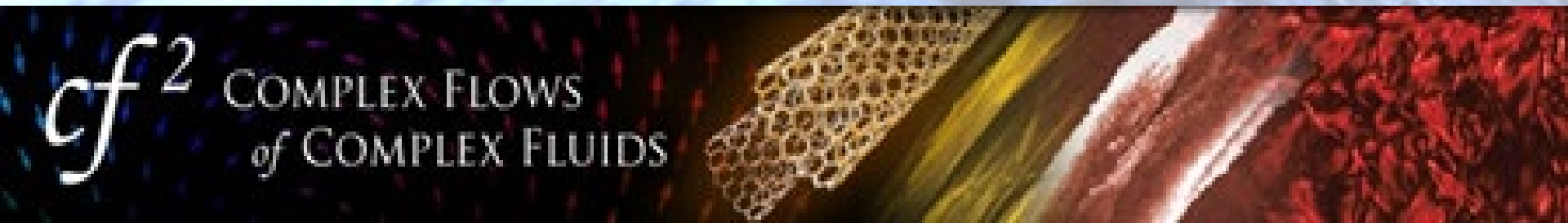
Soft Lightweight Conductors

Matteo Pasquali, Dmitri Tsentalovich, Francesca Mirri, Colin Young

Rice Technology Showcase
ISS Conference Facility, TX, 29 July 2014

Departments of Chemical & Biomolecular Eng., Chemistry, Materials Sci. & NanoEng.
The Smalley Institute for Nanoscale Science & Technology
The Ken Kennedy Institute for Information Technology
Rice University, Houston, TX; mp@rice.edu



CURRENT CLASSIFICATION OF MATERIALS

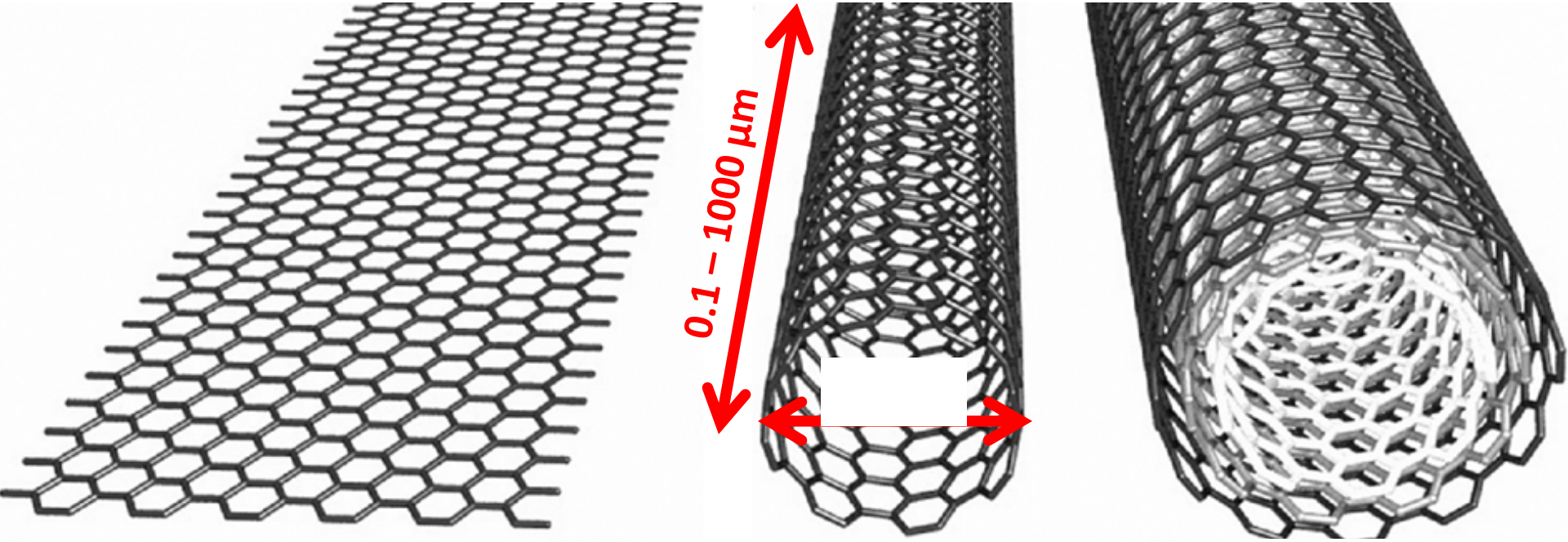
SOFT MATERIALS	HARD MATERIALS
polymers	metals
biomaterials	silicon
gels	graphite
…	…
CLASSICAL	*QUANTUM*

SOFT	HARD
AMORPHOUS	CRYSTALLINE
INSULATING	CONDUCTING
LOW DENSITY	HIGH DENSITY
FLEXIBLE	STIFF
Fatigue-resistant)	Fatigue-prone

Softness and conductivity require compromising: is this true?

Can we get both using Carbon Nanotubes?

CARBON NANOTUBES (CNTS)

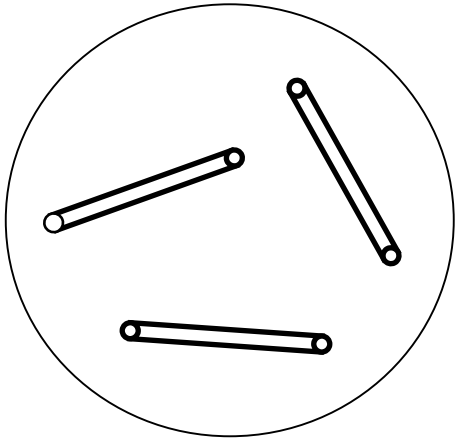


Source: Kreupl *et al.* (2004)

CNT Properties *(Baughman et al., Science, 2002 and Peng et al., Nat. Nano 2008)*

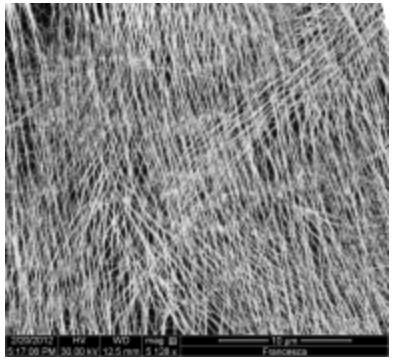
- Tensile Strength > 110 GPa (Steel 5.2 GPa, Carbon Fiber 6.4 GPa)
- Young modulus ~ 1.1TPa (Steel 0.3 TPa, PBO 0.36 TPa, Pitch Fiber 1 TPa)
- Electrical Conductivity ~ 100 MS/m → (Copper 59 MS/m, Silver 63 MS/m)
- Thermal Conductivity ~ 3000 W/m-K (Diamond 2000 W/m-K, Pitch Fiber 1100 W/m-K)
- Low Density ~ 1.4 kg/m^3 (Steel 8 kg/m^3, Aluminum 2.7 kg/m^3)

FLUID PROCESSING CARBON NANOTUBES

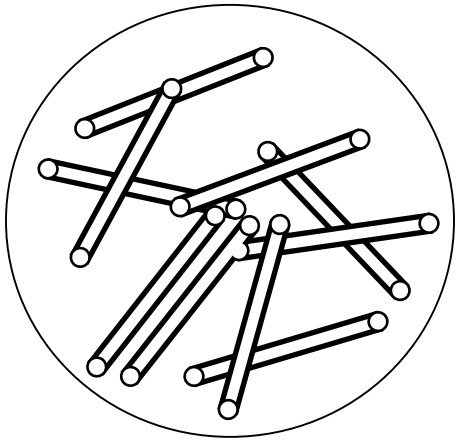


ISOTROPIC →

CNT Thin Films

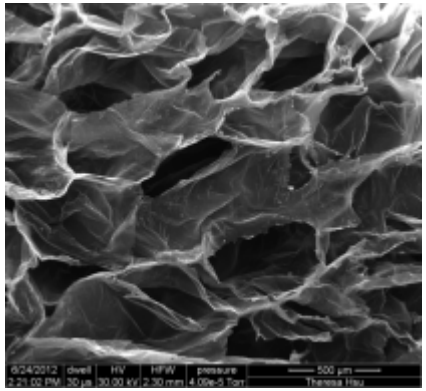


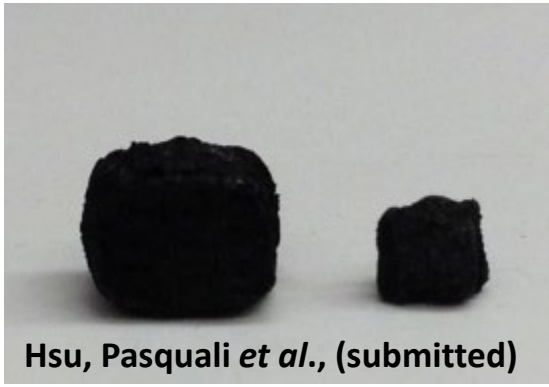
Mirri, Pasquali *et al.*, *ACS Nano* 2012



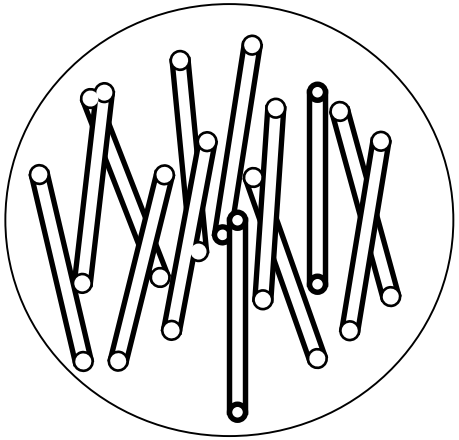
BIPHASIC →

CNT Foams



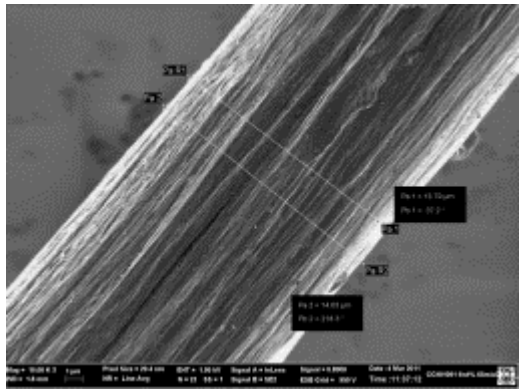


Hsu, Pasquali *et al.*, (submitted)



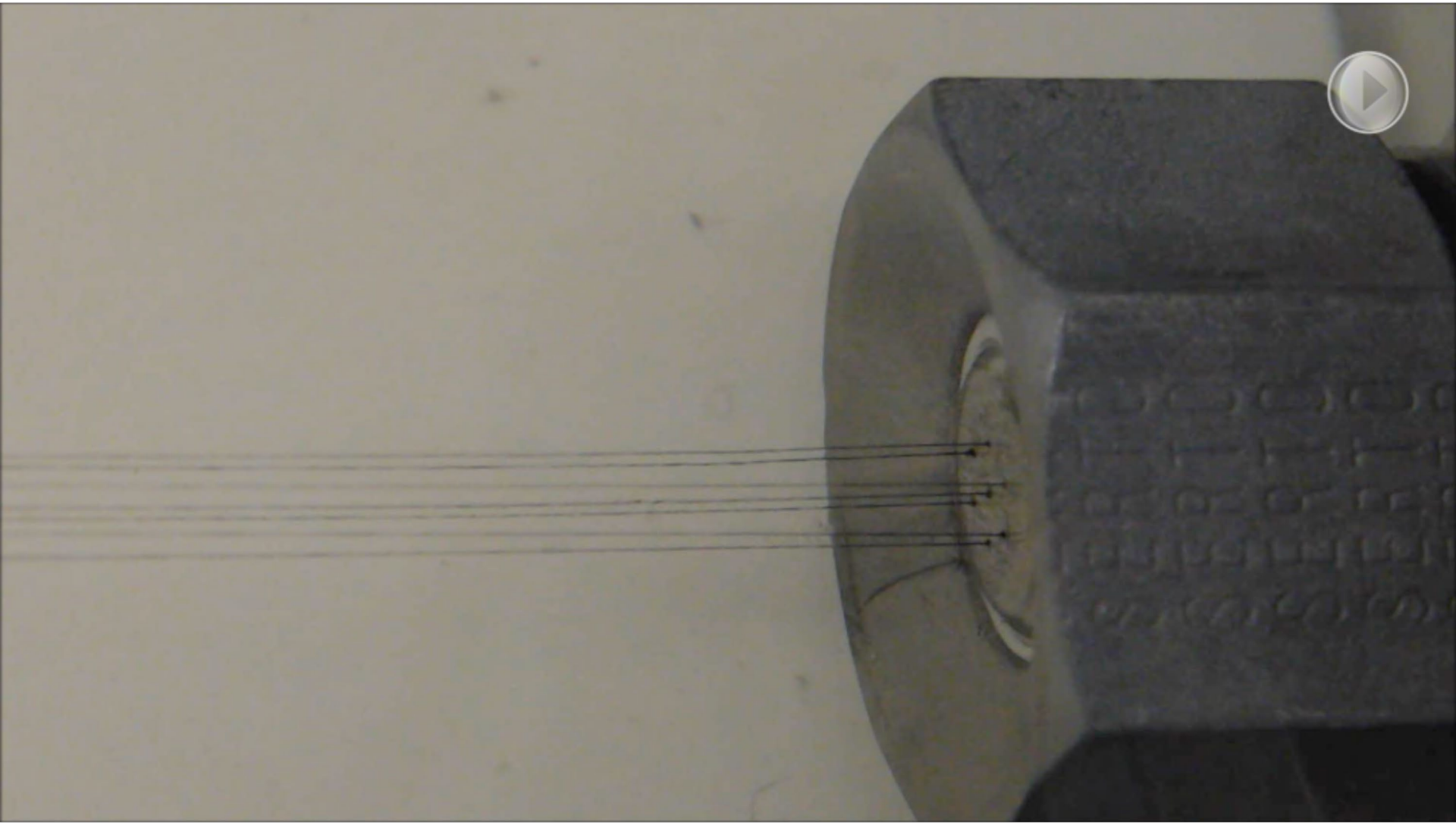
LIQUID CRYSTALLINE →

CNT Fibers



Behabtu, Pasquali *et al.*, *Science* 2013

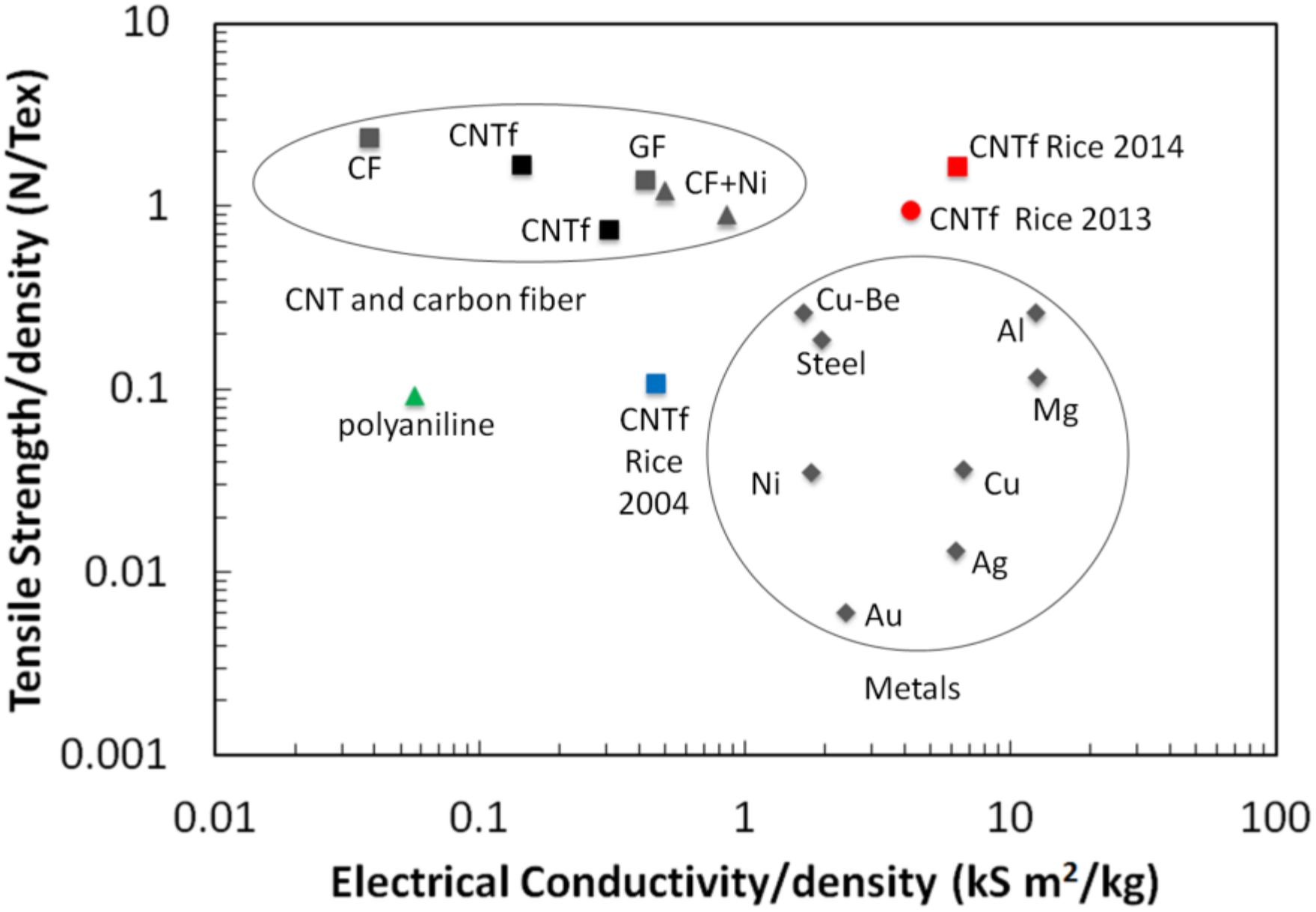
FIBER SPINNING



Behabtu, Young, Tsentalovich, Pasquali, et al, *Science*, 2013

Collaboration with Teijin Aramids BV, manufacturers of Twaron (PPTA)

CNT FIBER PROPERTIES



Behabtu, Young, Tsentalovich, Pasquali *et al.*, *Science*, 2013

MULTIFUNCTIONALITY

Behabtu *et al.* Science 2013

POTENTIAL APPLICATIONS

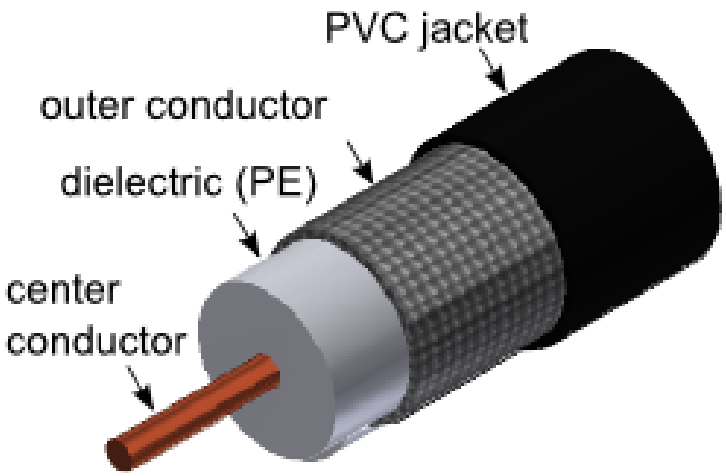
Aerospace

Subsea Umbilicals

CNT audio cables from van den Hul

CNT (€ 8000)
1-meter pair

COAXIAL CABLES



Shielding in standard metal cables:

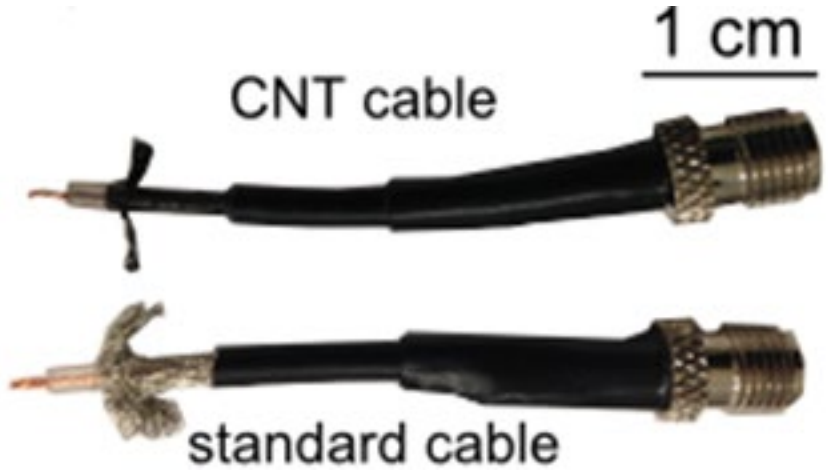
- Minimize electromagnetic interference (EMI)
- Heavy
- Cannot be bent
- Flexible but poor flex fatigue

				
Home Entertainment	GPS	Security Video	Telecommunications	WAN/LAN
TV,DVR, Audio signals	Connections between receiving antennas	Video transmission from camera to display	Cell towers & communication equipment	Wide area networks/local area networks

CNT CABLES ARE VERY LIGHT

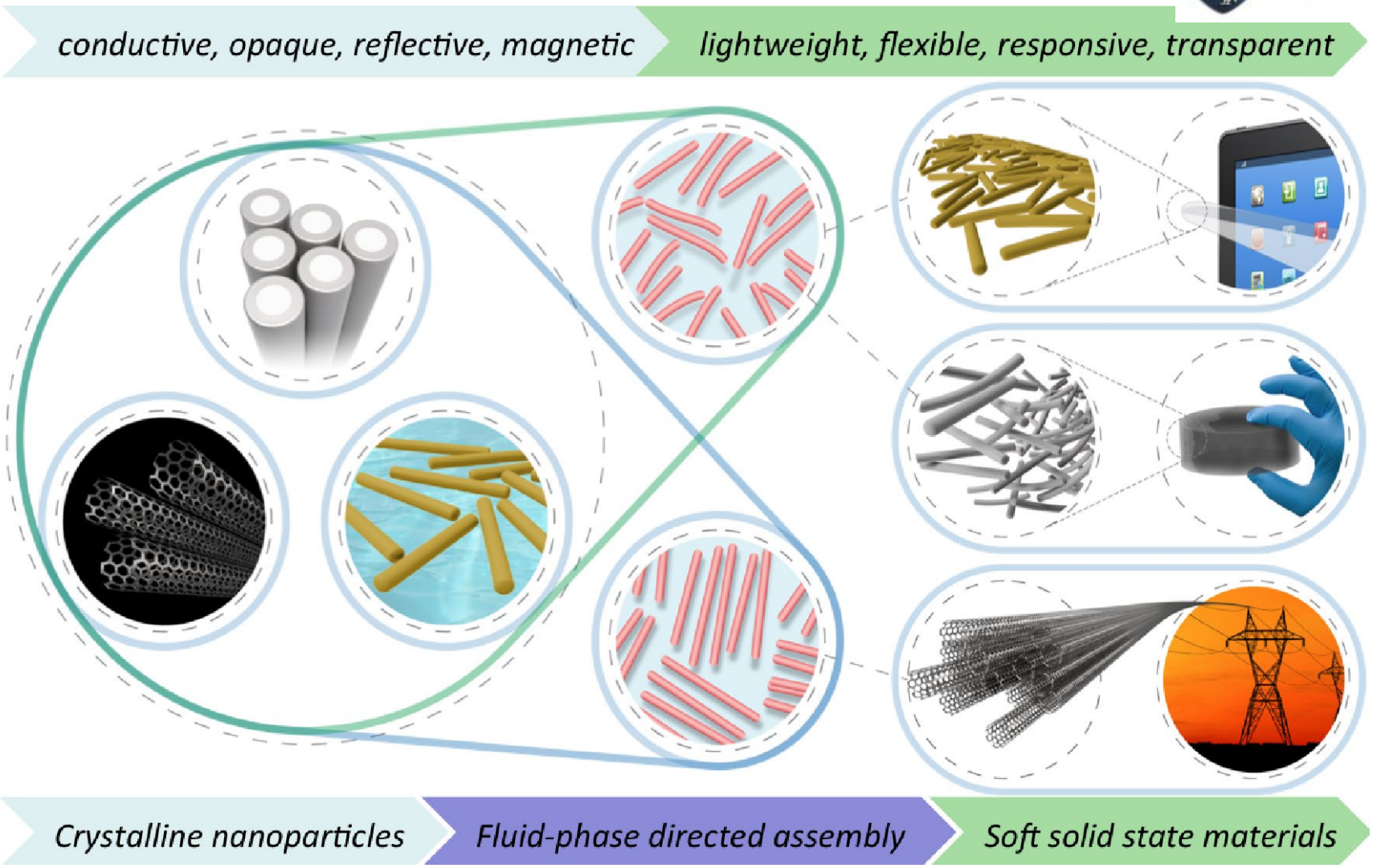
Compared with standard coax cables:

- CNT shielding meets the military standard for signal attenuation
- CNT shielding weighs less than 3% of standard cable shielding
- 60% overall weight reduction from CNT shielding layer



Component	Standard cable (g/m)	CNT cable (g/m)
Inner conductor	1.17	1.17
Dielectric (PE)	1.73	1.73
Outer conductor	**5.40**	**0.025 - 0.1**
Insulating jacket (PVC)	4.35	4.35

DESIGN PRINCIPLE? SOFT, LIGHT CONDUCTORS



- Decouple length scales: short-range order (transport), long-range disorder
- *Combine crystalline building blocks (for electrical & thermal transport) into partially ordered macrostructures (softness)*

COLLABORATORS

- Naty Behabtu, Colin Young, Francesca Mirri, Amram Bengio, Robert Headrick, Junli Hao
- Micah Green, Anson Ma, Theresa Hsu, Bryan Whiting, Alex Lee, Flavia Vitale
- Jun Kono, P.M. Ajayan
- Ishi Talmon, Yachin Cohen, Olga Kleinerman, Judith Schmidt, Ellina Kesselman (Technion)
- Marcin Otto, Ron ter Waarbeek, Jorrit de Jong, Ron Hoogerwerf, Erik Westerhof (Teijin)
- Steve Fairchild, Benji Maruyama, John Ferguson (AFRL)
- Kalman Migler, Nate Orloff, Angela Height-Walker (NIST)

FUNDING

- Air Force Office of Scientific Research
- Air Force Research Laboratory
- Teijin Aramids & Teijin
- Office of Naval Research
- NSF
- NASA
- Welch Foundation