



LIQUID METAL ELASTOMER COMPOSITES AS A SOFT THERMAL INTERFACE MATERIAL FOR LOW TEMPERATURE (- 80° C) APPLICATIONS

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Presented By

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Thermal & Fluids Analysis Workshop

TFAWS 2019

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NASA Langley Research Center

Hampton, VA



TFAWS

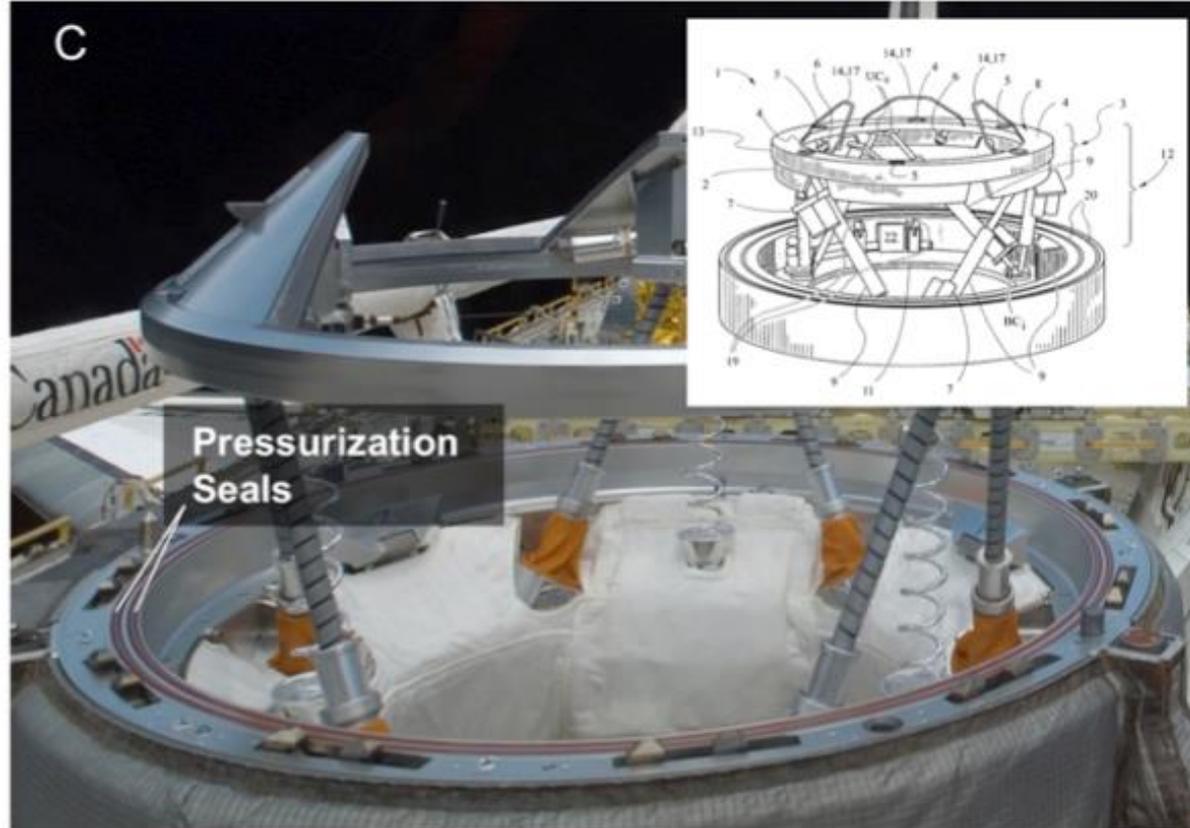
LaRC 2019



Gaskets & O-rings



Docking Mechanisms



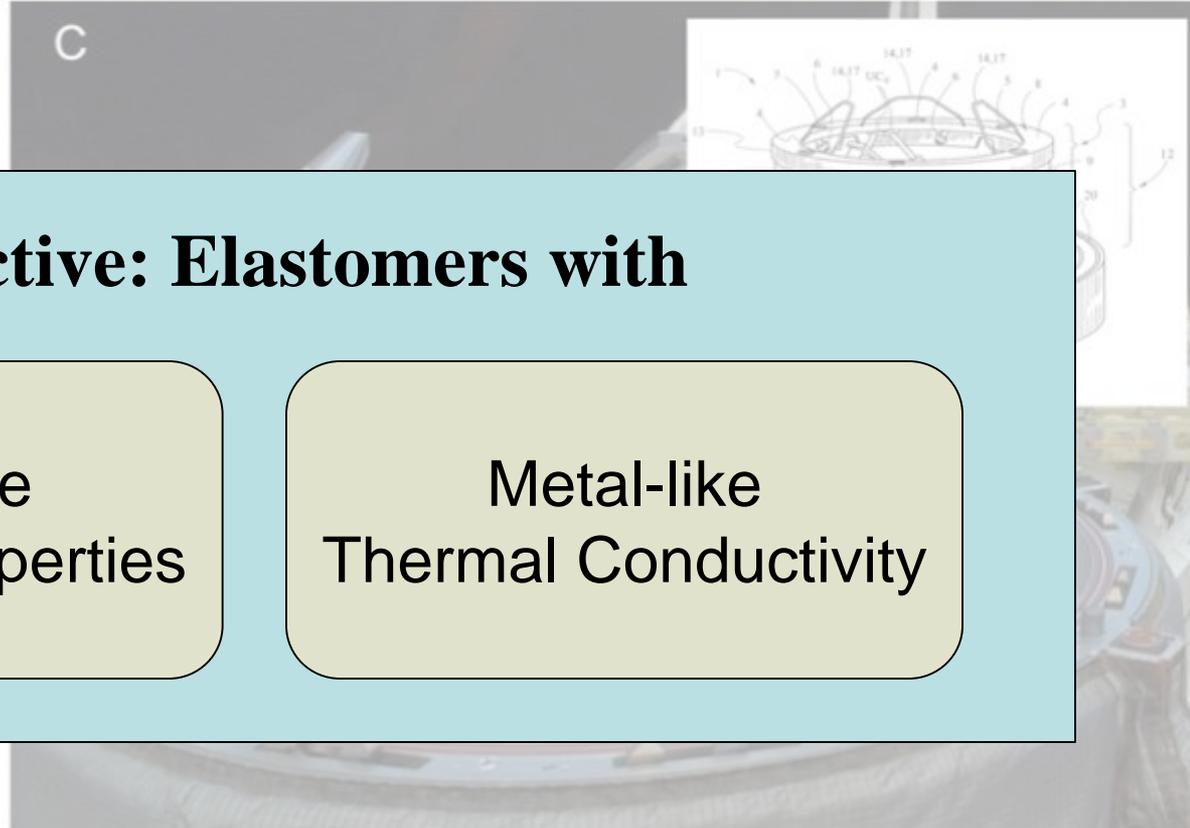
Diaphragms



Gaskets & O-rings



Docking Mechanisms

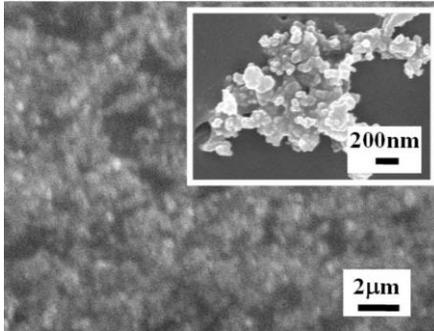


Objective: Elastomers with

Rubber-like
Mechanical Properties

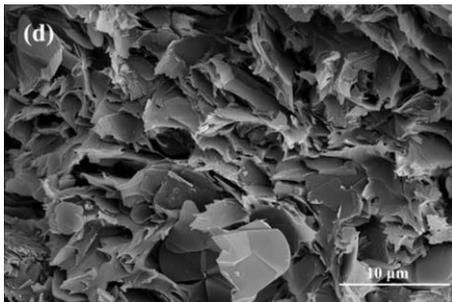
Metal-like
Thermal Conductivity

C+PDMS 28 wt%



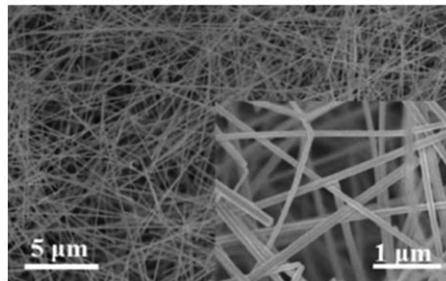
Niu et al., Adv. Mater., 2007

Boron Nitride (40 wt%)



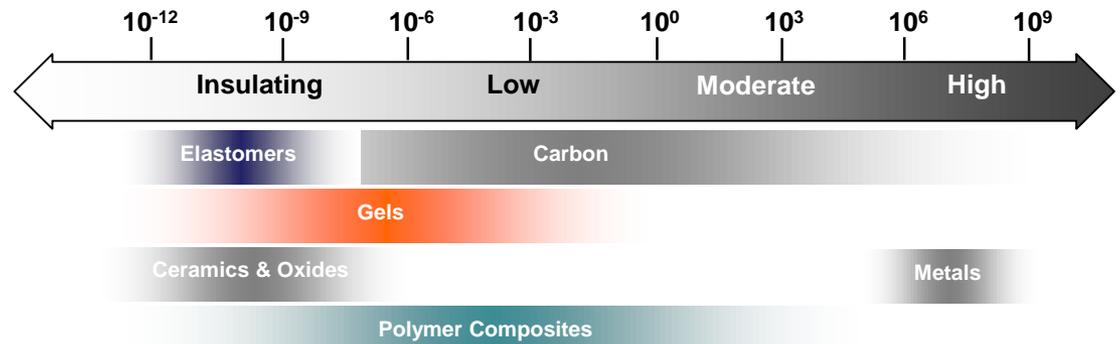
Yang et al., RSC Advances, 2016

Carbon Nanotube

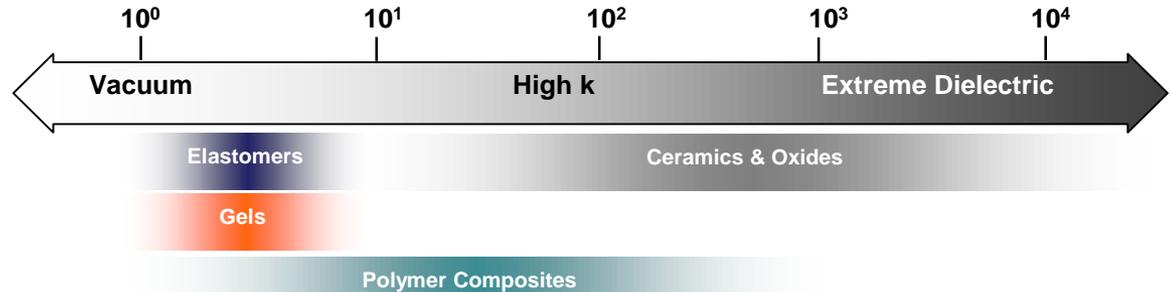


Jung et al., Sci. Rep, 2012

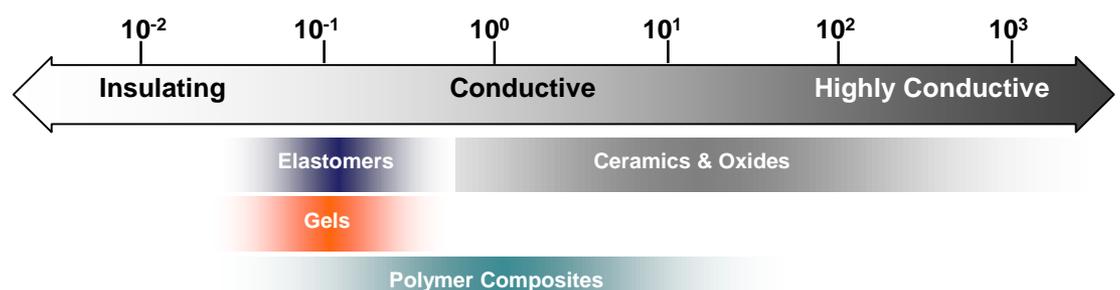
Electrical Conductivity • Volumetric Conductivity (S/m)



Electric Permittivity • Dielectric Constant

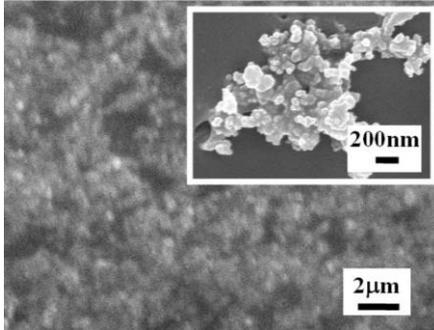


Thermal Conductivity • *electrically insulating materials* (W/m·K)



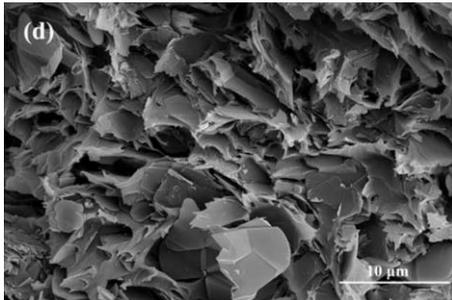
Kazem et al., Adv. Mat., 2017

C+PDMS 28 wt%



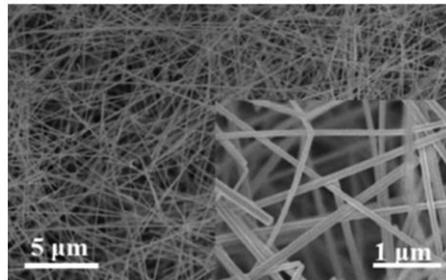
Niu et al., Adv. Mater., 2007

Boron Nitride (40 wt%)

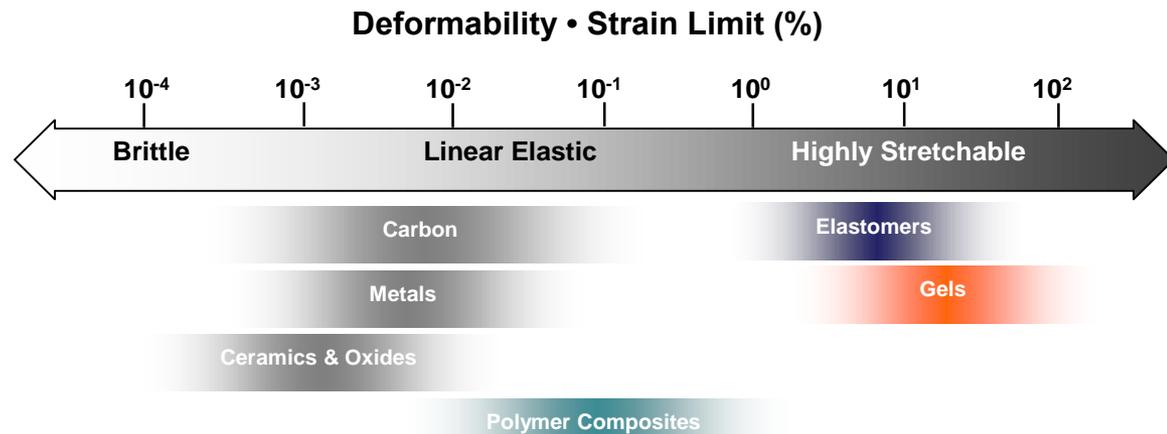
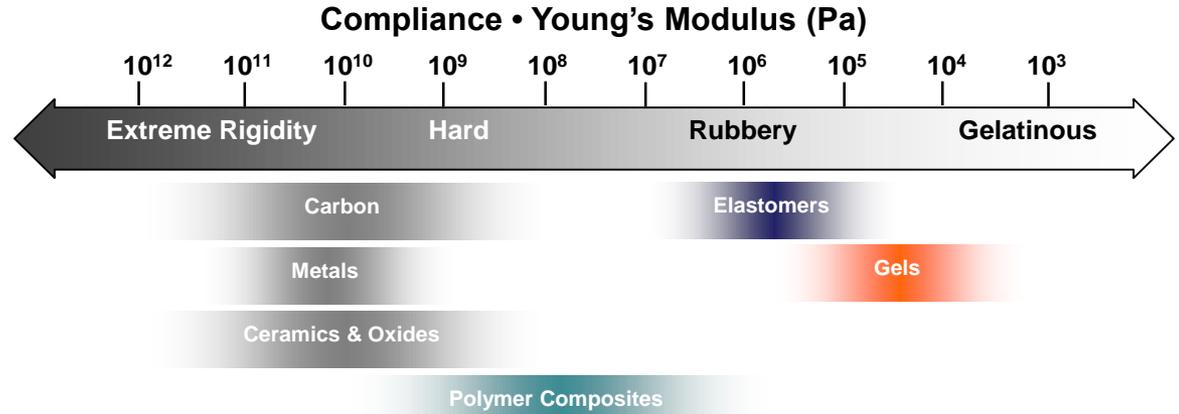


Yang et al., RSC Advances, 2016

Carbon Nanotube



Jung et al., Sci. Rep, 2012



Kazem et al., Adv. Mat., 2017



Indium Corp.

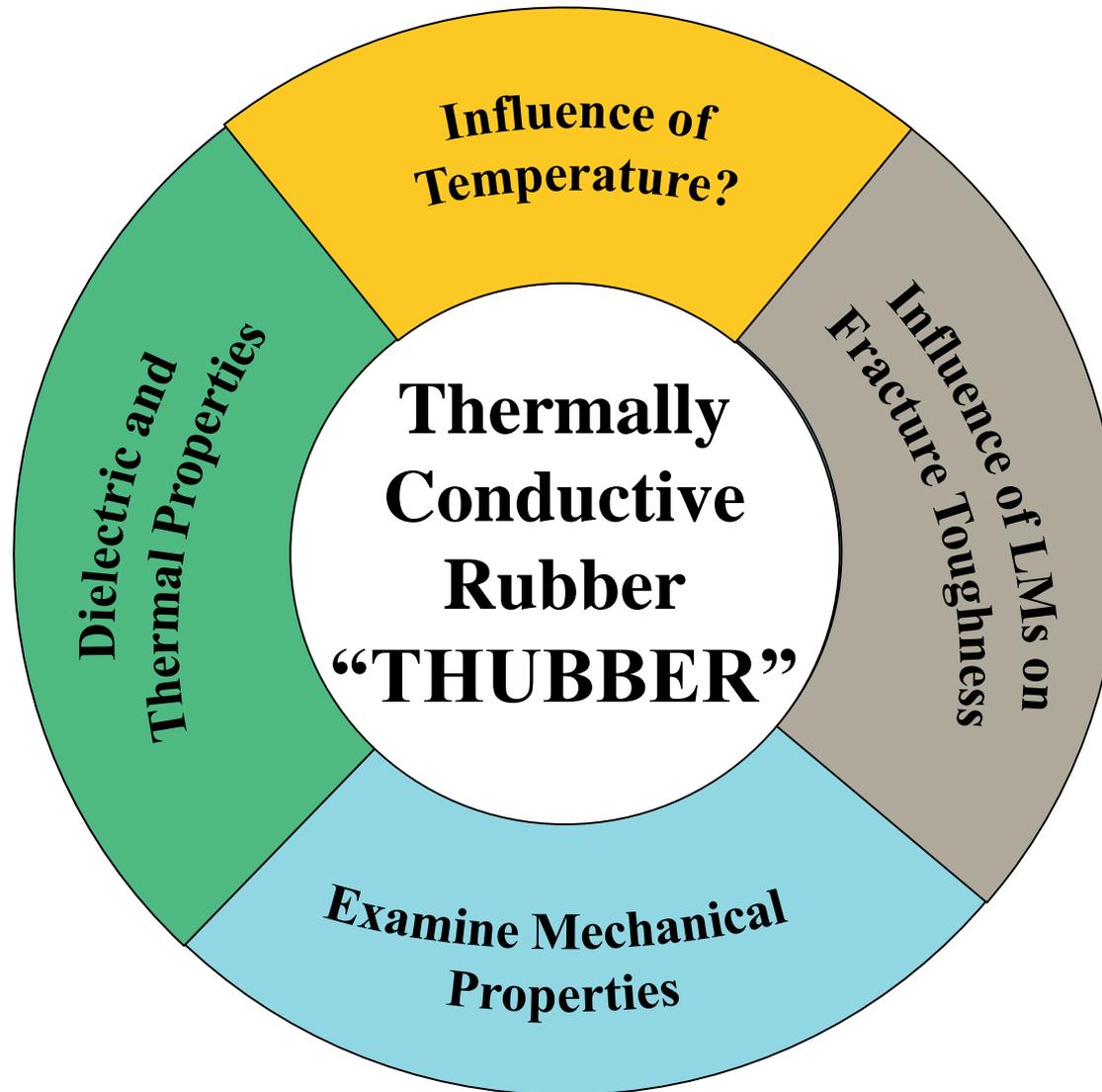


Chiechi et al., Angew. Chemie - Int. Ed. 2008

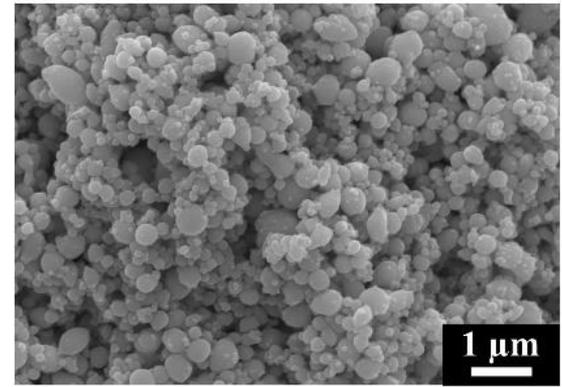
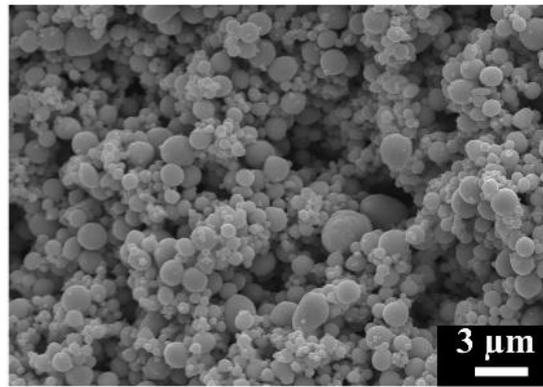
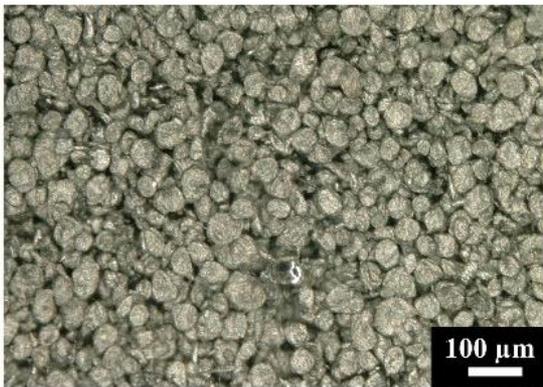
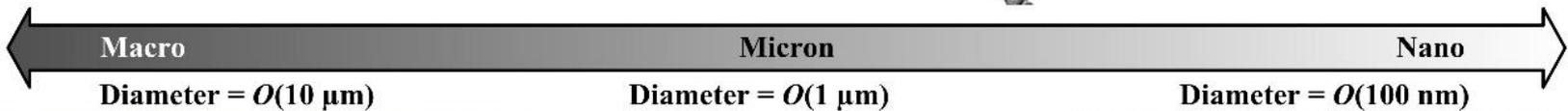
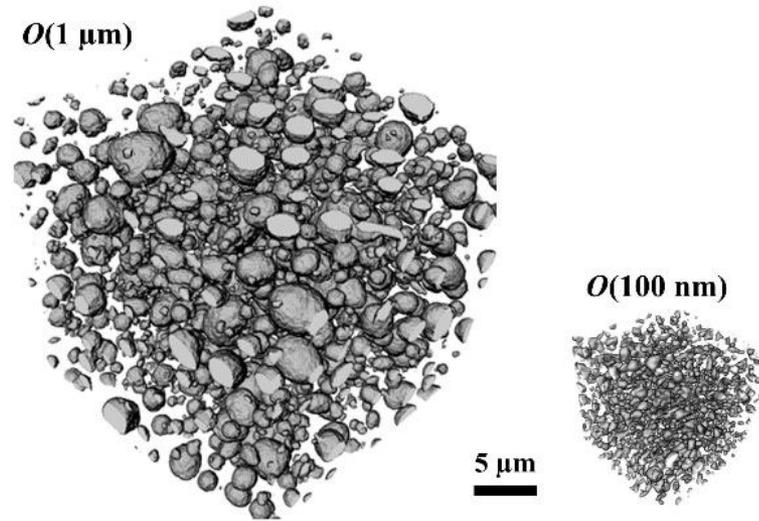
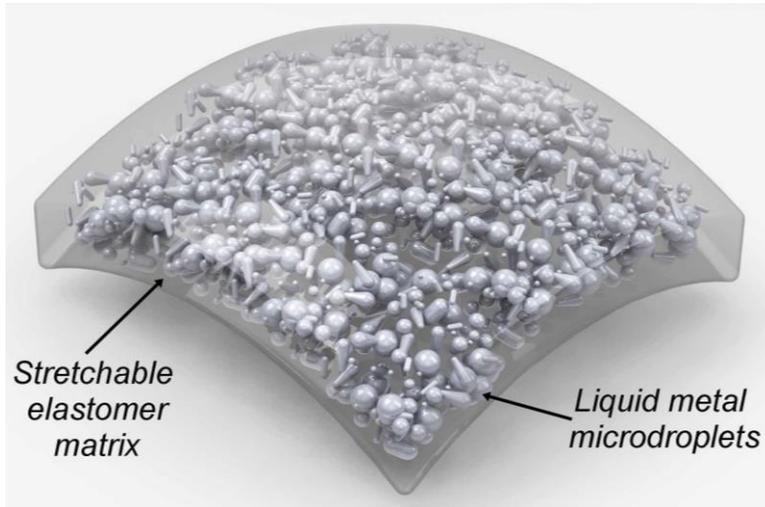


Joshi et al., J. Mater. Chem. C., 2015.

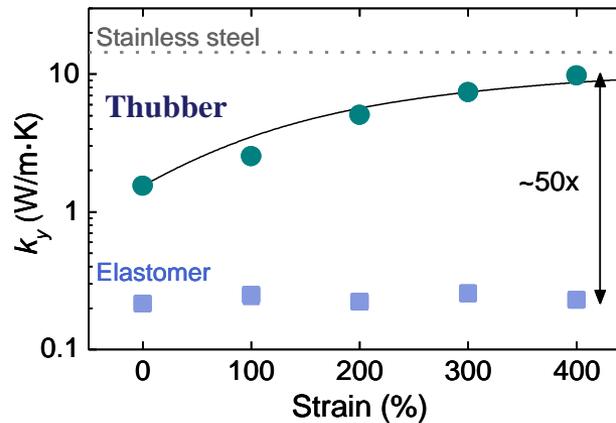
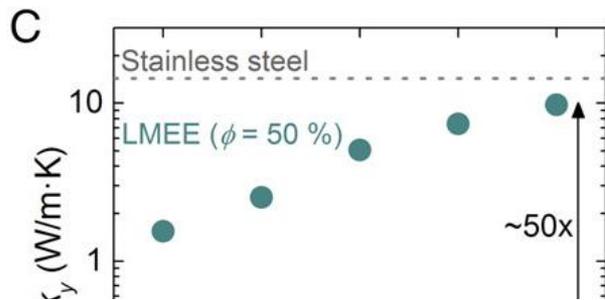
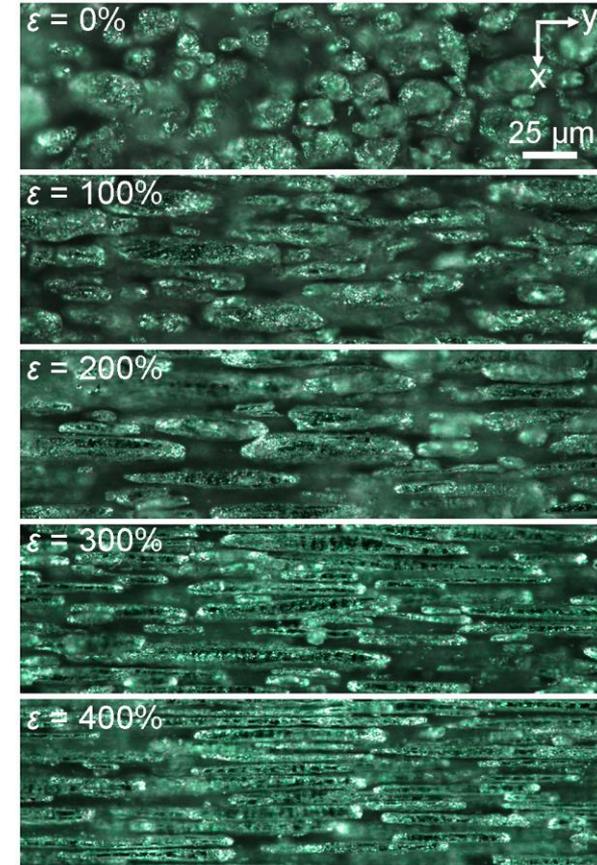
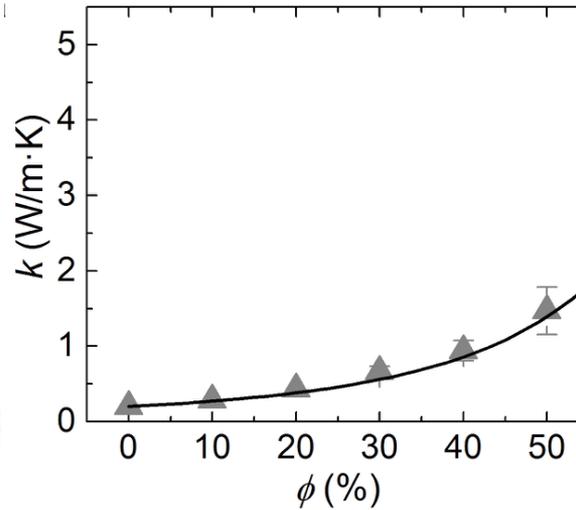
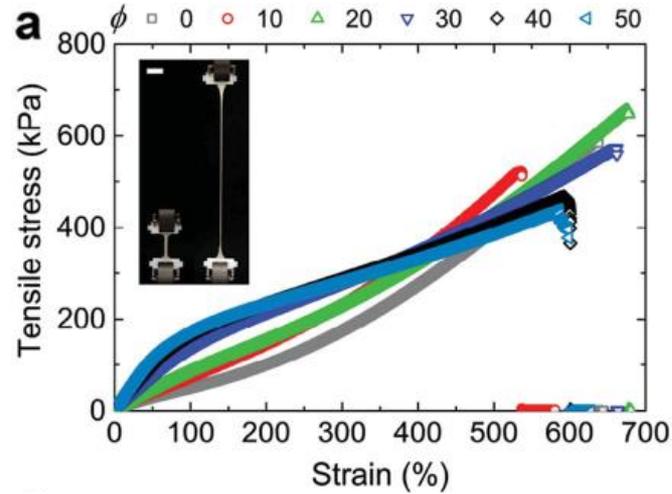
- Eutectic Gallium Indium (74.5% Ga, 24.5% In; by weight)
- Low melting point $\sim 15.5^\circ \text{C}$
- Negligible toxicity
- Low viscosity 1.99 mPa.s
- High electrical and thermal conductivity ($\sigma = 3.4 \times 10^6 \text{ S/m}$, $k = 26.4 \text{ W/m}\cdot\text{K}$, at $\sim 30^\circ \text{C}$)



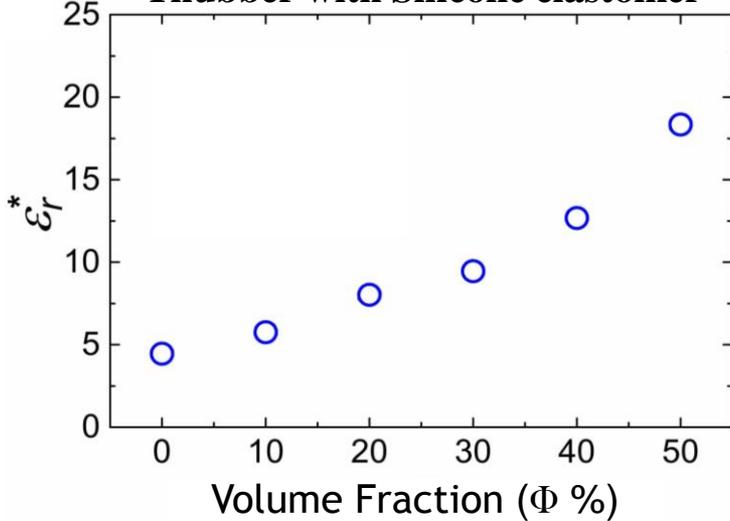
Thubber's Microstructure



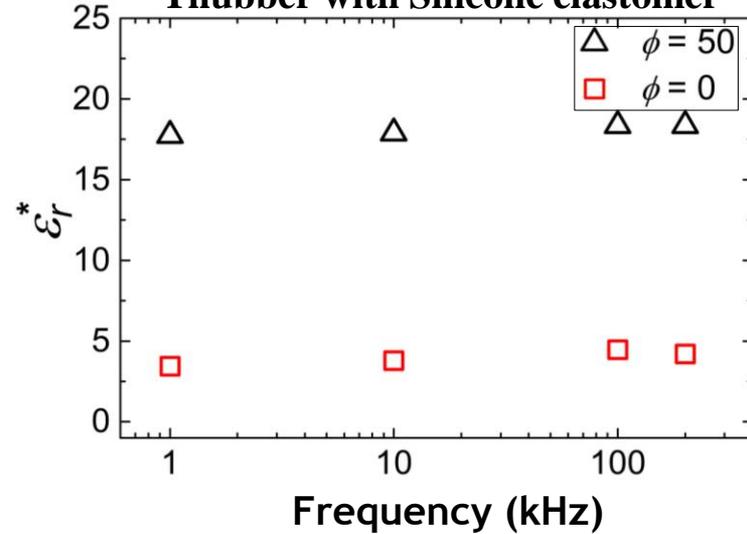
Pan et al., Adv. Mat., 2019



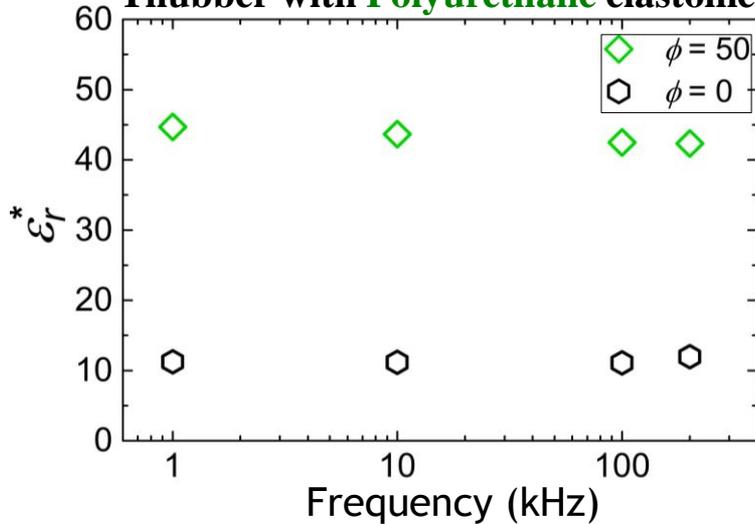
Thubber with Silicone elastomer



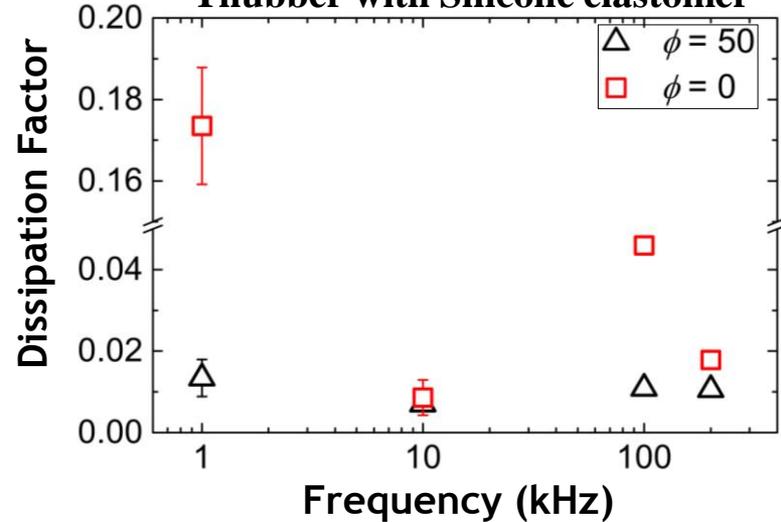
Thubber with Silicone elastomer



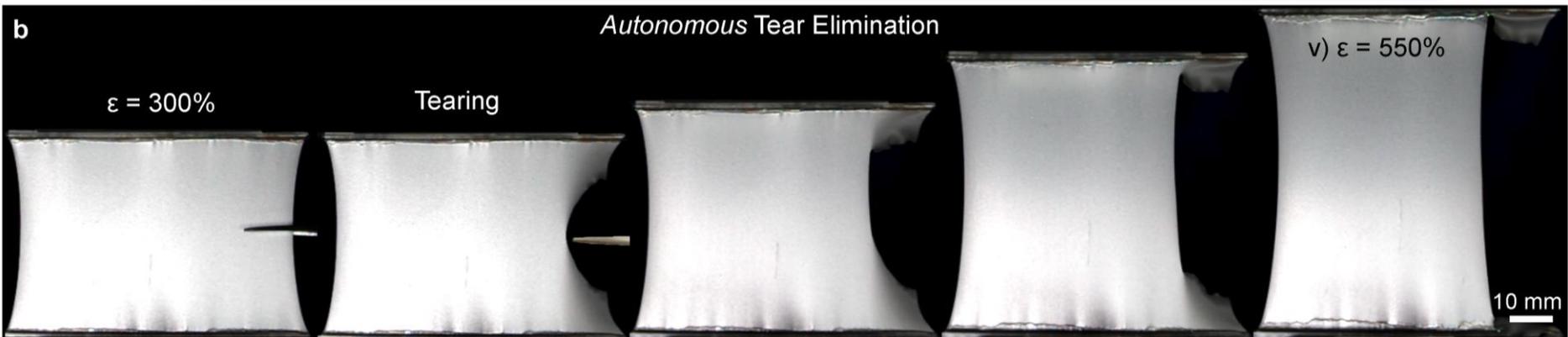
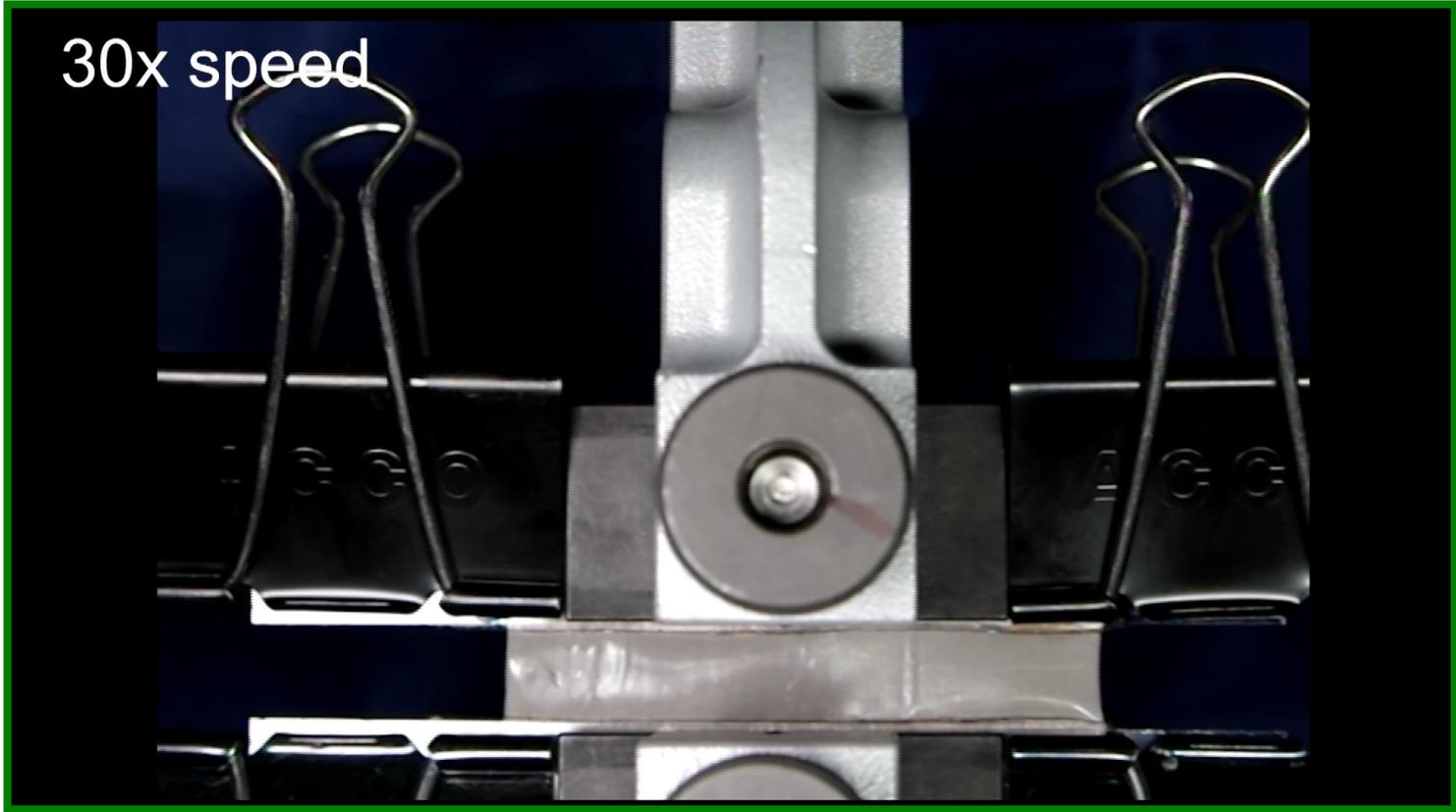
Thubber with Polyurethane elastomer



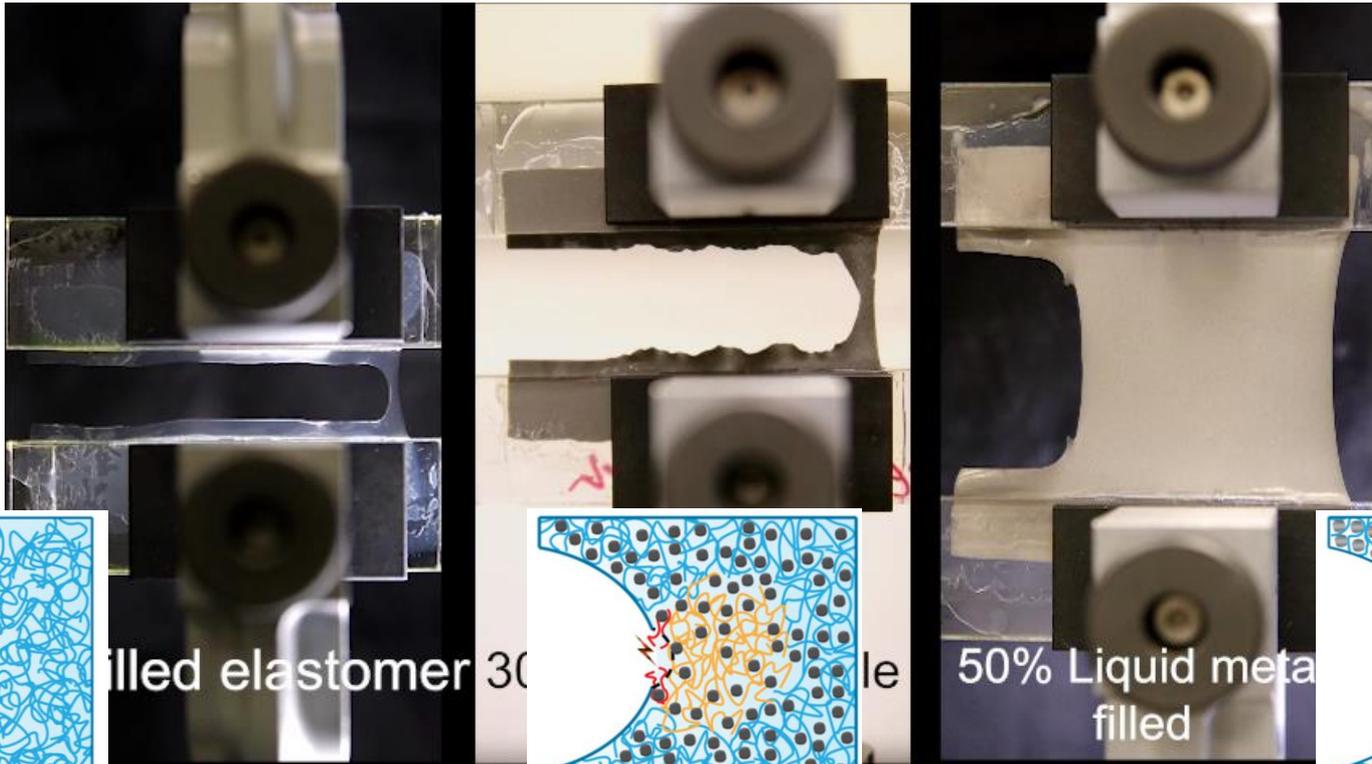
Thubber with Silicone elastomer



Tear Elimination



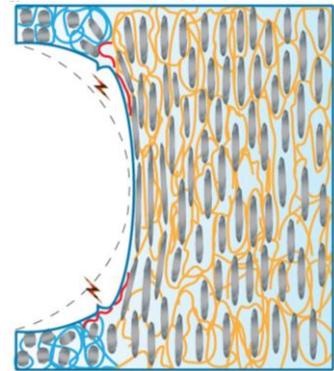
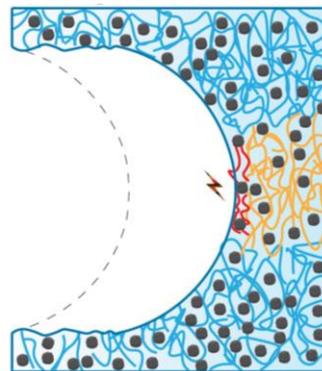
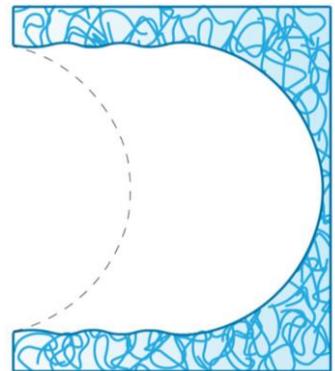
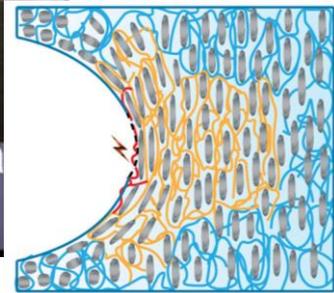
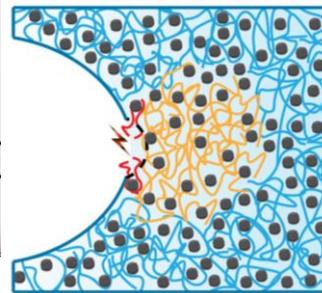
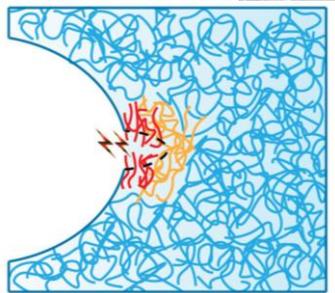
Tear Elimination

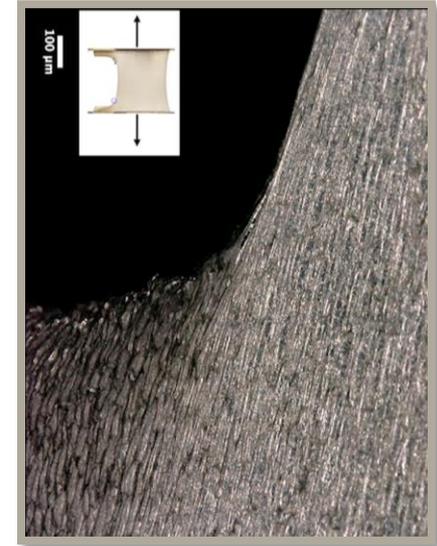
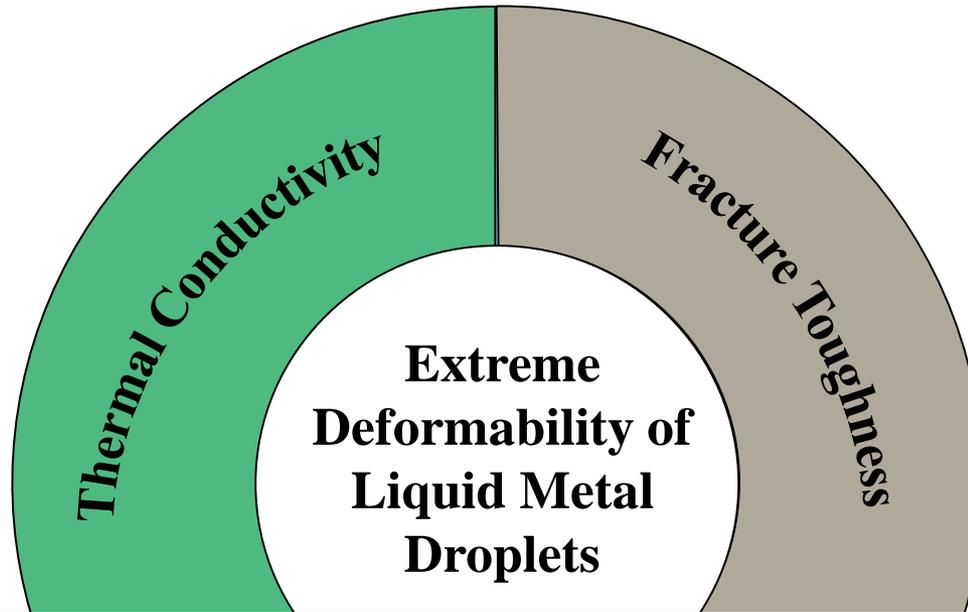
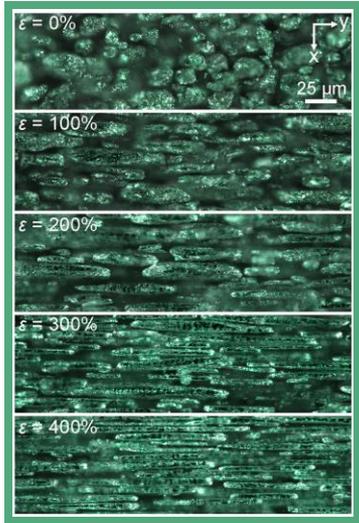


filled elastomer 30

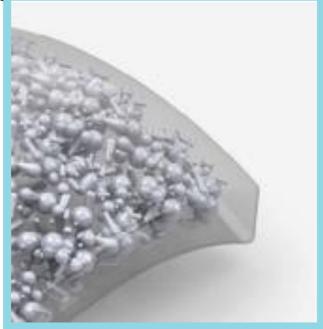
le

50% Liquid meta
filled





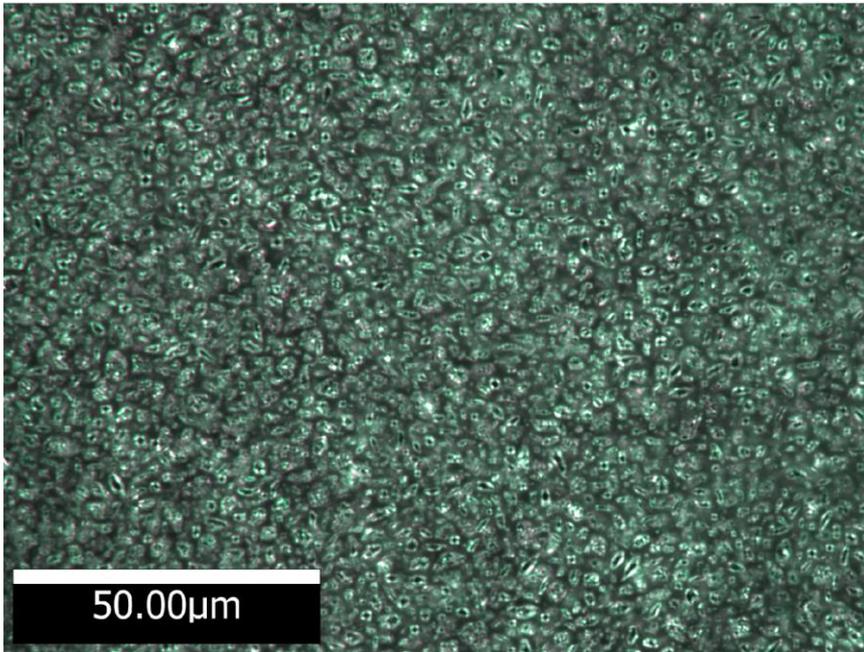
Influence of Temperature on elasticity?



- What is the extent of temperature in which LM inclusions remain liquid?
- Does the matrix materials affect the working temperature?

Test Specimen

EGaln droplets (50%vol.) in Sylgard 184 (50%vol)



Characterization Methods

1. Dynamic Mechanical Analysis (DMA)

Tensile Configuration

1% strain

1 Hz

Specimen Geometry: 10mmX4mmX1mm

Temperature Range (–90°C to 35 °C)

RSA-G2 - TA Instruments

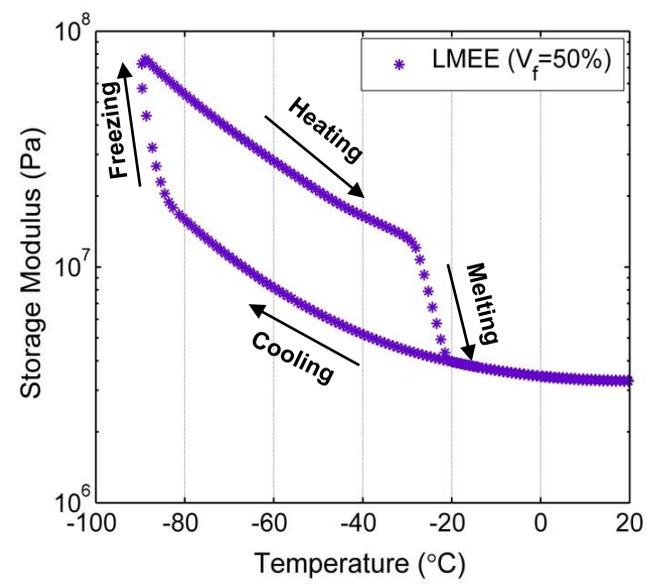
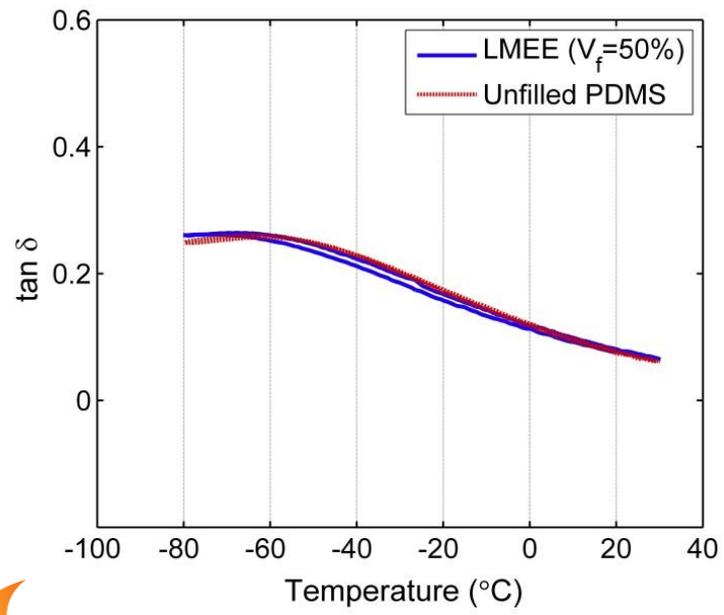
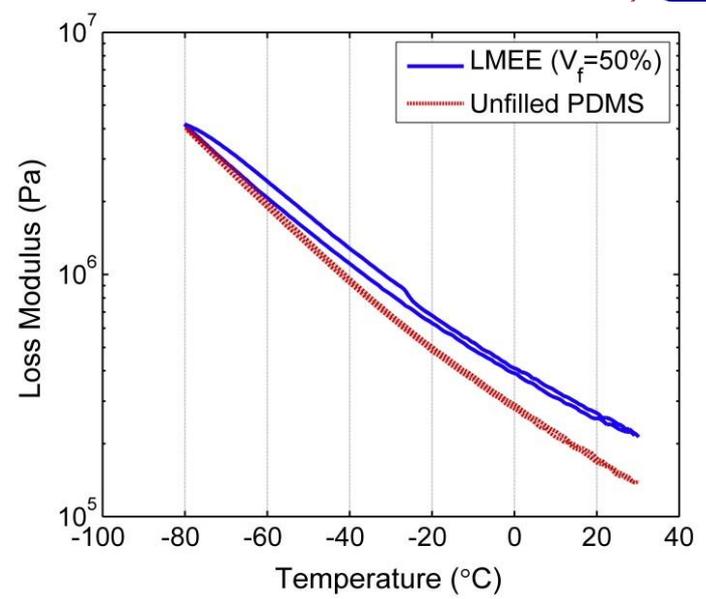
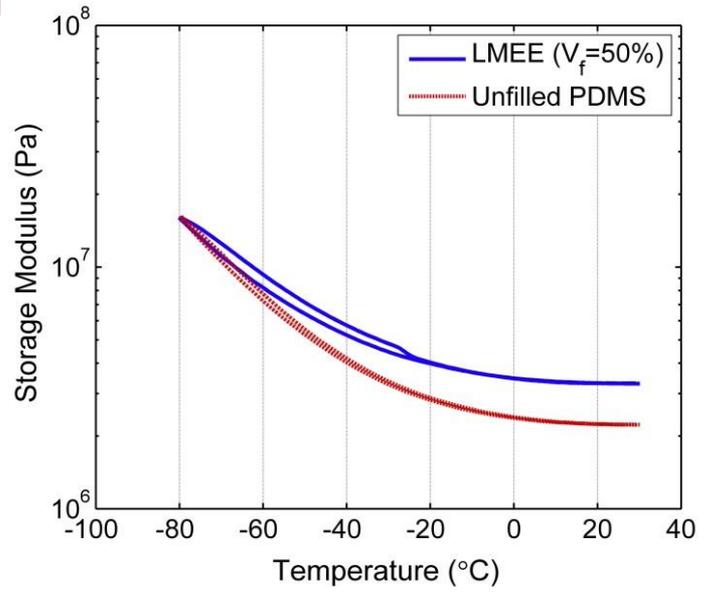
2. Differential Scanning Calorimetry (DSC)

Specimen weight: 5-15 mg

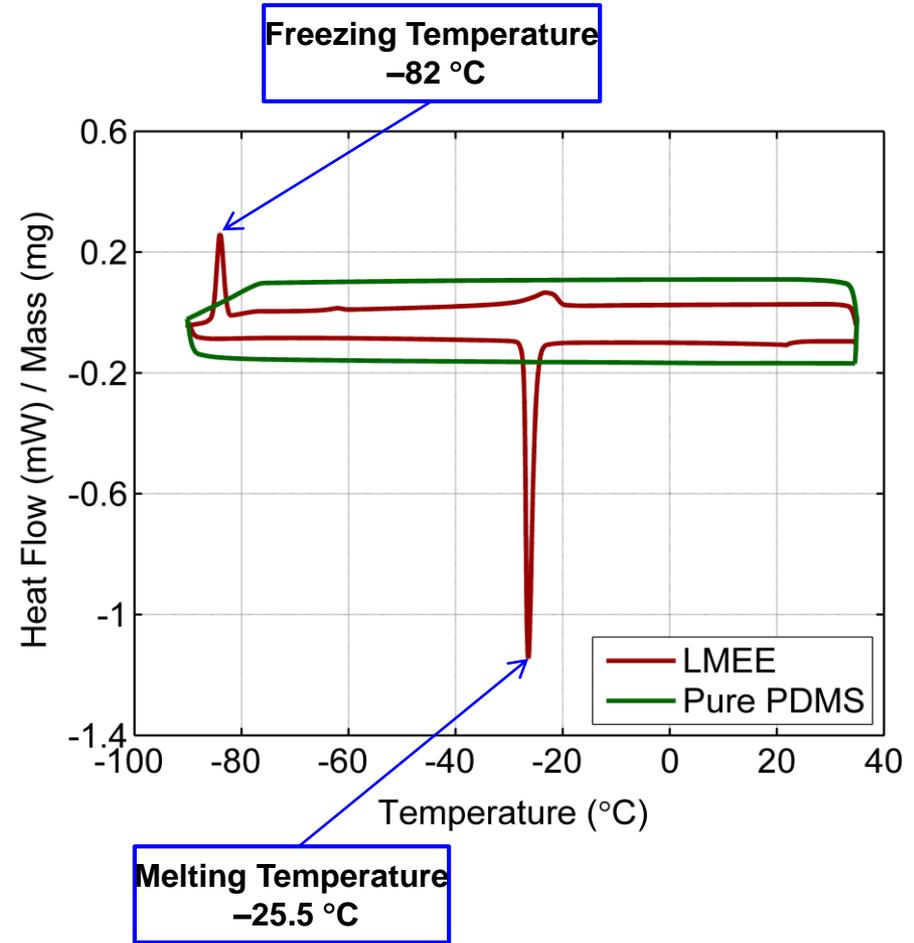
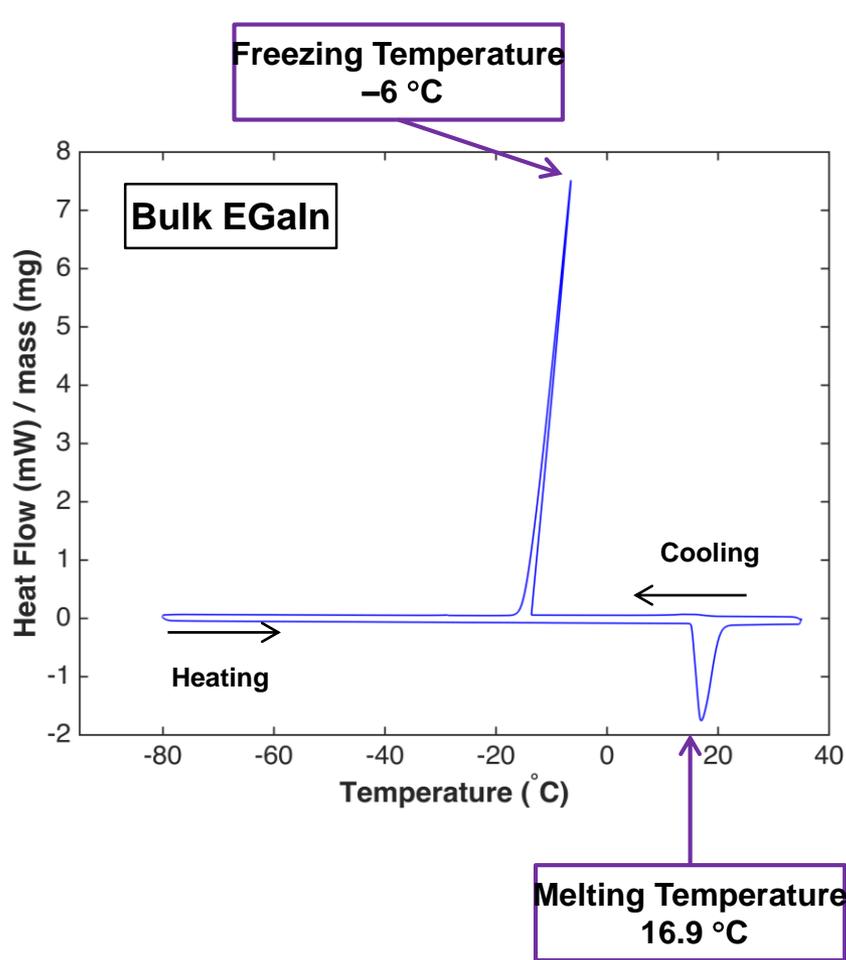
T-zero aluminum pan

Temperature Range (– 90°C to 35 °C)

Q20 - TA Instruments

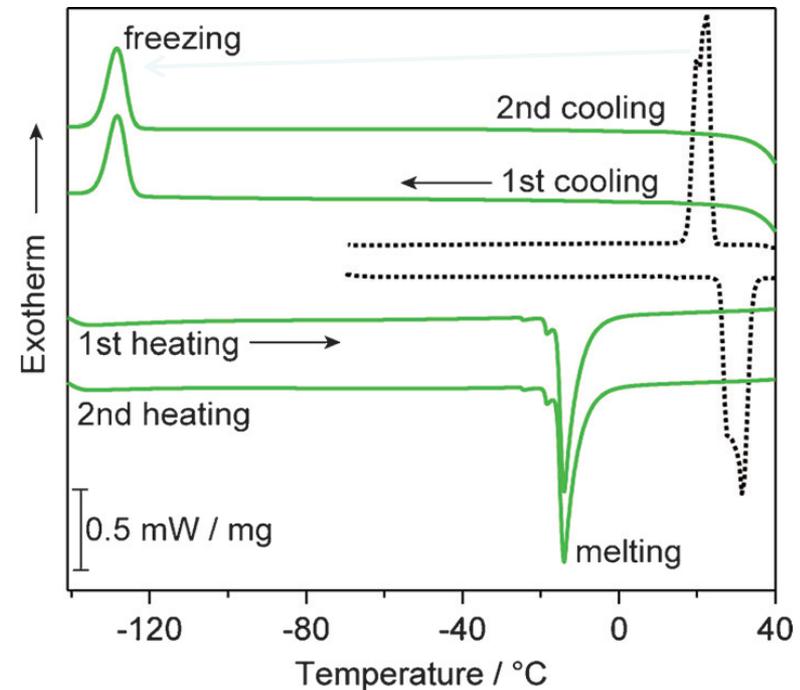
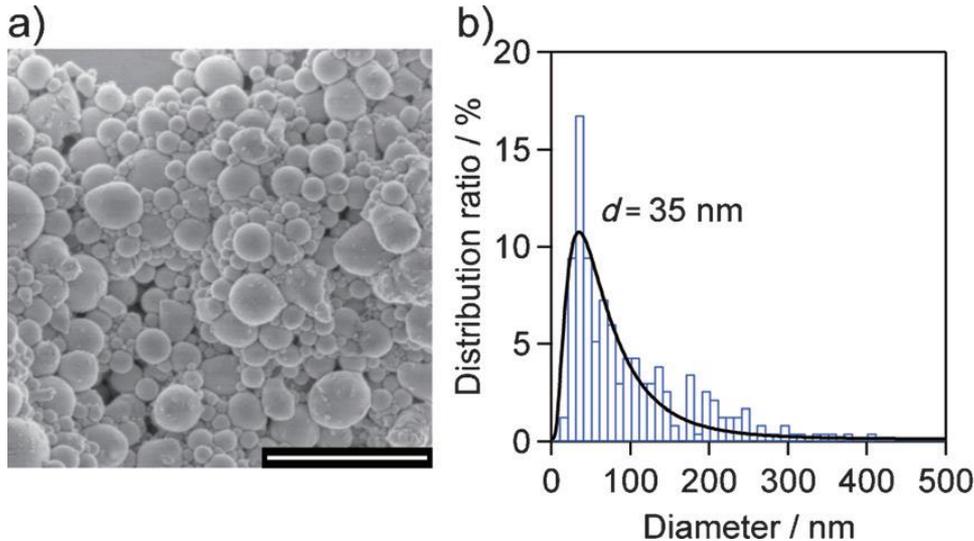


- Significantly reduced melting and freezing (crystallization) temperatures



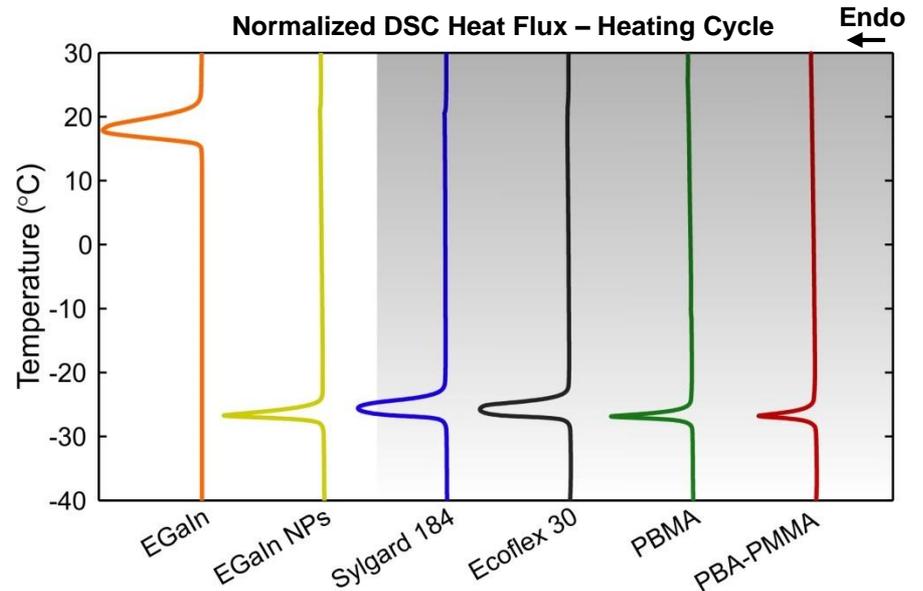
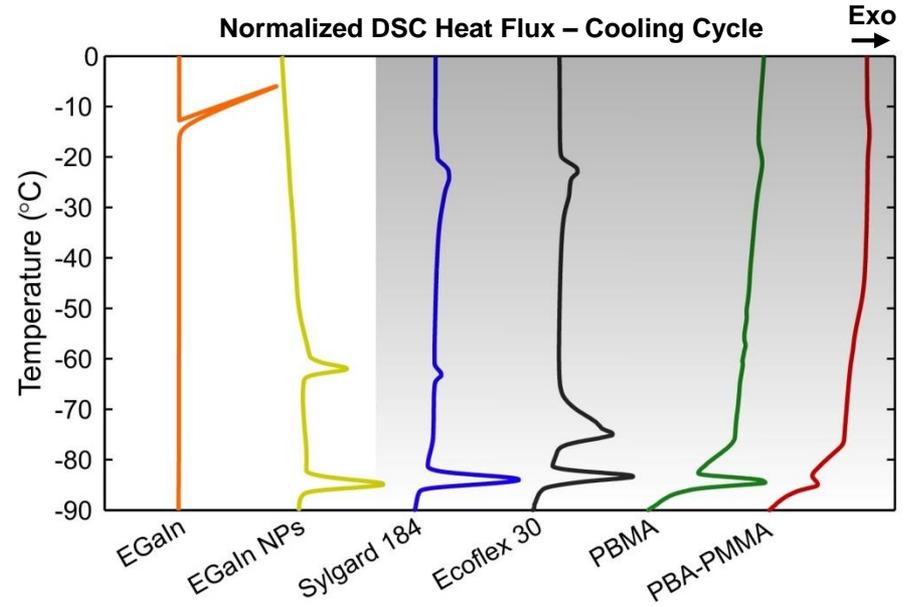
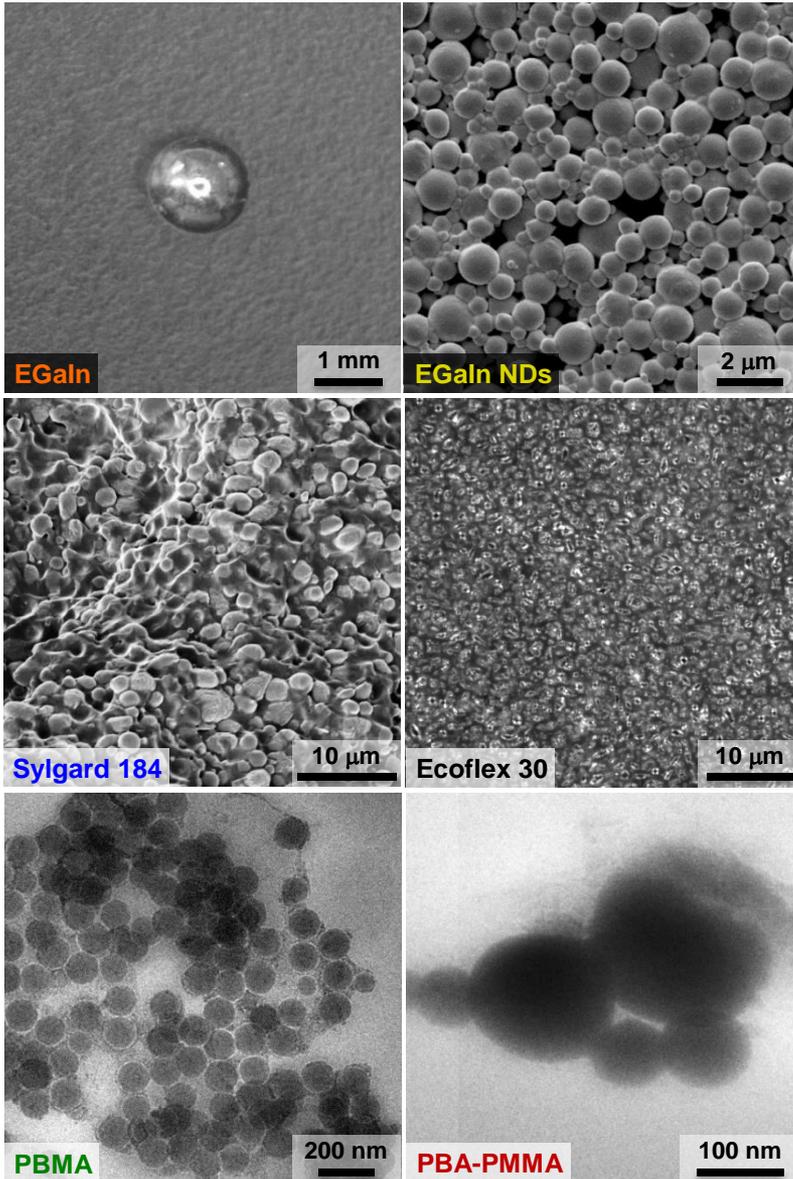
The confinement of gallium in **micro- to nanometer-sized particles** resulted in a lowering of the freezing and melting temperatures

Gallium Nano-Particles

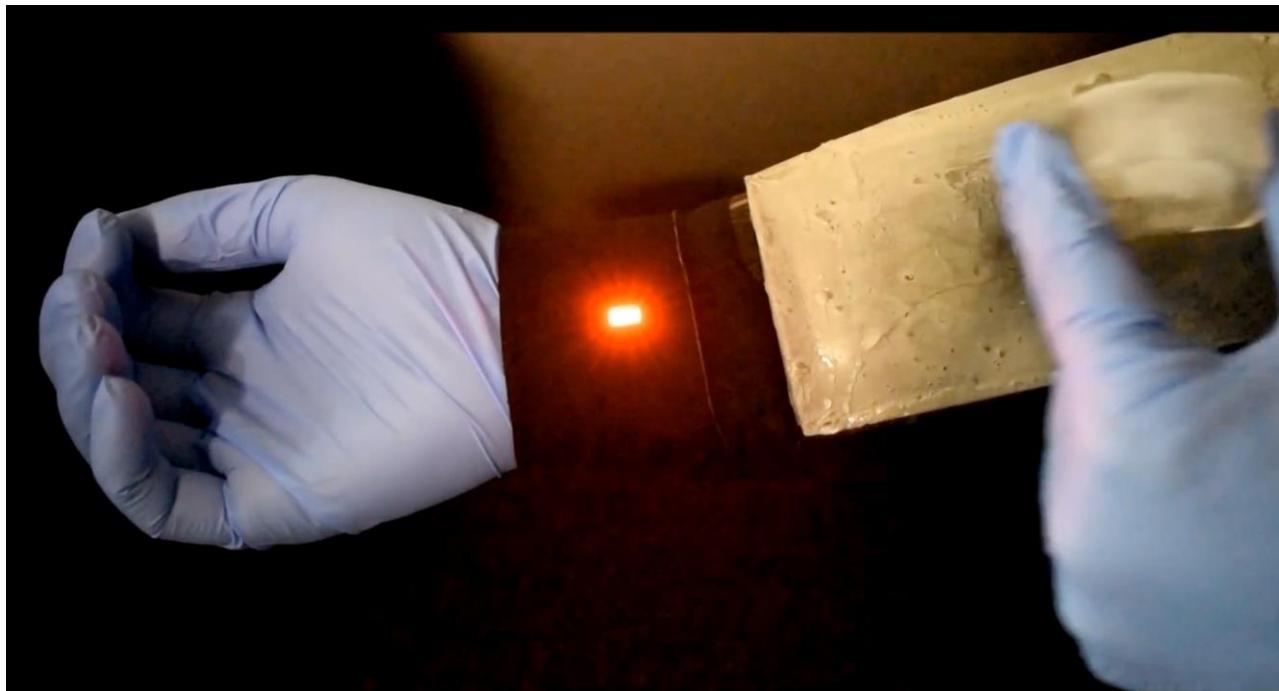
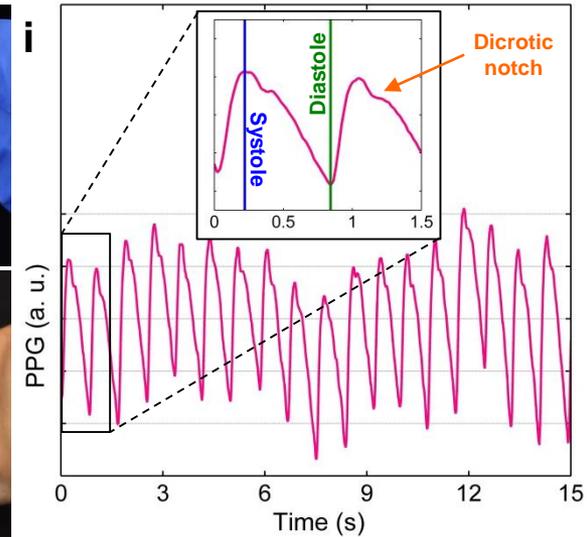
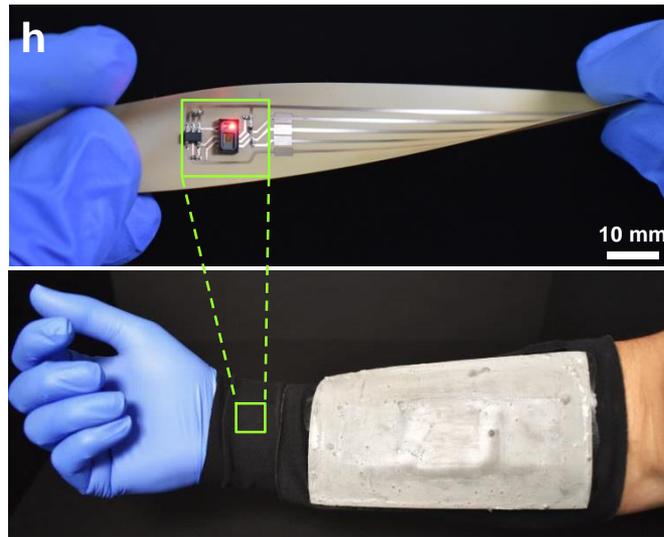
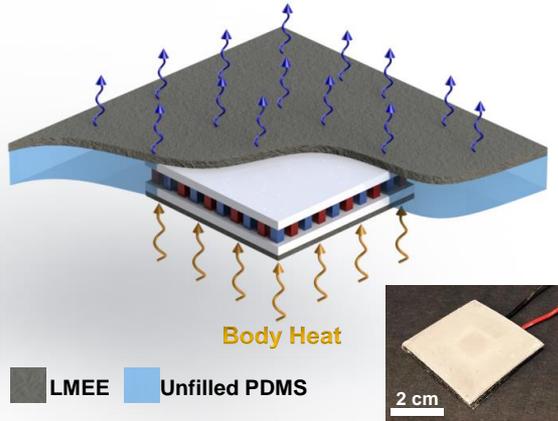


Yamaguchi et al. *Angew. Chem. Int. Ed.* 2015

Effect of Polymer Matrices



Thubber for Wearable TEG



Collaborators:



Prof. Mohammad Malakooti



Prof. Michael Bartlett



Matthew Powell-palm



Dr. Andrew Fassler



Prof. Eric Markvicka



Chengfeng Pan



Prof. Krzysztof Matyjaszewski



Dr. Jiajun Yang



Dr. Navid Kazem



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