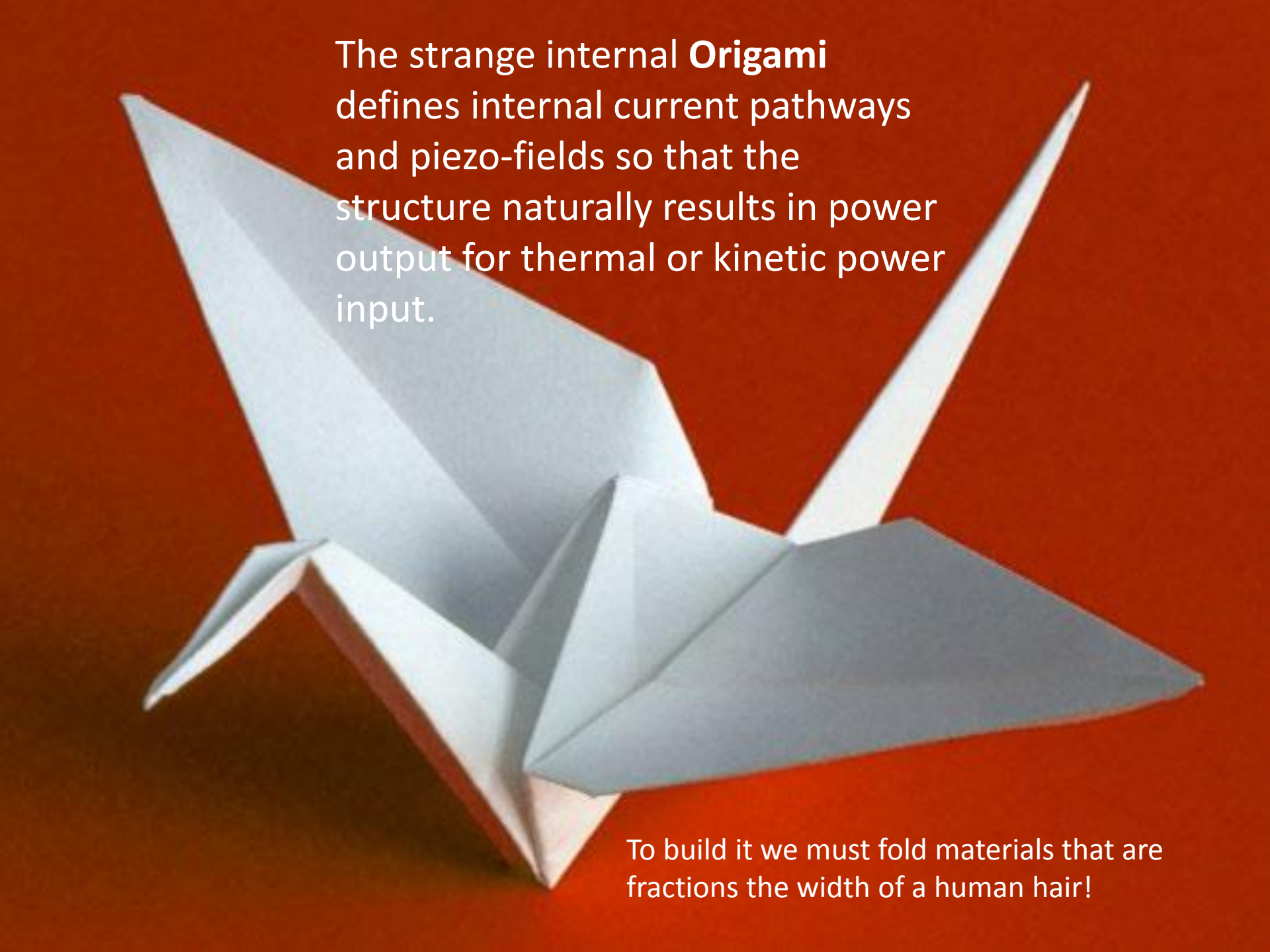



Thermoelectric component 2013
Thermoelectric component 2014
Piezoelectric component 2014
body temperature / walking frequency
ΔT
f (HZ)
Power (W/m²)
0
10
20
30
40
50
1
10
100
1000
0.01
0.1
1
10

3

PowerFelt is a nanoengineered textile – not a device! It uses a quantum functional matrix and its power comes as an intrinsic part of its makeup…

Hewitt *et al.*, *Applied Physics Letters*, **2011**, 98, 183110.

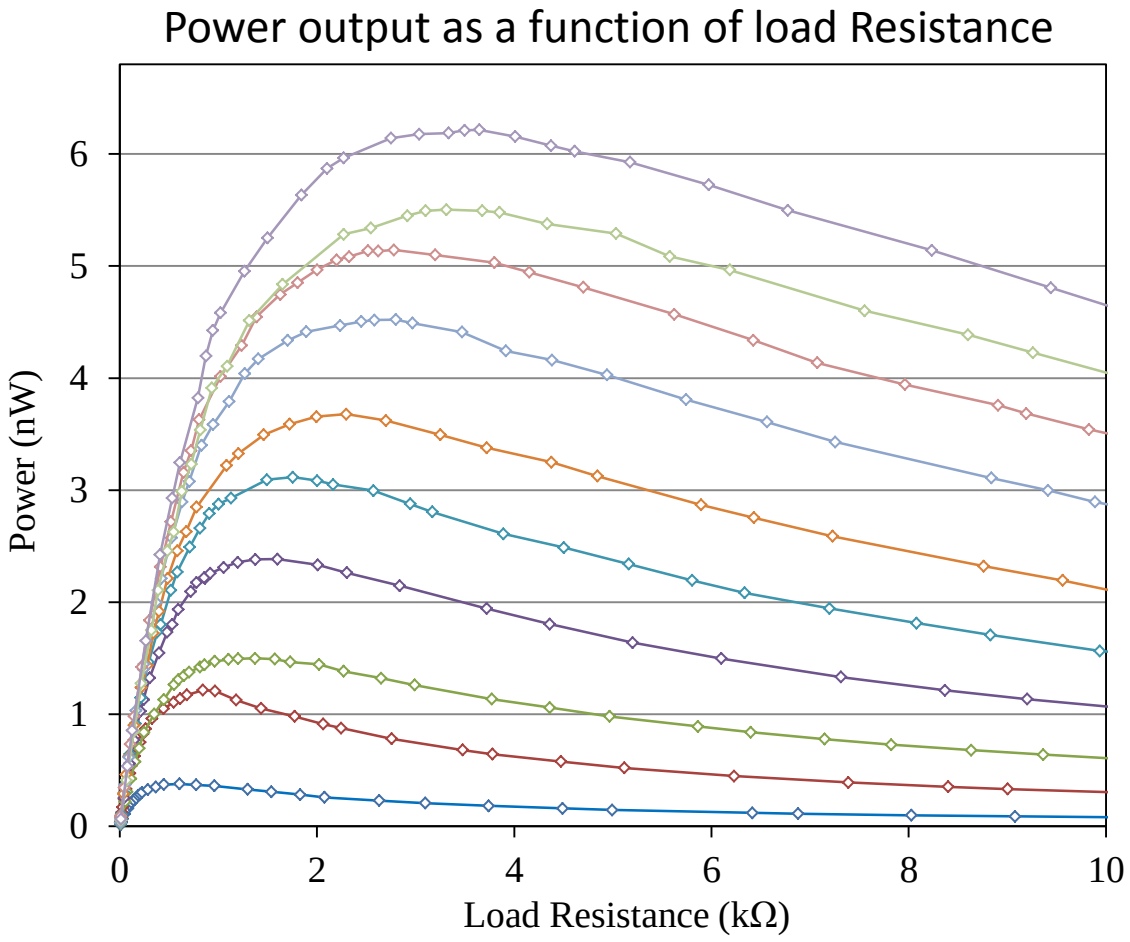

The strange internal **Origami** defines internal current pathways and piezo-fields so that the structure naturally results in power output for thermal or kinetic power input.
To build it we must fold materials that are fractions the width of a human hair!

4

PowerFelt can not make more power than is there…

(but there is a whole lot there)

YES, for each layer you fold-in you get a little more power…




But to really make power – you must make PowerFelt large…
WAKE FOREST
WF
WAKE FOREST
UNIVERSITY
Department of Physics

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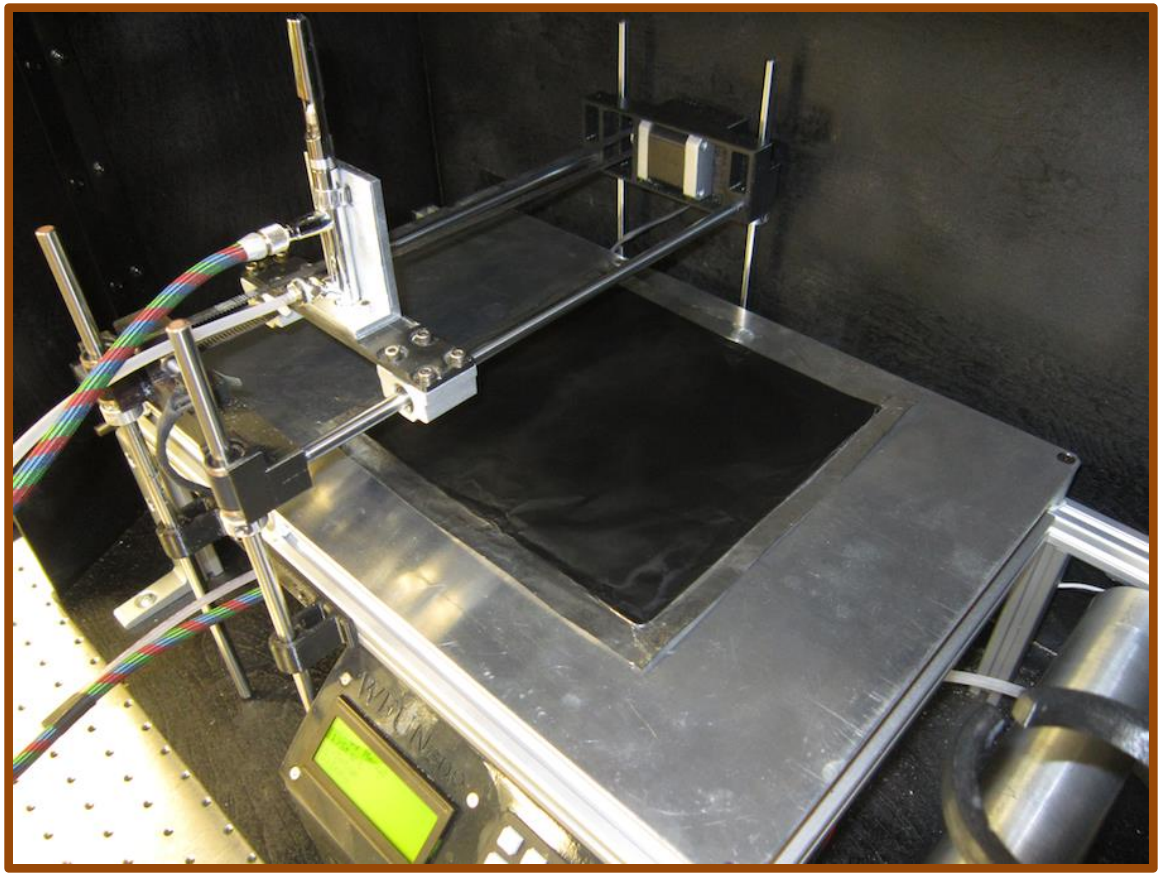
	Activity	Power generated (est)	Comments
Max Power f > 20 Hz Stroke > 1mm ΔT > 20K	Hi energy activity - Hiking with fabric close to body in cold weather	~ 2W/m^2	Would power a cell phone and most mobile electronics with moderate use. It could also power safety lighting or location beacons.
Medium Power f > 5 Hz Stroke > 1mm ΔT > 10K	On a backpack walking in an airport	~ 0.5W/m^2	Would extend a cell phone battery by 50% or run most mobile sensors like a fitbit. Could recharge a cell phone in several hours.
Low Power f = 0 Stroke = 0 ΔT > 8K	On a backpack stationary	~ 100mW/m^2 (worn on the back) ~1mW/m^2 (against a low heat source)	Against a low-heat source it would still run fitbit, Nike, and other fitness sensors. Worn on the back it will extend battery life of a cell phone by 10%.

5

The process for making PowerFelt is very much like paper making (Fourdrinier). This gives it an amazing ROI…

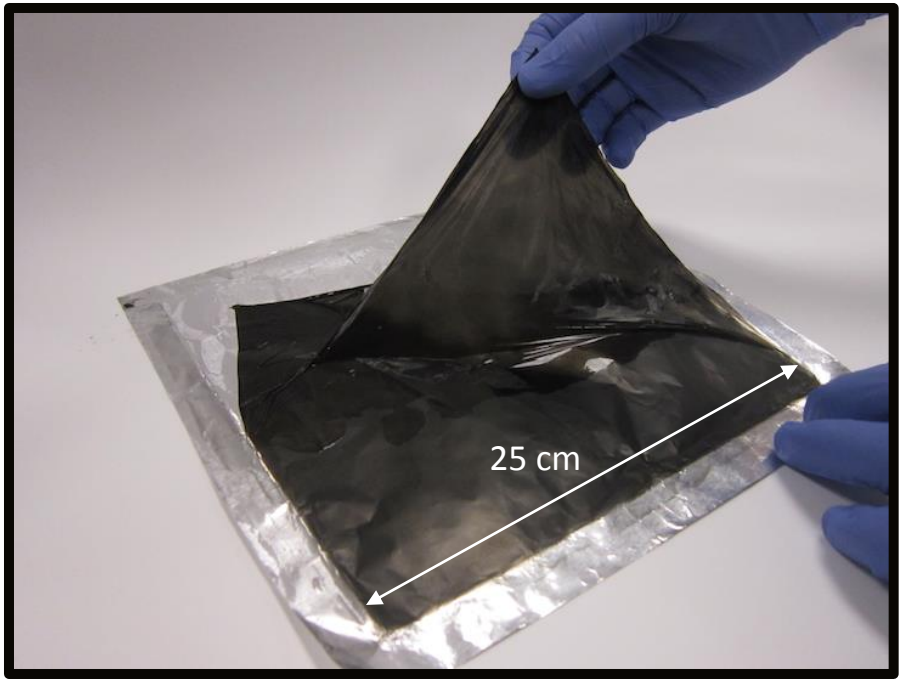
Automated Spray Cast

- Scalable Automated Carbon Nanotube
- Spray Cast System



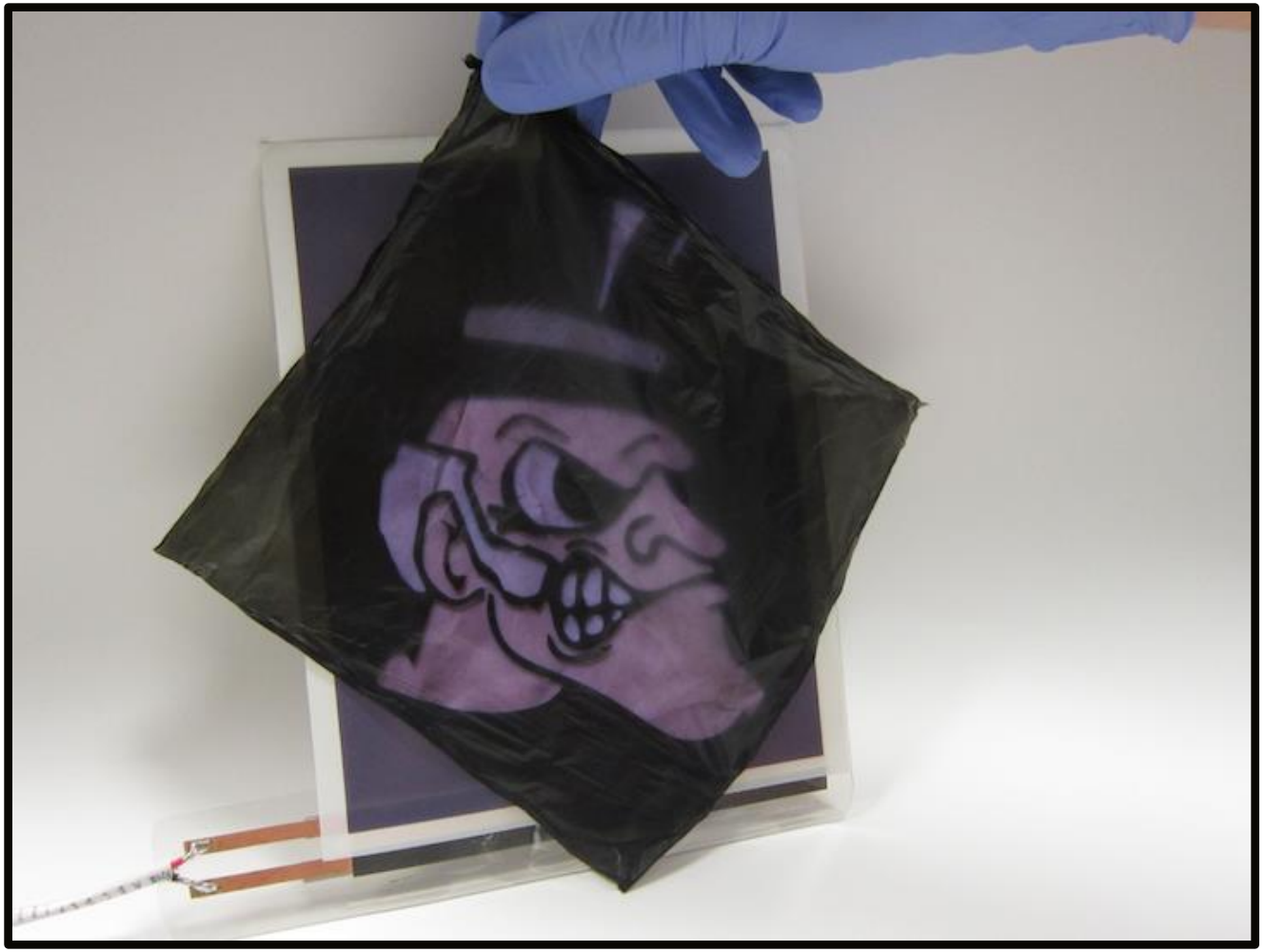
Automated Spray Cast

- Variable
  - The spray cast film can be any
  - desired length within a 28cm width.
  - It is capable of spraying films from
  - 15 microns to 1 micron thick.
  - The 1 micron thick films are
  - very consistent and relatively
  - durable. Films thinner than 1
  - micron have successfully been
  - sprayed but are currently being
  - tested.

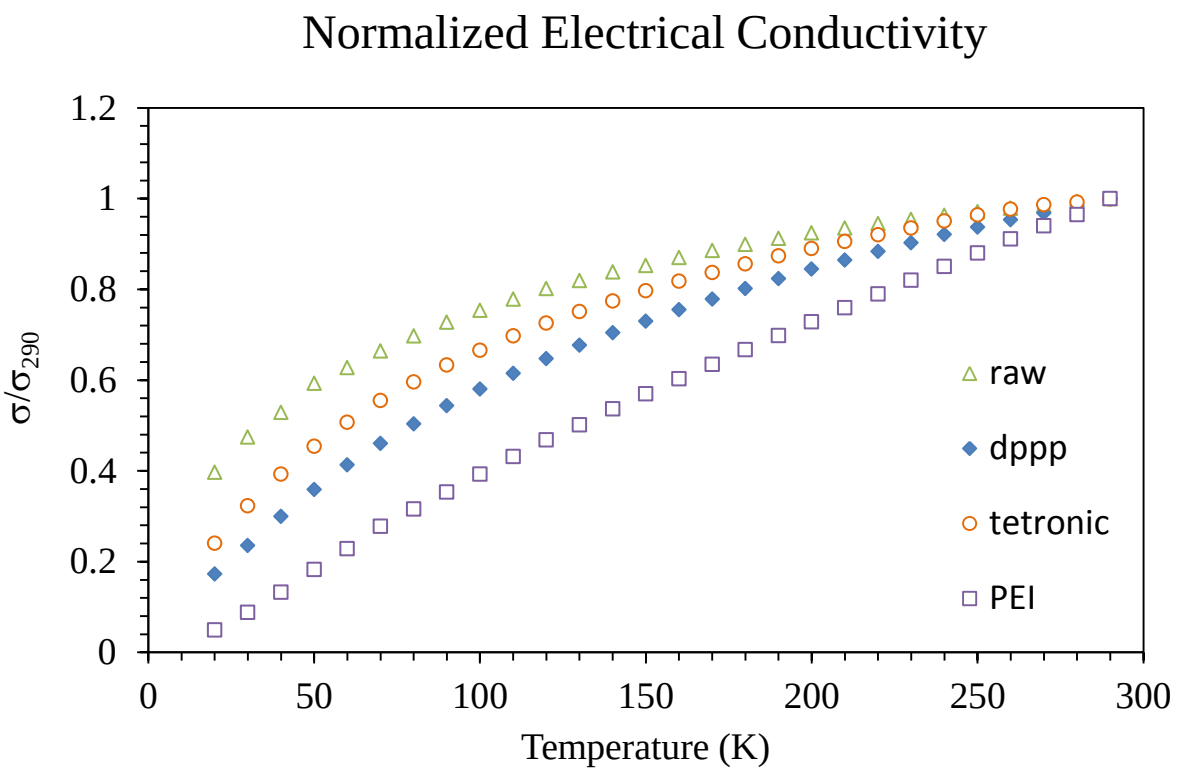


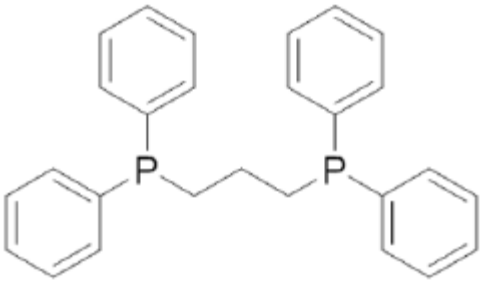
–The film pictured has a thickness of about 1.2 microns. The electrical conductivity still remains constant at 1590 S/m with a Seebeck coefficient of 37 µV/K. The conductivity and Seebeck coefficient remain constant even with films measured to be 0.6 microns.

Automated Spray Cast

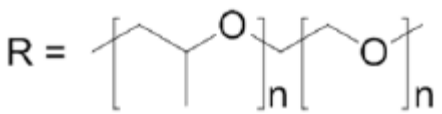


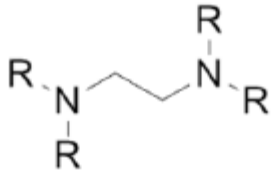
T Dependent Doping



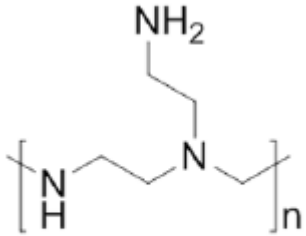


dppp





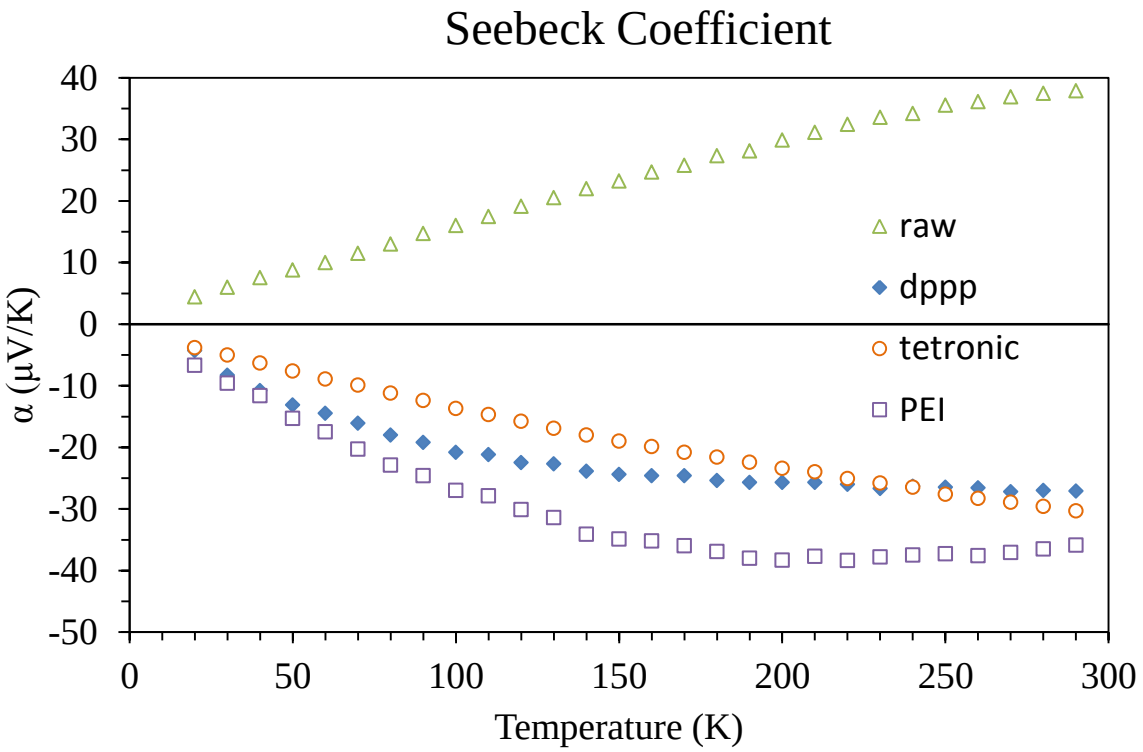
Tetronic 1107



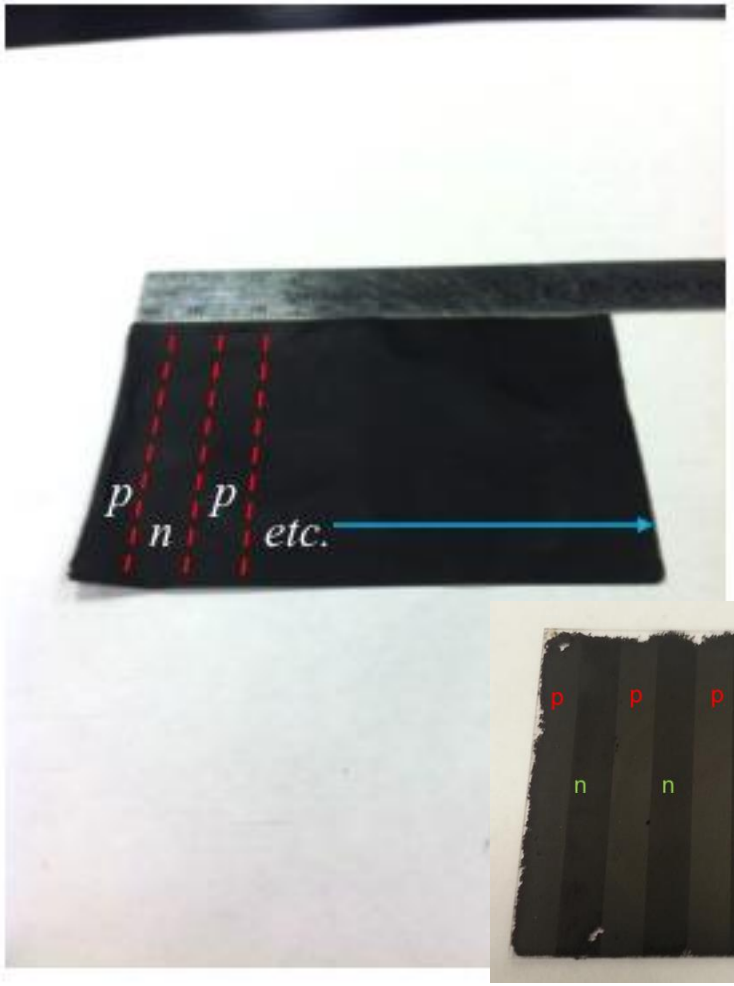
PEI

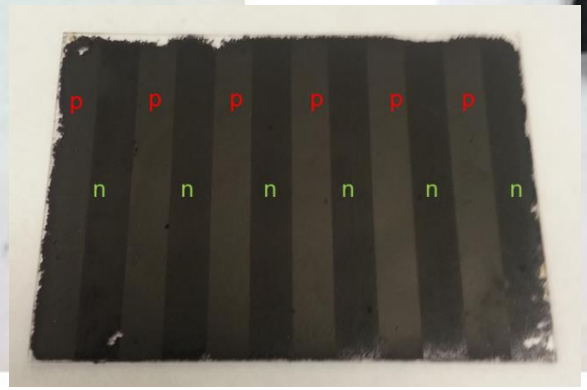
- Variable Range Hopping T dependent behavior
- RT values ranging from 6k to 18k S/m

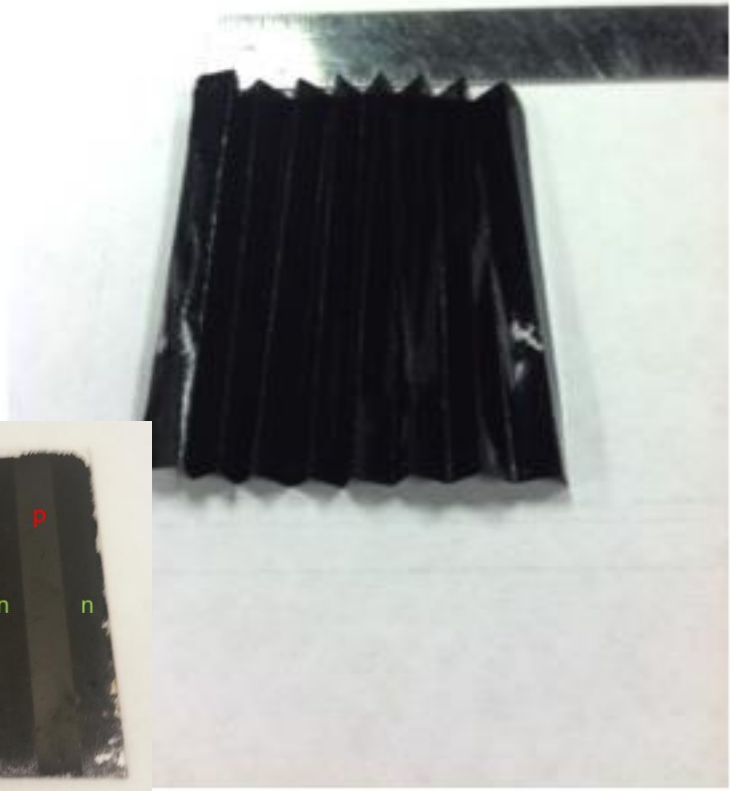
T Dependent Doping



- Range of T dependent behavior from heterogeneous (PEI) to near metallic (tetronic)



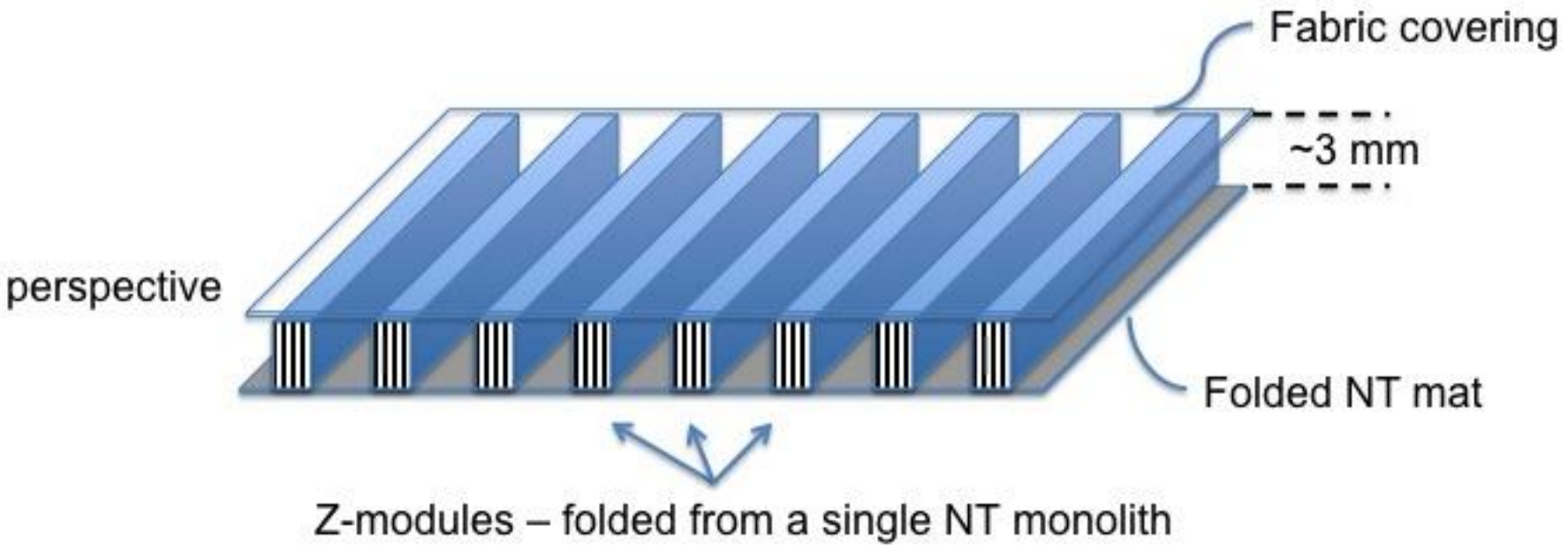


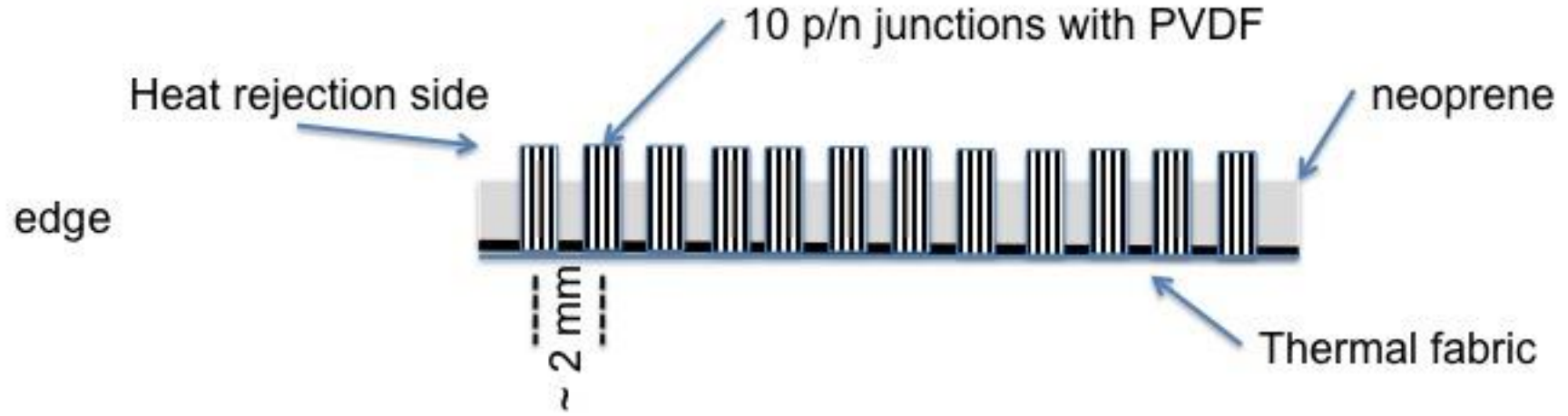


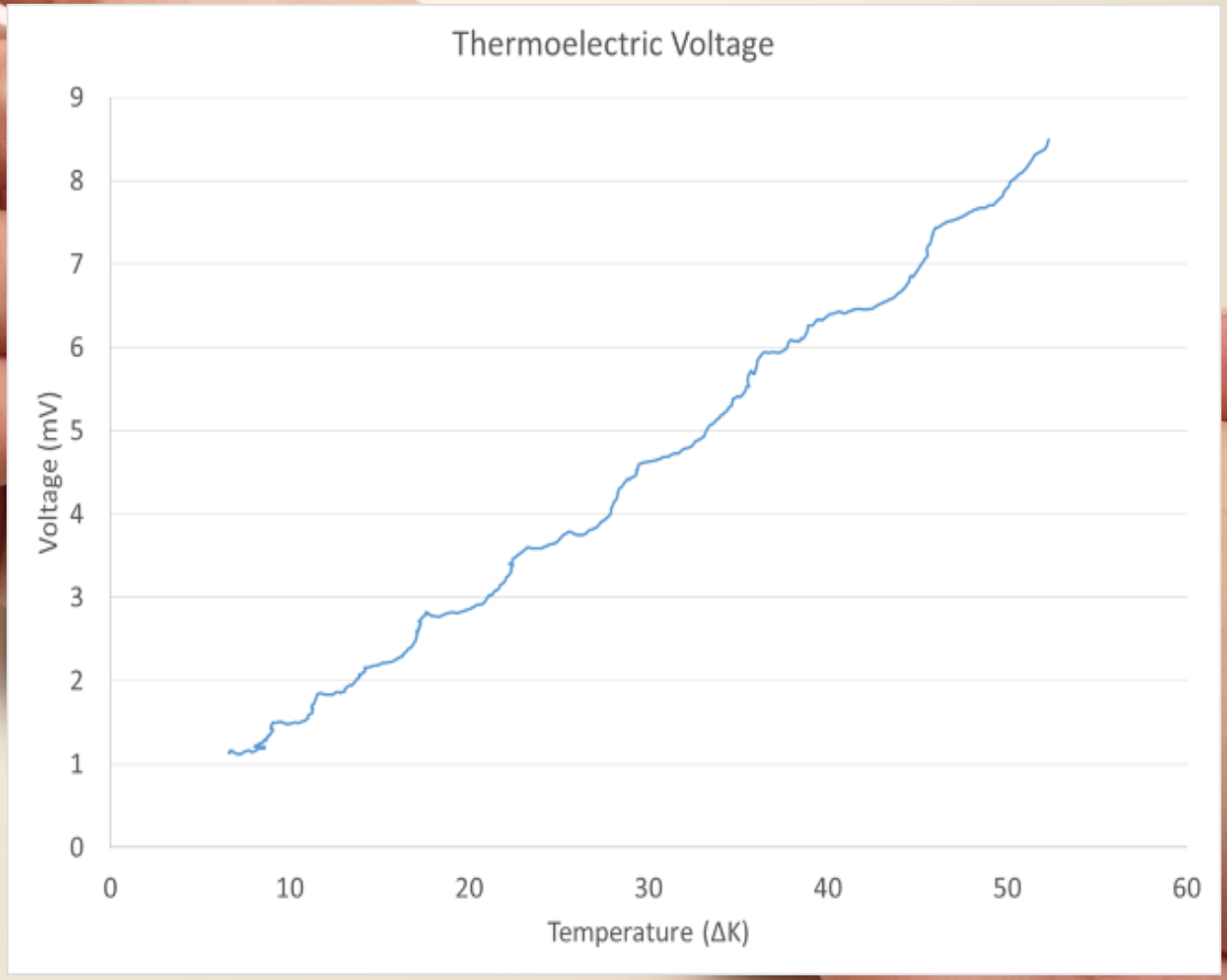
alternating dropcast p-n layers

folded along p-n junctions

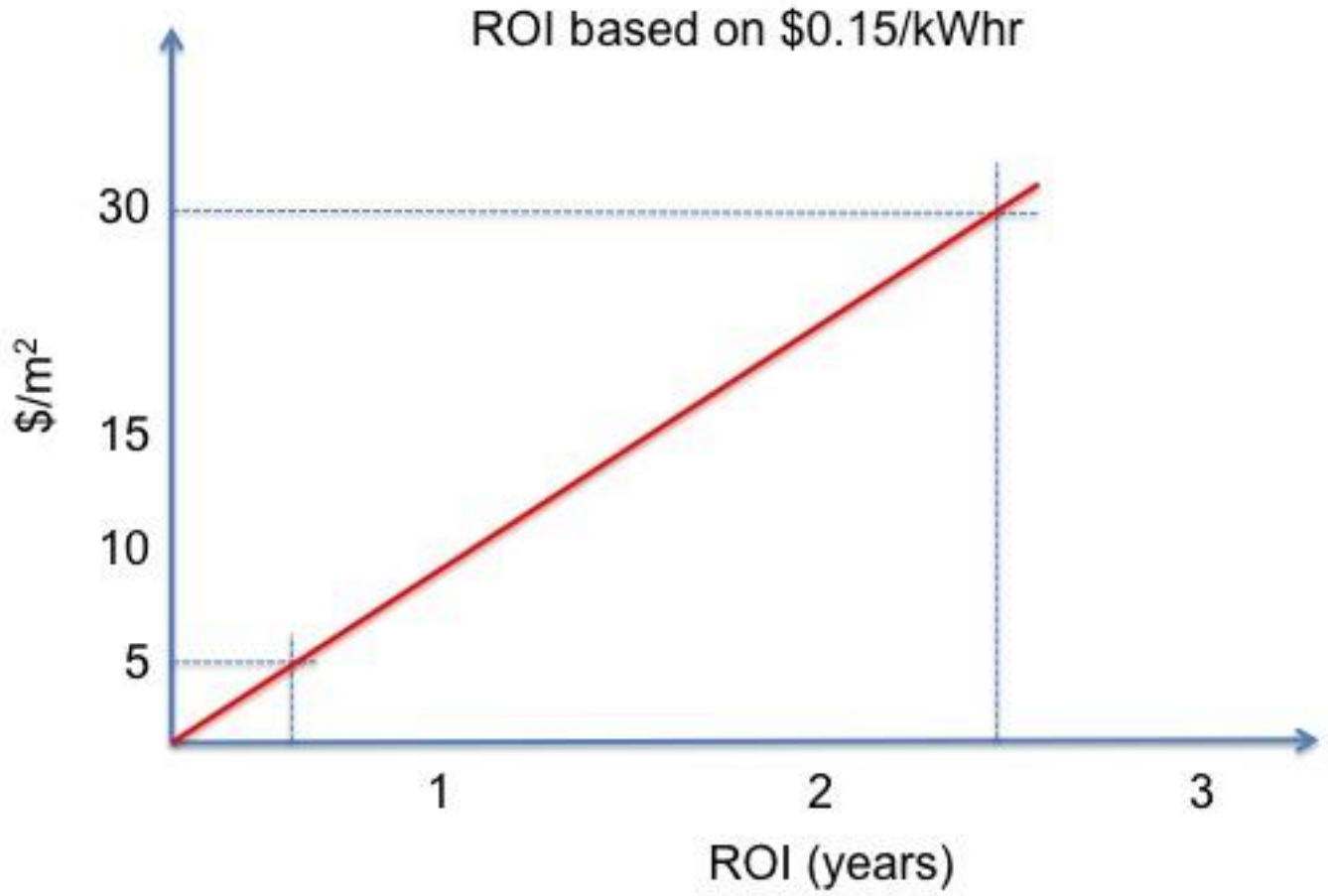
PowerMat


Fabric covering
~3 mm
perspective
Folded NT mat
Z-modules – folded from a single NT monolith


10 p/n junctions with PVDF
Heat rejection side
neoprene
edge
~ 2 mm
Thermal fabric


Thermoelectric Voltage
Voltage (mV)
0
1
2
3
4
5
6
7
8
9
0
10
20
30
40
50
60
Temperature (ΔK)

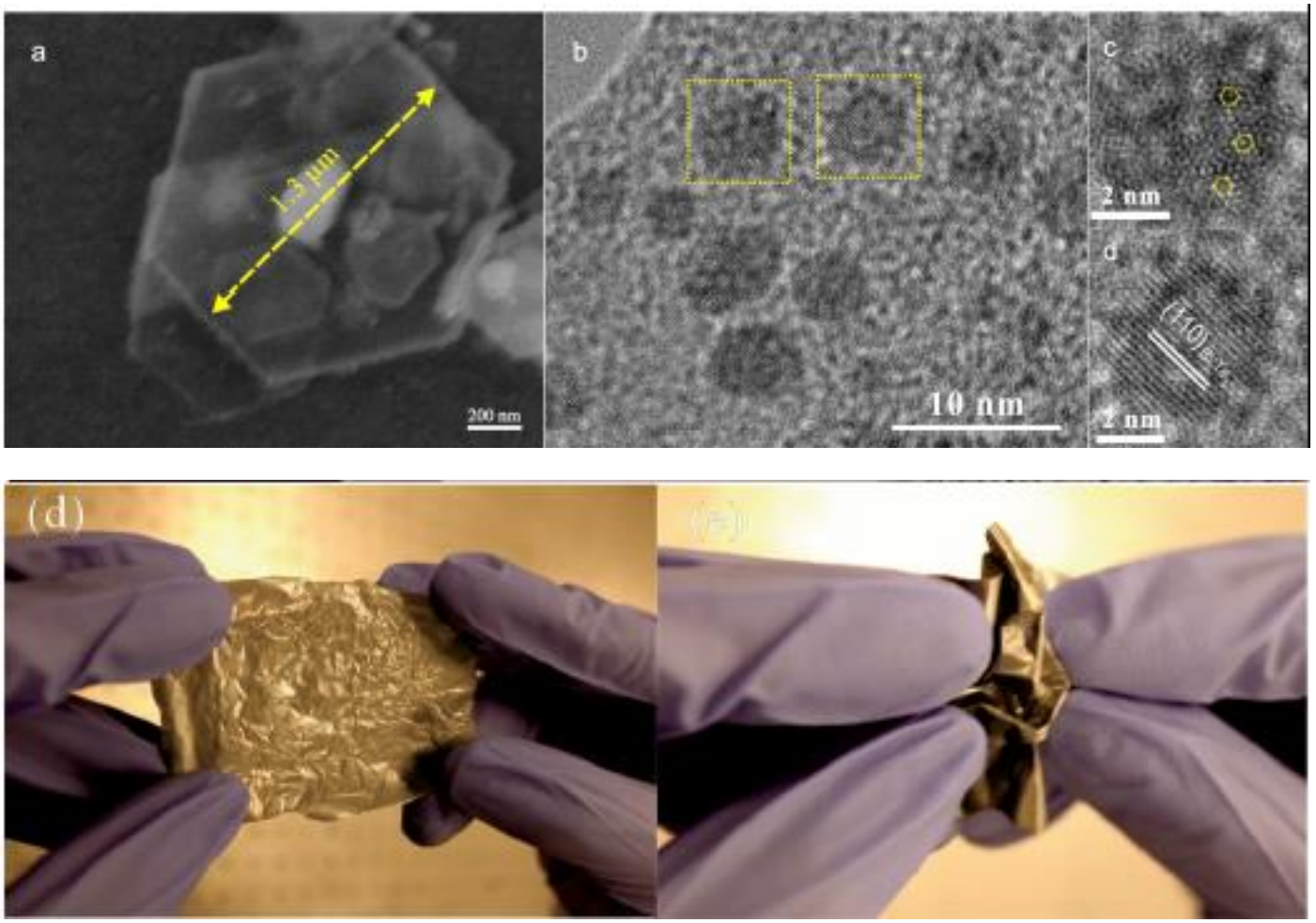
Could clothes pay for themselves?



So these are the five things:

1) PowerFelt is a power generator – not a storage device
2) PowerFelt is a T-PEG: not a thermoelectric or piezoelectric device
3) PowerFelt isnt a device at all! Its natural function is to convert thermal and kinetic energy into electrical power where ever it finds it.
4) PowerFelt can not make more power than it finds.
5) PowerFelt is made using simple manufacturing techniques – meaning it CAN be cheap!

What is next?



Remarkable results from 2D systems – but that is for another talk…

T-PEG research has been funded at the Center for Nanotechnology and Molecular Materials at Wake Forest University by these agencies and foundations…

Finally…

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Thank You!