Nanomaterials for

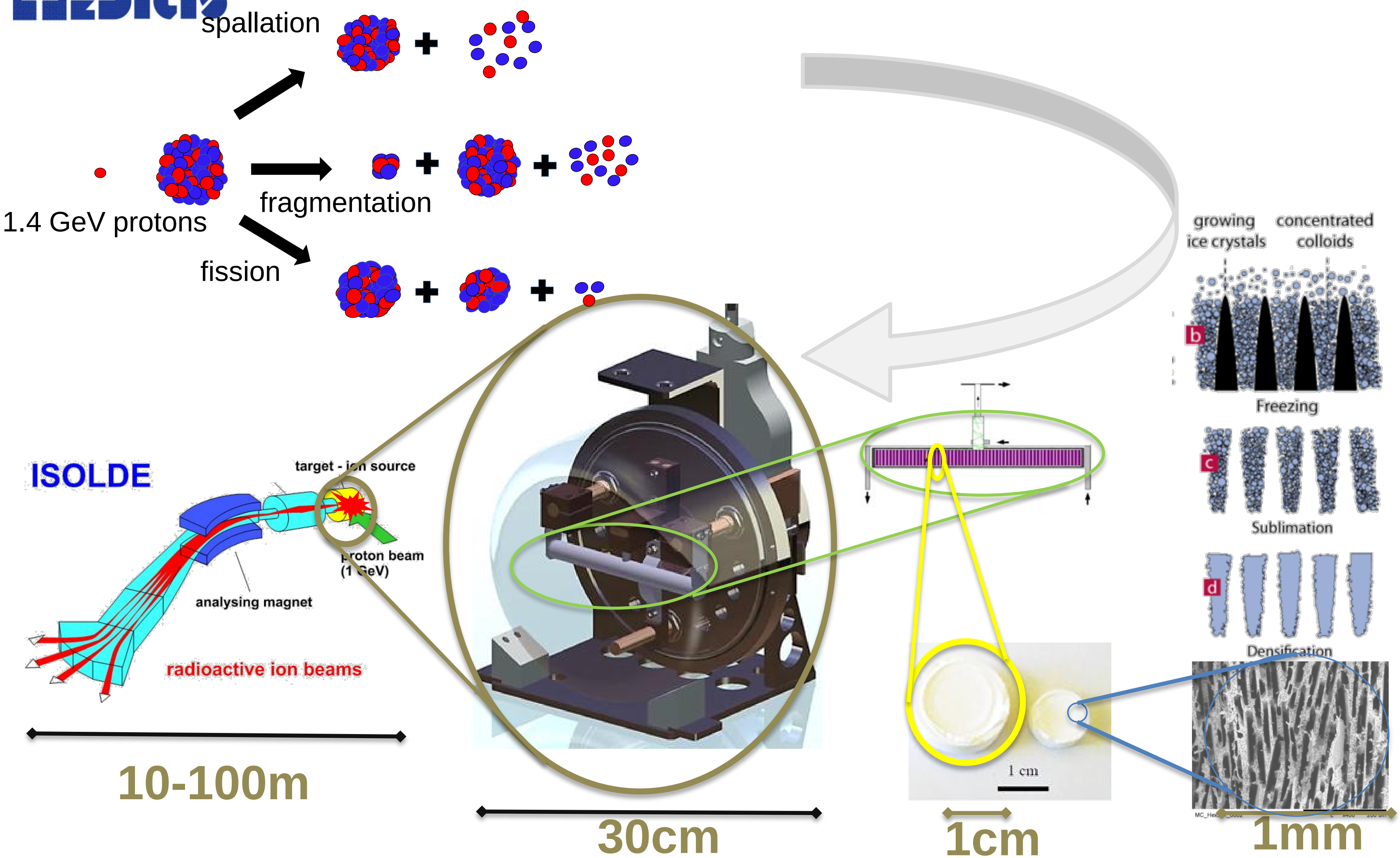
Refractory spallation targets (isotopes)

and for

Microfabrication

Thierry.Stora@cern.ch T. Stora

Radiosotope beams by ISOL method



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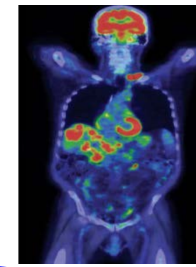
For what type of physics?



Nuclear physics

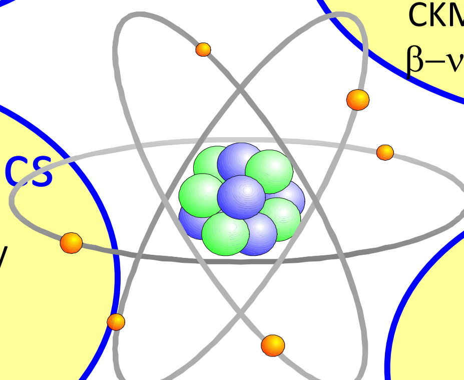
Nuclear Decay Spectroscopy
and Reactions
Structure of Nuclei
Exotic Decay Modes

Fundametal physics

Direct Mass Measurements,
Dedicated Decay Studies - WI
CKM unitarity tests, search for
$\beta-\nu$ correlations, right-hande
currents

Applied physics

Condensed matter physics
and Life sciences
Tailored Isotopes for
Diagnosis and Therapy
MEDICIS Project



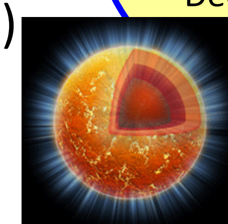
Atomic physics

Laser Spectroscopy
and direct Mass
Measurements
Radii, Moments, Nuclear
Binding Energies

Astrophysics

Dedicated Nuclear
Decay/Reaction Studies
lement Synthesis,
Solar Processes

f(N,Z)



Ion. Pot. (At) = 9.31751(8) eV
Nature Comm. 14May2013

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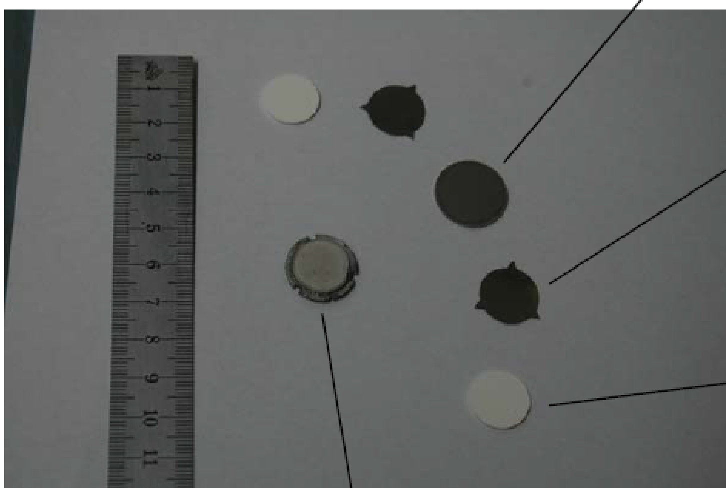
Refractory metal/oxide ceramics composites at very high temperature

- Niobium metal foil thickness 0.5mm
- Ti90 / Al6 / V4 (TA6V) alloy foil thickness 0.1mm
- Aluminium oxide thickness 1mm



Nb

TA6V

Al_2O_3

Final pellet after laser cutting (Ø 18.35 mm)

Nd: YAG laser (0.01mm, 1J, 35 W, 610mm/min)

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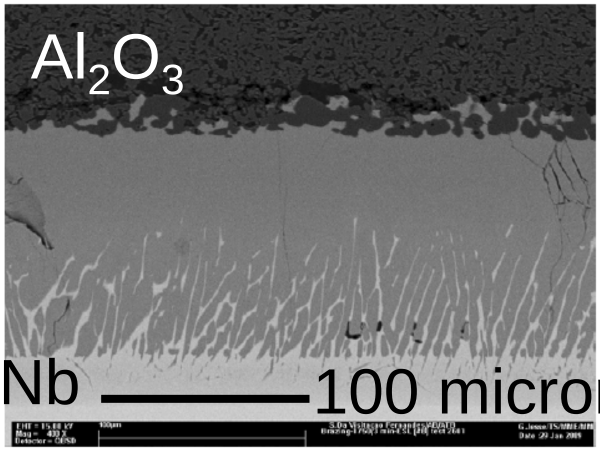
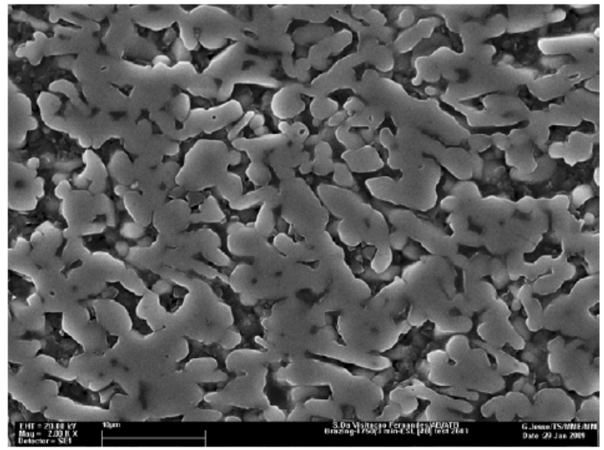
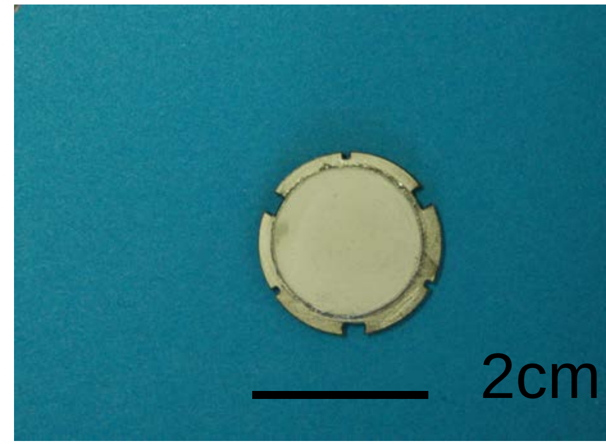
Reactive metal/oxide brazing
Stable at high T
to increase heat dissipation from oxides



Brazing interface Al_2O_3/ TA6V/ Nb



Al_2O_3 microstructure after brazing

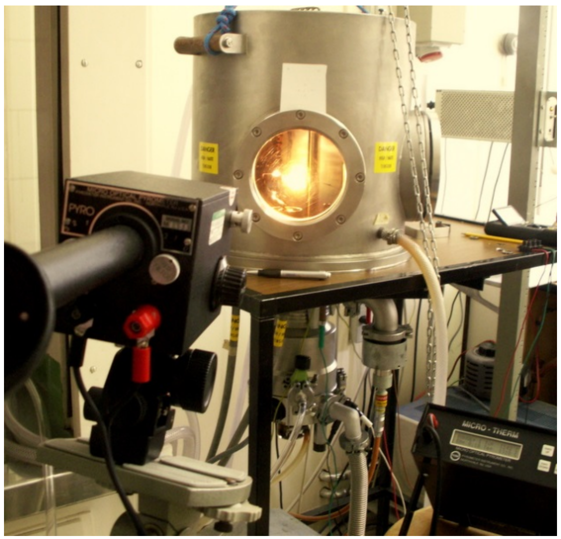


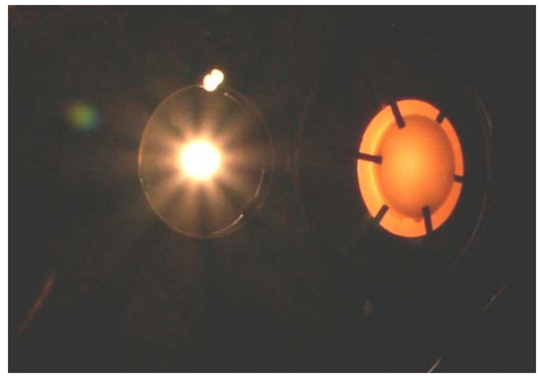
Material	Density (g/cm³)	Melting point (°C)	Thermal conductivity (W/(m·K))
Al_2O_3	2.75 (%69.5 TD)	2054	3.0 - 3.7 (T = 1400°C)
TA6V	4.42	1650	-
Nb	8.57	2468	50-80 (T = 1273 - 2073°C)

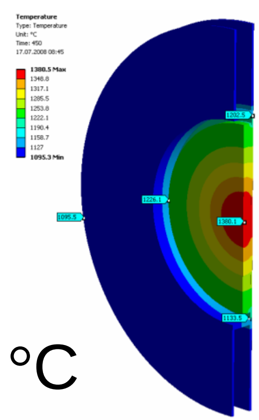
2 relevant properties
(for us, maybe also for you ?)

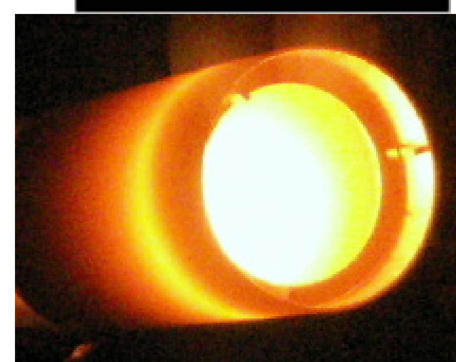
Thermal conductivity & contact conductance

Defective brazing









K > 20'000 W/m^2 K

Resist dilatation/stress at T=1400 °C and ΔT = 400°C

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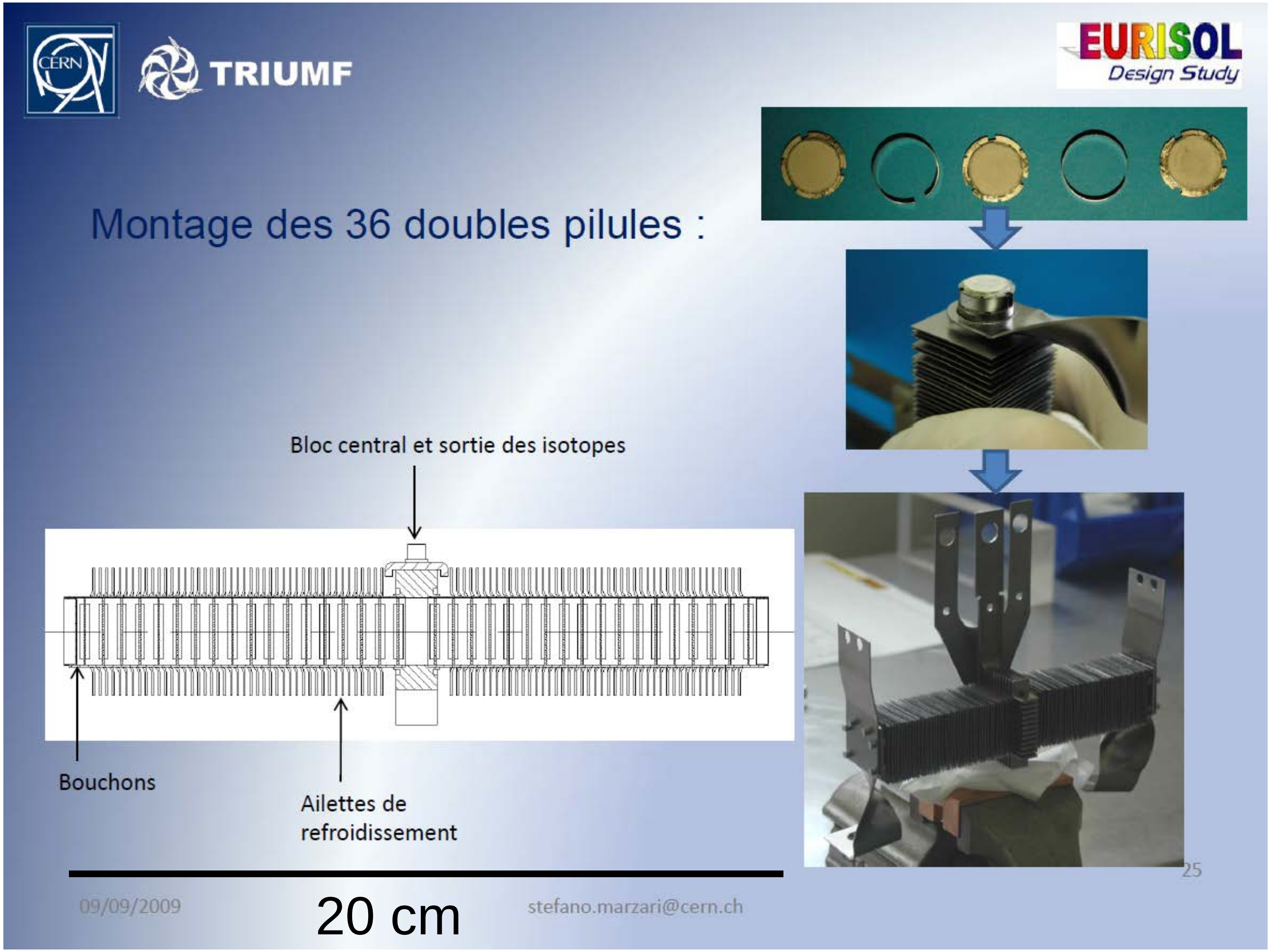
Loading a full cylinder



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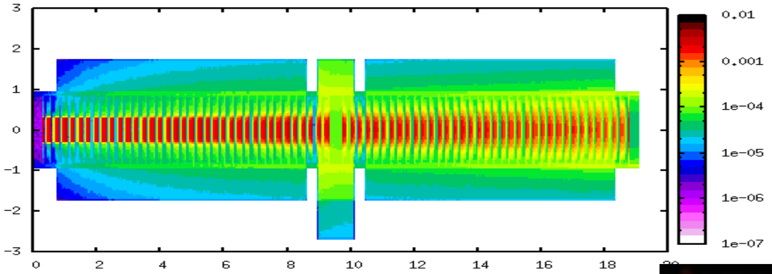
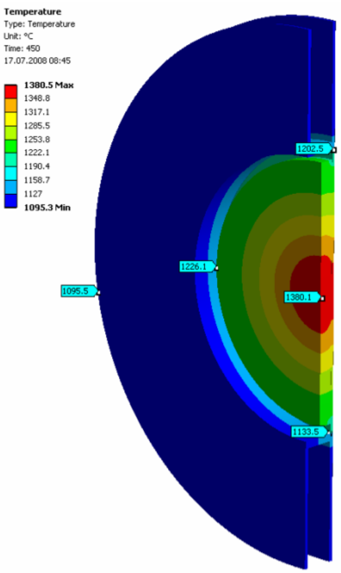
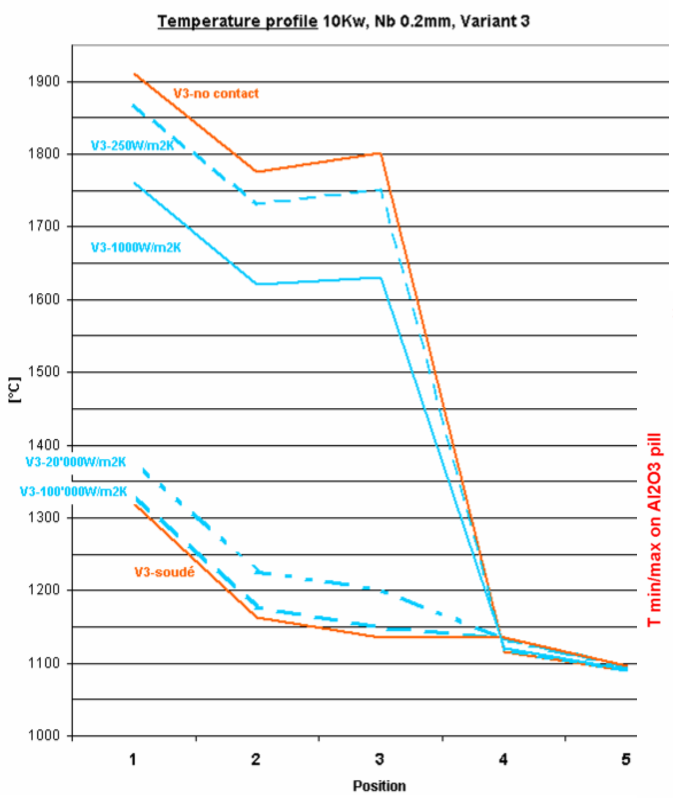
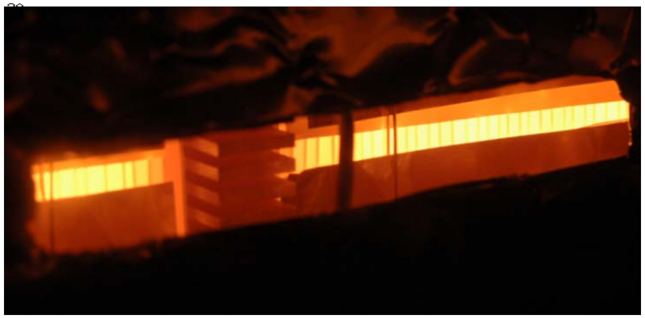
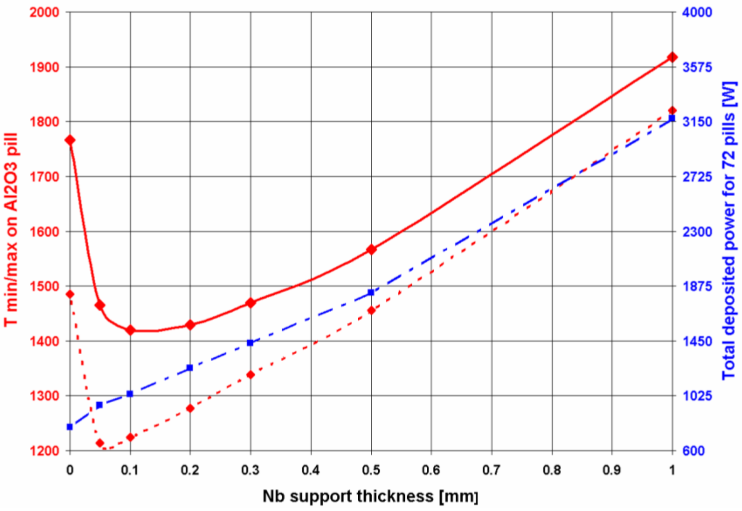
Thermal conductivity & contact conductance











Otherwise, the ceramics does not stand the beam/heat

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Test under beam irradiation : Highest proton beam intensity ever on oxide target

TRIUMF

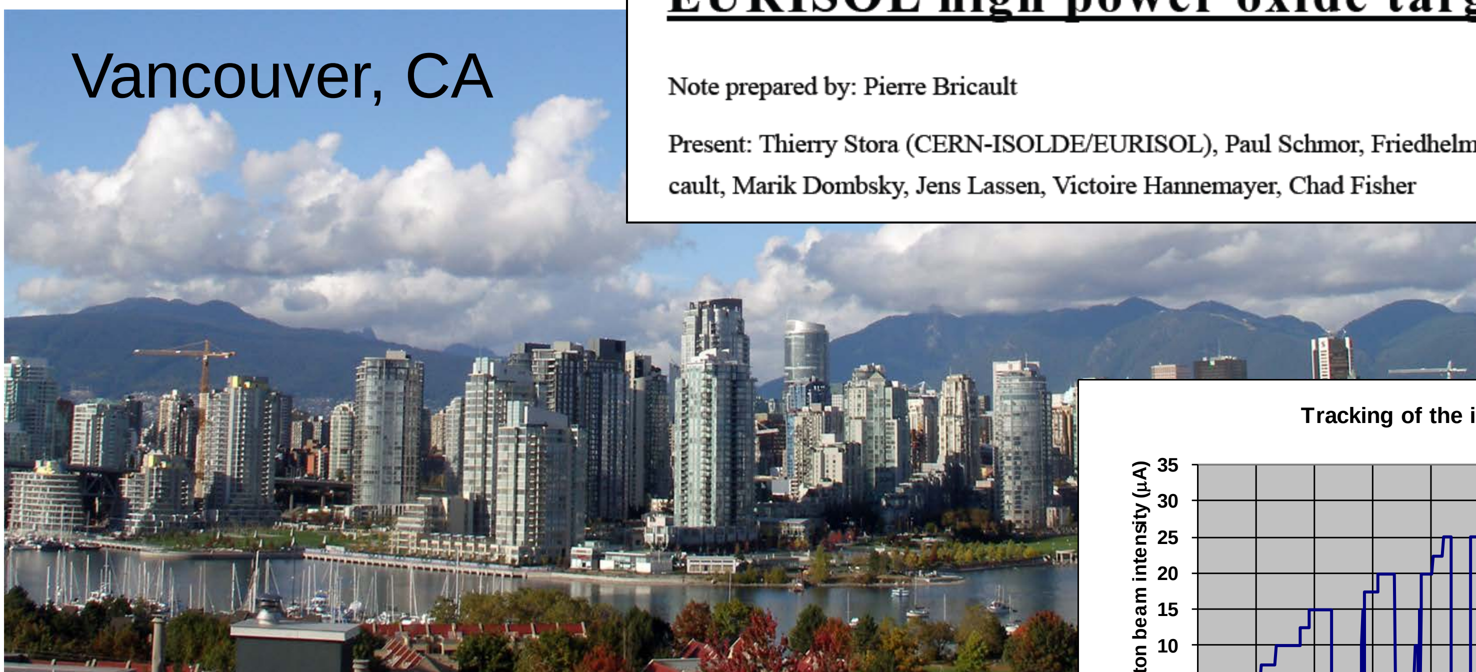
4004 Wesbrook Mall
Vancouver, BC,
Canada V6T 2A3

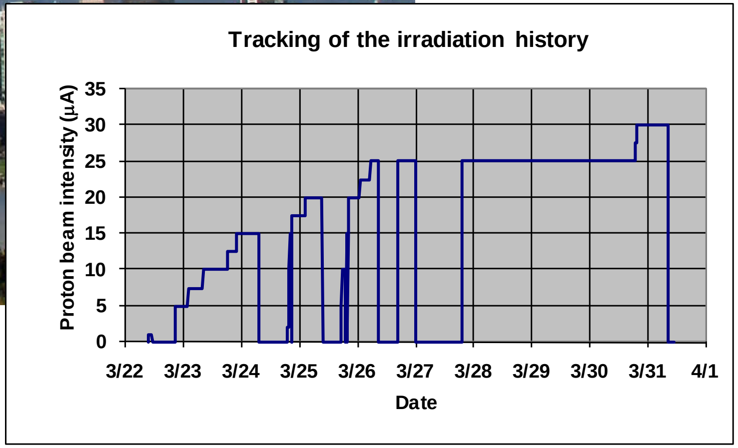
Meeting Note

EURISOL high power oxide target test

Note prepared by: Pierre Bricault

Present: Thierry Stora (CERN-ISOLDE/EURISOL), Paul Schmor, Friedhelm Ames, Pierre Bricault, Marik Dombsky, Jens Lassen, Victoire Hannemayer, Chad Fisher





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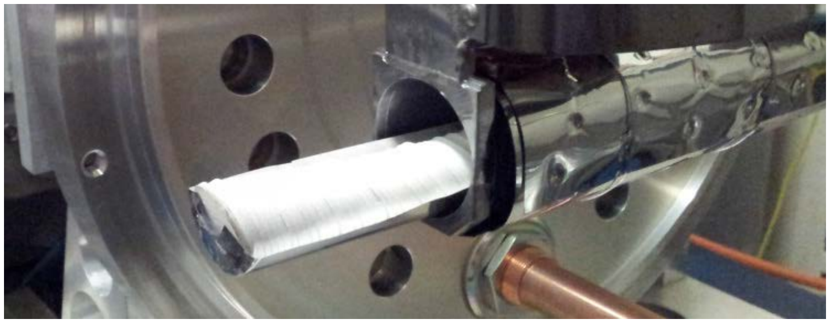
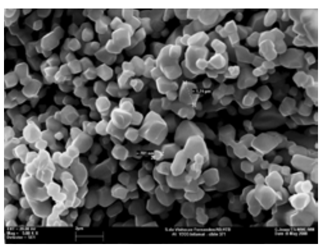
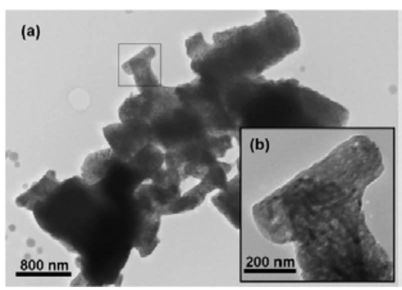
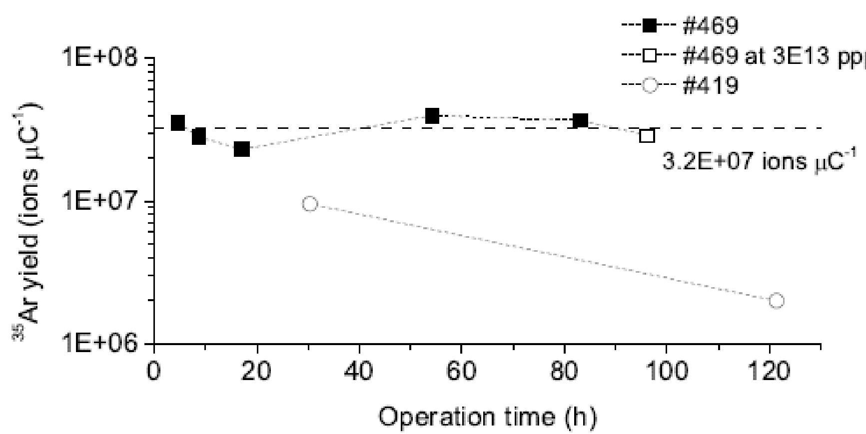
Porous refractory nano-ceramics for other applications ?

Y_2O_3, CaO,
Al_2O_3 with unidirectional porosity,
BeO^*, ZrO_2^*
α-SiC, α-SiC/Carbon nanotubes,
TiC (ongoing)
UC_2/Carbon nanotubes (ongoing)
*:Tested under beam at high T









Highly porous microstructure stable under beam irradiation at high T.

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Nanocomposites for microfabrication

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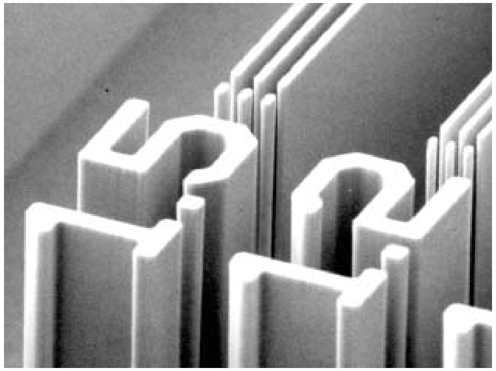

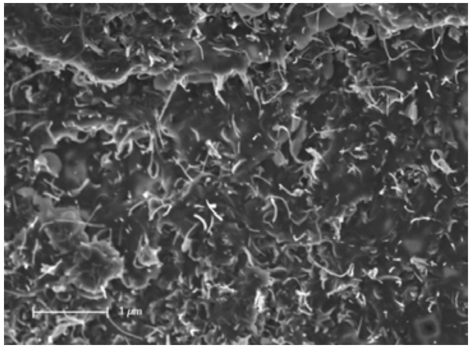

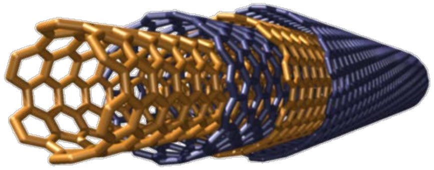

PhD thesis of M. Mionic @EPFL

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Matrix for our composites: SU8

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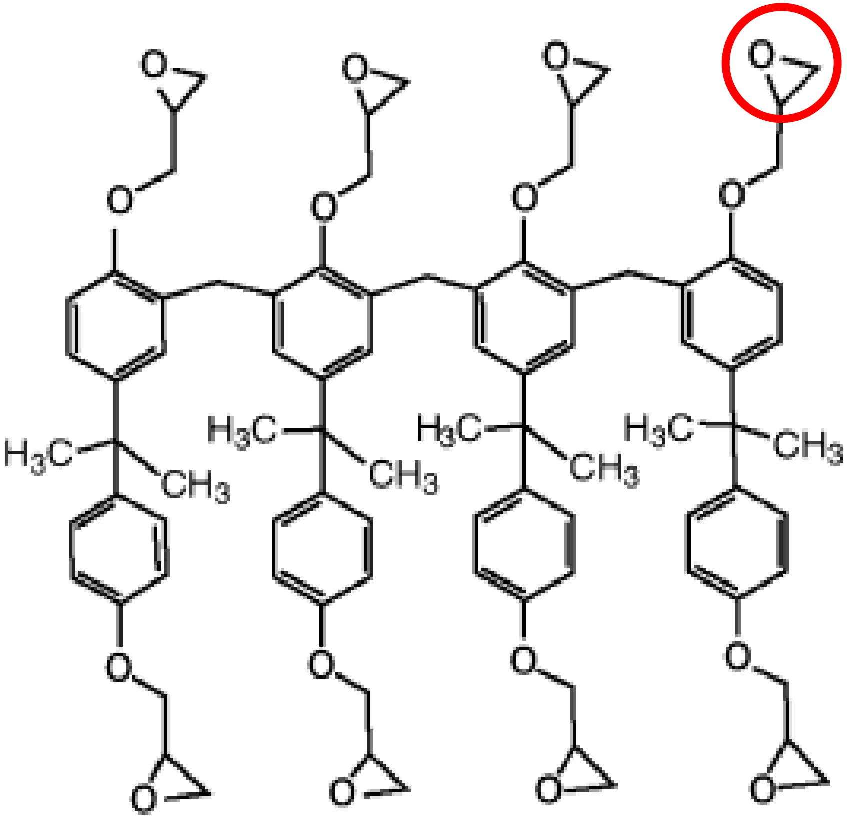
Polymer

UV curable negative ton epoxy resin



Applications

MEMS (Micro-electro-mechanical systems)
MOMES Optoelectronic
BioMEMS Lab-On-a Chip
Advanced packaging
Nanoimprint
Coating layer
Bonding layer
Microfluidic
LIGA-Micro mould
Micro-machining
Stamp manufacturing
Inkjet manufacturing
3D interconnect

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N. Zhang, et al., Smart Mater. Struct. 12 (2003) 260–263.

Illustration for applications of SU8

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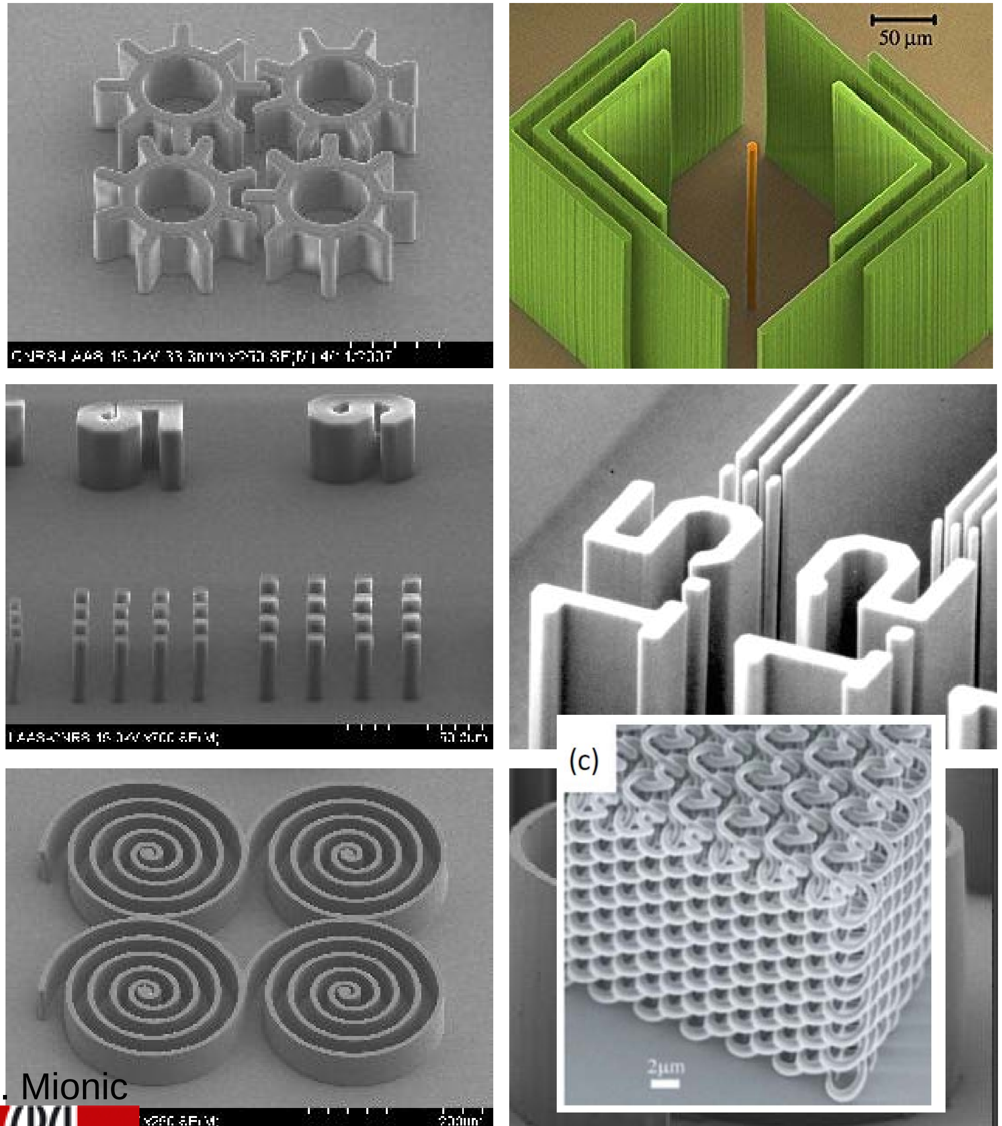

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Advantages:

- Processable with UV
- high aspect ratio structures

Disadvantages:

- Electrical insulator
- Thermal insulator
- Brittle

CNTs

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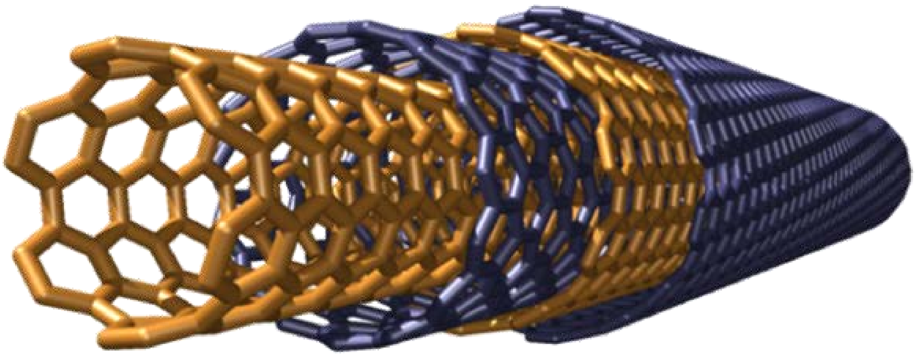

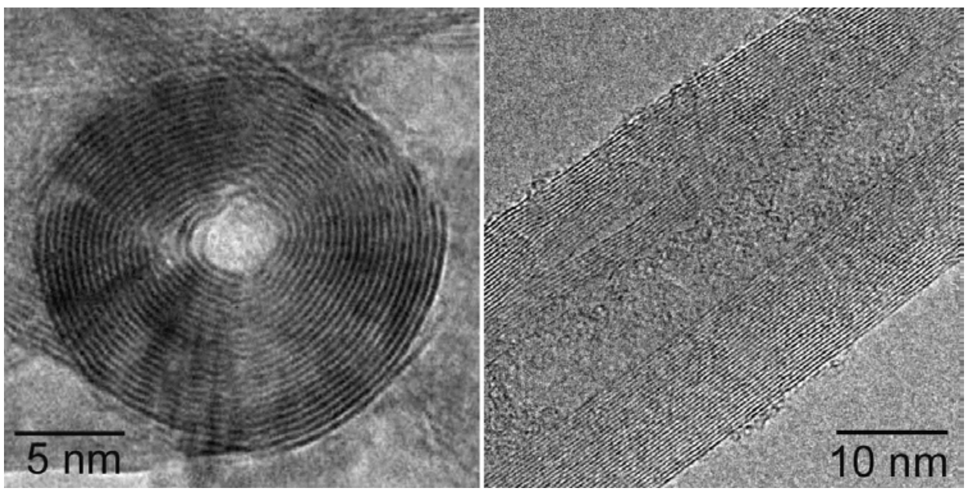

Diameter (from □4Å to □100nm)

Length (from 200nm to □20cm)

High mechanical strength (E_Y□1TPa)

High thermal conductivity (□3000W/mK)

Low resistivity (> 10^{-8}□m)

Low density (from 1.3 to 2.6g/cm^3)

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Control of aggregation/network with surfactant and solvent

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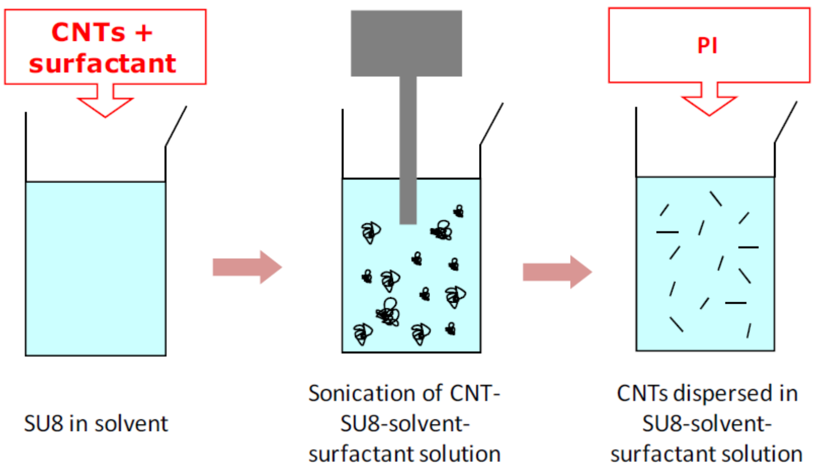

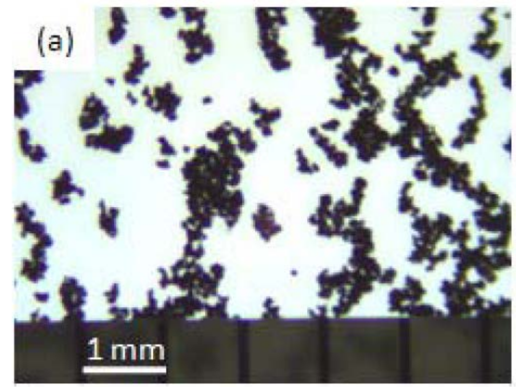

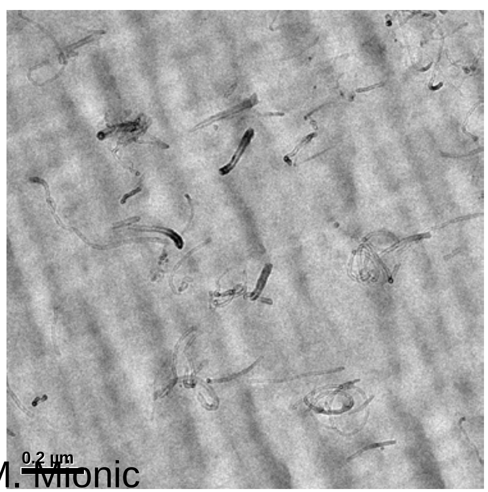

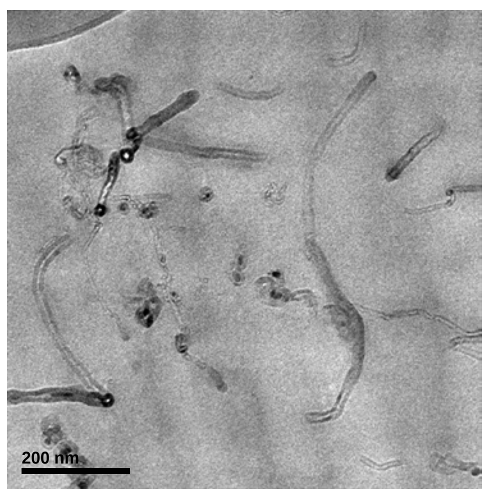

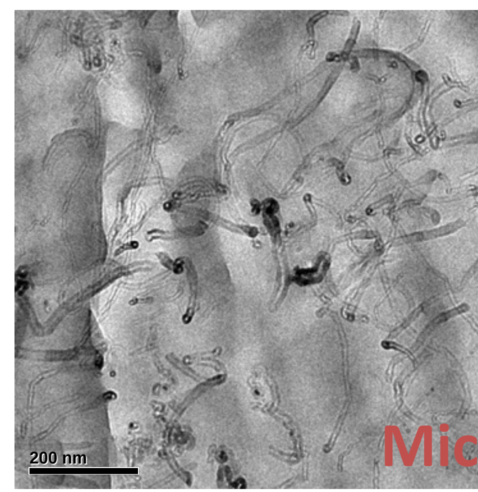

Microtome

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% of CNTs in SU8 | 0.5 wt% of CNTs in SU8 | 1.4 wt% of CNTs in SU8

Mechanical test: nanoindentation

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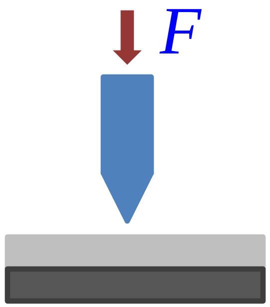
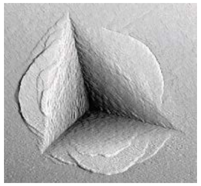
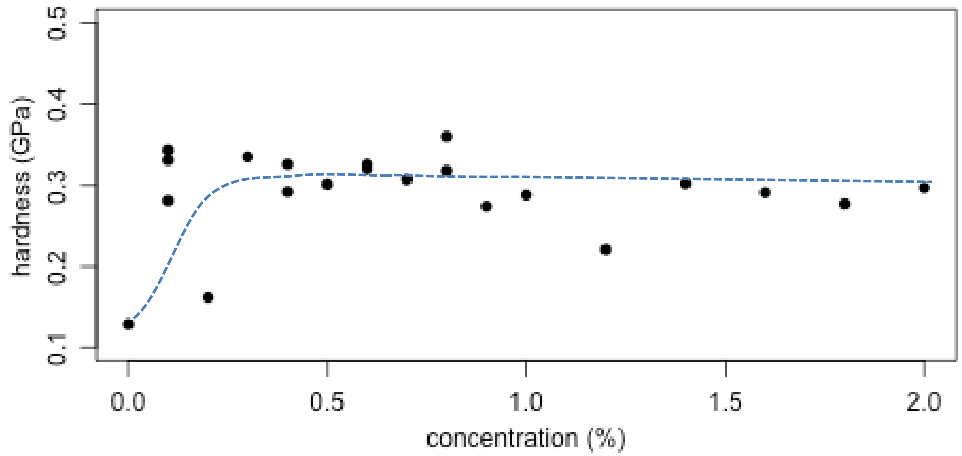
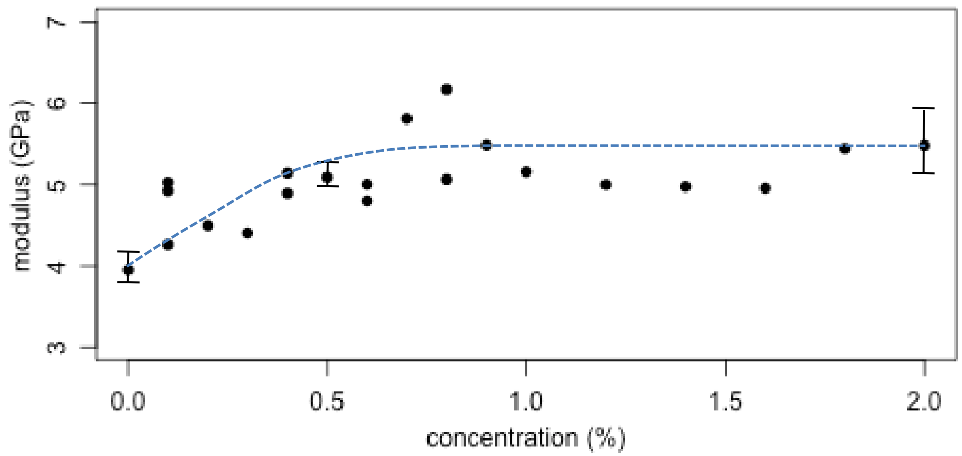




$$H = \frac{F_{max}}{A}$$

$$E = \frac{S\left(1-\nu^2\right)\sqrt{\pi}}{2\beta\sqrt{A} - \frac{S\sqrt{\pi}\left(1-\nu_i^2\right)}{E_i}}$$



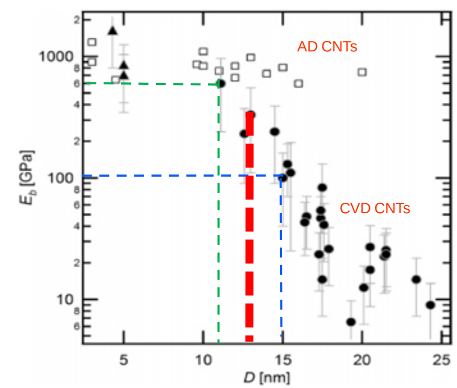


$$E = E_{CNT}V_{CNT} + E_{SU8}(1 - V_{CNT})$$

(role of mixture)

$d_{aver.} \approx 13$ nm

$E_{CNT} \approx 300$ GPa



CNTs	ETheory	EMeasured
0.2%	4.5GPa	4.5GPa
0.8%	6.3GPa	6.2GPa

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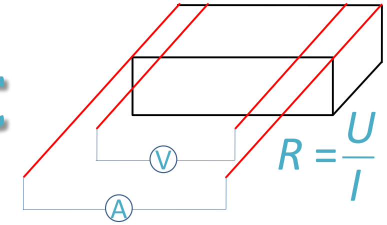
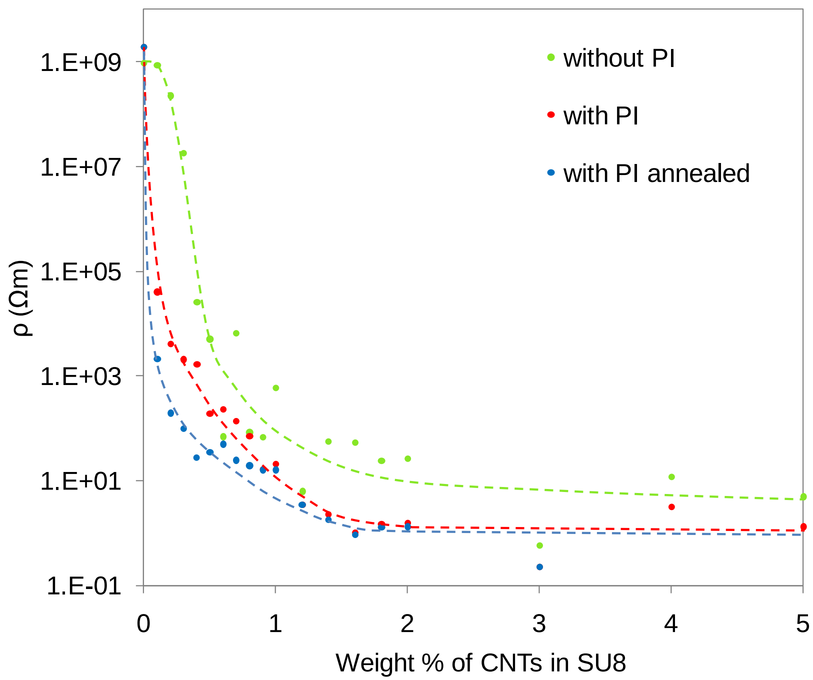
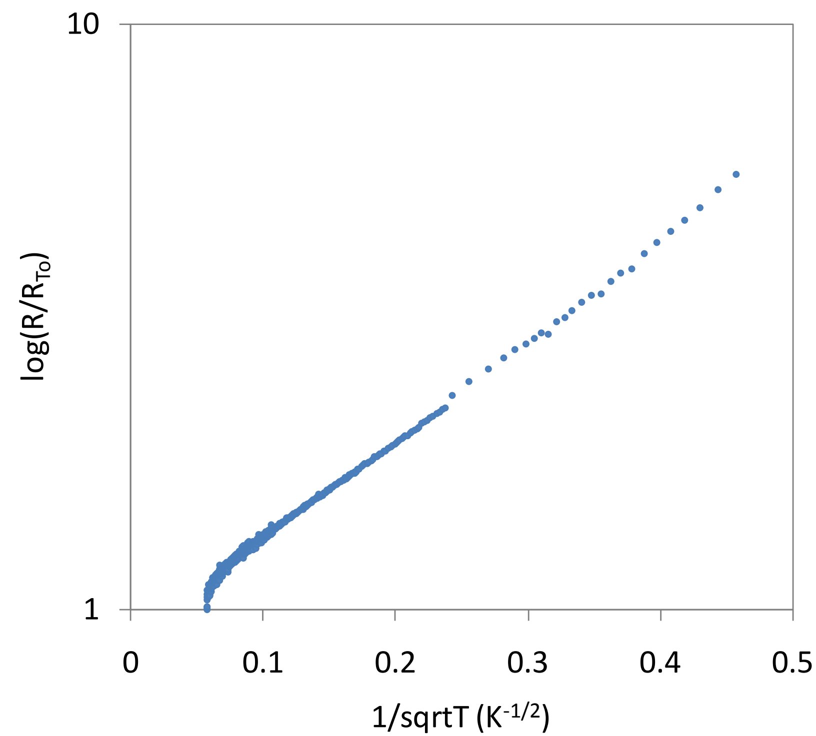
Resistivity measurement



Percolation threshold



Conduction mechanism



< 0.2wt% of CNTs => homogeneous arrangement of CNTs

$$R \propto T^{-\alpha} \qquad \alpha = \frac{1}{2}$$

In generally attributed to the presence of Coulomb gap

-In the homogeneous system of localized interacting e

- in the form of charging E in a granular metal systems

M. Mionic

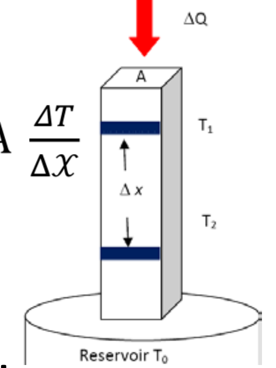
Efros and Shklovskii, JPC 1975,

P. Sheng, PRL 1973

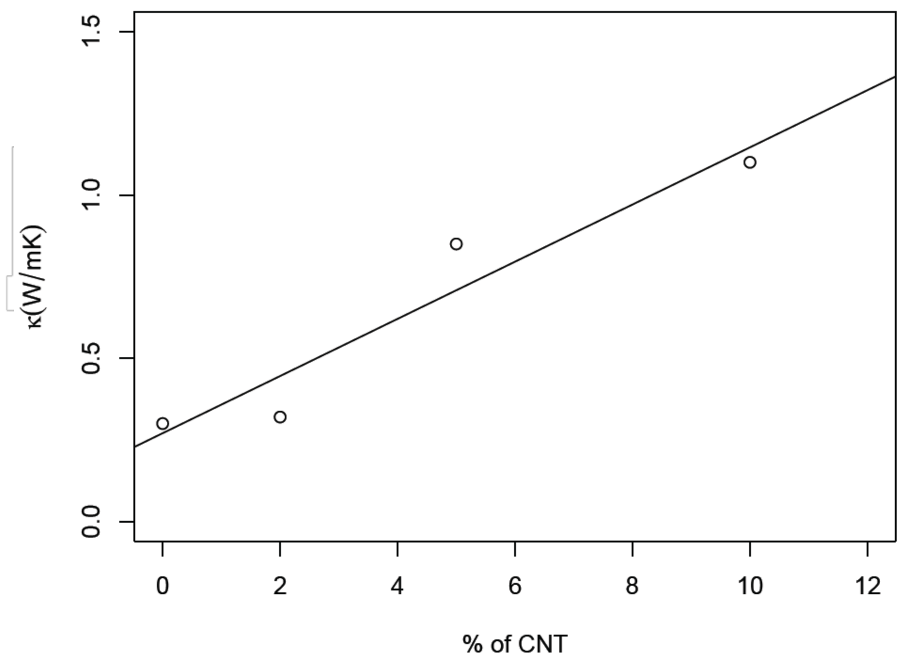
Work with R. Gaal

Thermal conductivity

$$\frac{\Delta Q}{\Delta t} = -\kappa A \frac{\Delta T}{\Delta x}$$

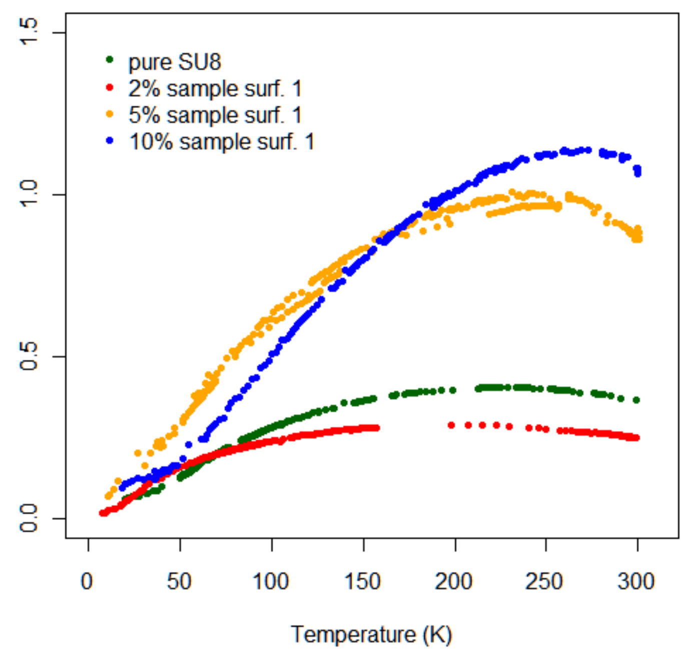


Thermal conductivity at room temperature



With 10wt% of CNTs – 4 fold increase

Mechanism of thermal conductivity



Governed by lattice thermal conductance

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Processing of CNTs-SU8 composite

- Photolithography
- Inkjet printing
- Screen printing

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Photolithography

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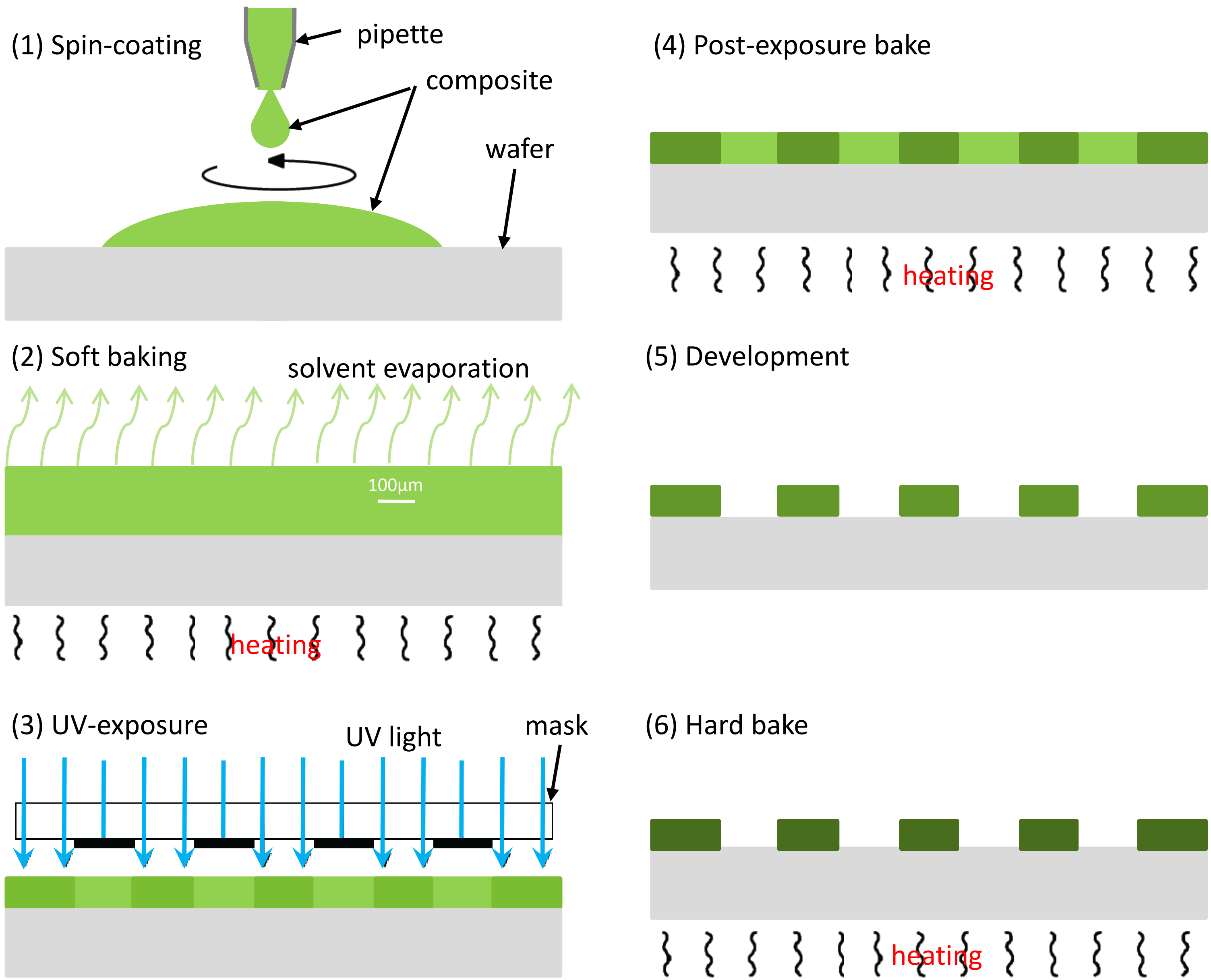

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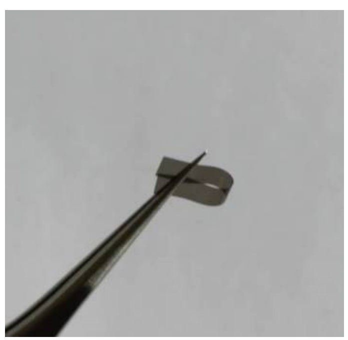
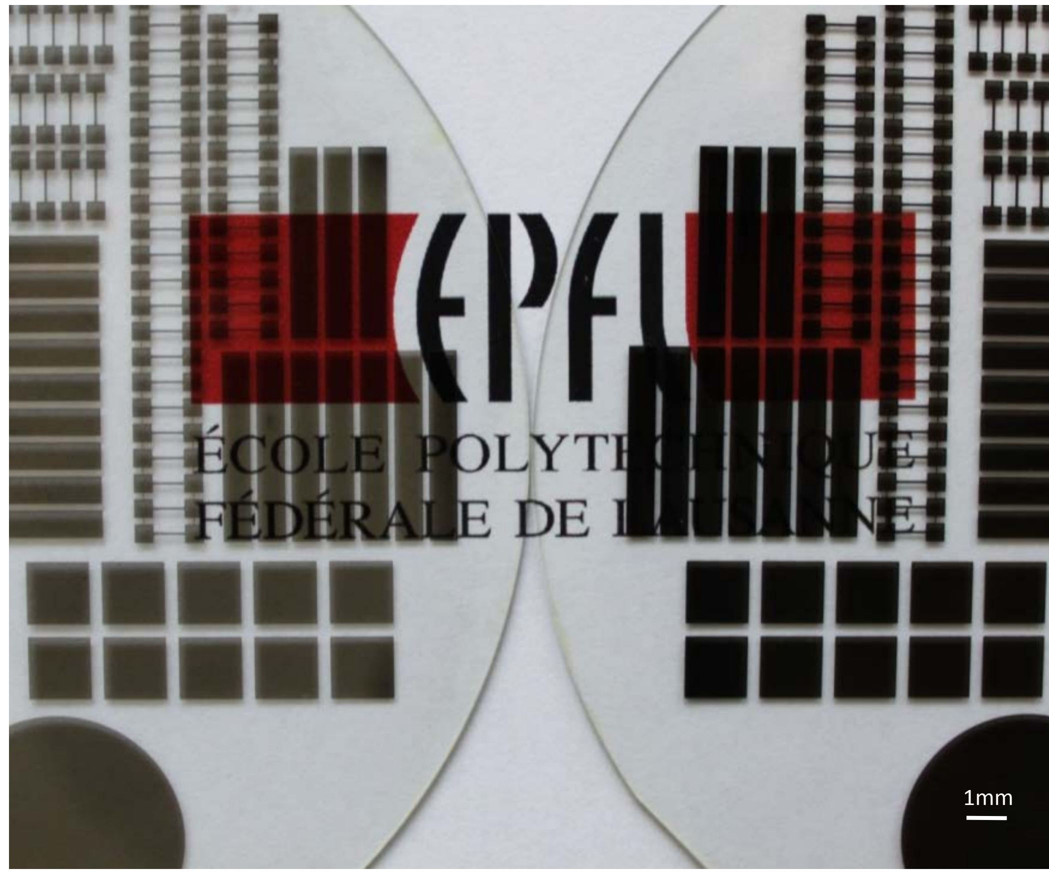
Photolithography





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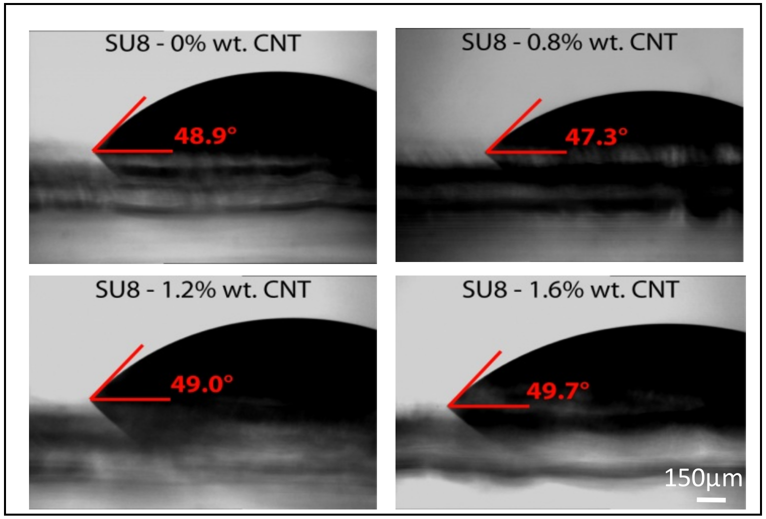
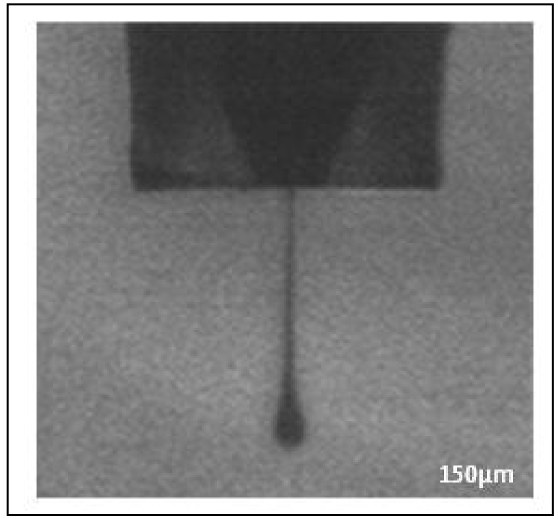
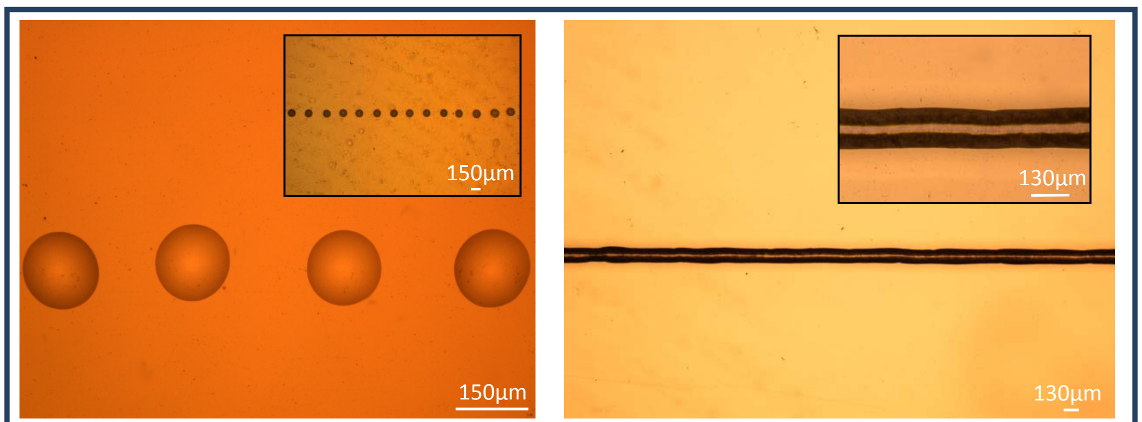
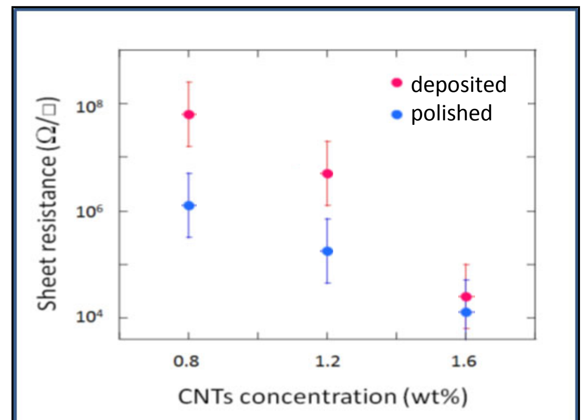
Inkjet printing









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M. Mionic *et al. Journal of Materials Chemistry* **22** (2012) 14030-14034

Screen printing

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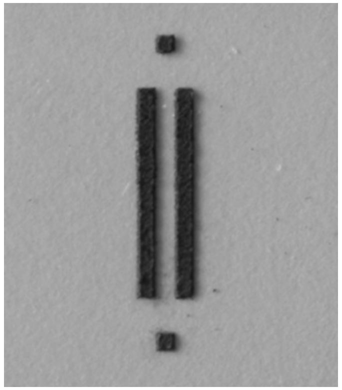
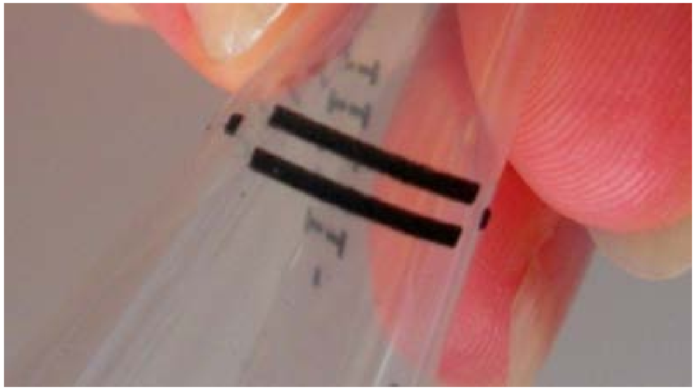
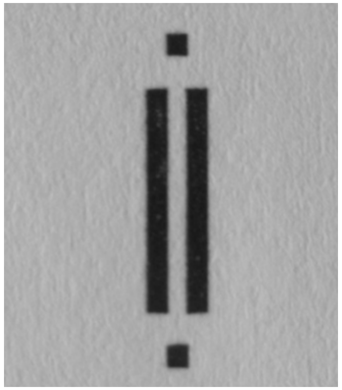
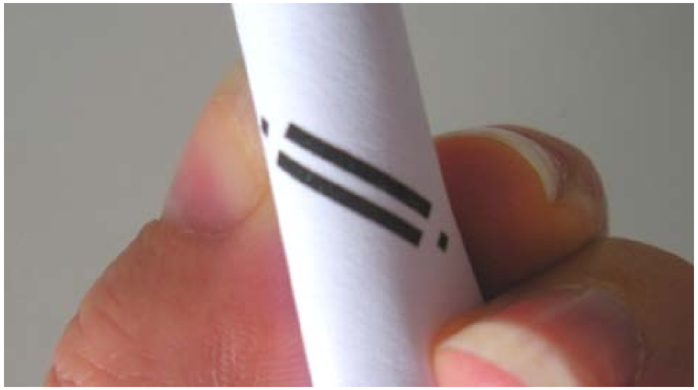
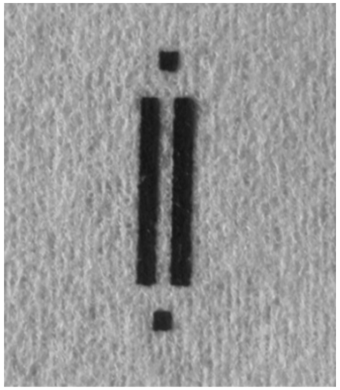



On plastic foil

On paper




On textile

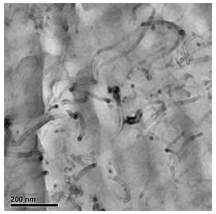
M. Mionic

Summary and outlook

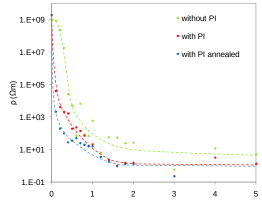
T. Stora

Summary

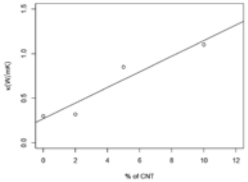
-Preparation of homogeneous CNTs-SU8 composites



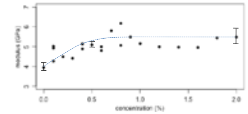
- Turned into good electrical conductor



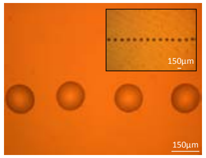
- Improved thermal conductivity



- Better mechanical response



- Easy processability



Outlook

- Composite ready for real applications

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Outlook, references

Logo and safety protocols related to processes with nanopowders (A. P. Bernardes).

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FP6 EURISOL-DS, FP7 ENSAR, FP7 ITN Marie-Curie CATHI, HIE-DS

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