



nanoUmbilical Workshop

Steps to Manufacture the PNU

Yao Zhao, Divya Kannan Chakravarth, Padraig Moloney,
Lori Jacob, Dean Hulseley and Dr. Enrique V. Barrera

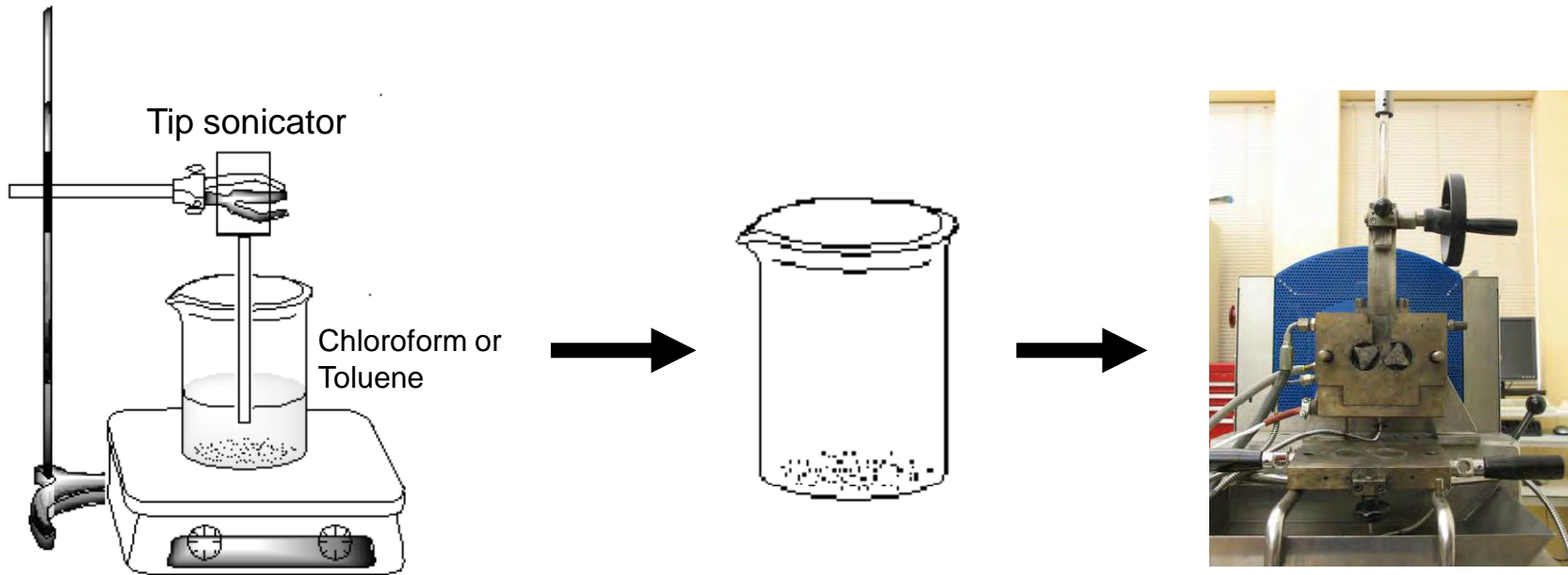
Outline

- Dispersing nanotubes in the polymer matrix
- Manufacturing fibers and wires
- In-situ and post treatments

Dispersing nanotubes in the polymer matrix

- Nanotubes/HDPE (RU developed process)
 - Incipient wetting
 - Mechanical mixing
- Nanotubes/MDPE (Use of autoclave)
 - Creating porous MDPE powder
 - Solution mixing assisted by ultrasonic agitation
 - Mechanical mixing

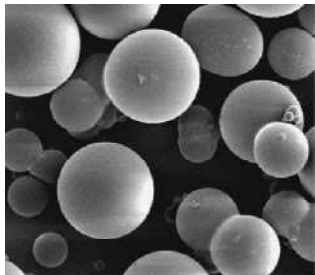
Dispersing CNTs in the HDPE matrix



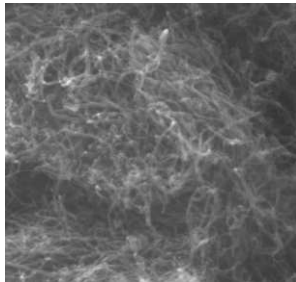
Incipient wetted HDPE powder

HDPE powder

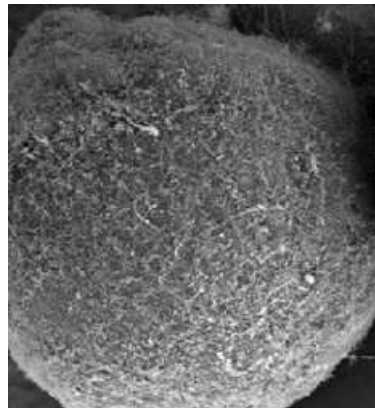
CNTs



+



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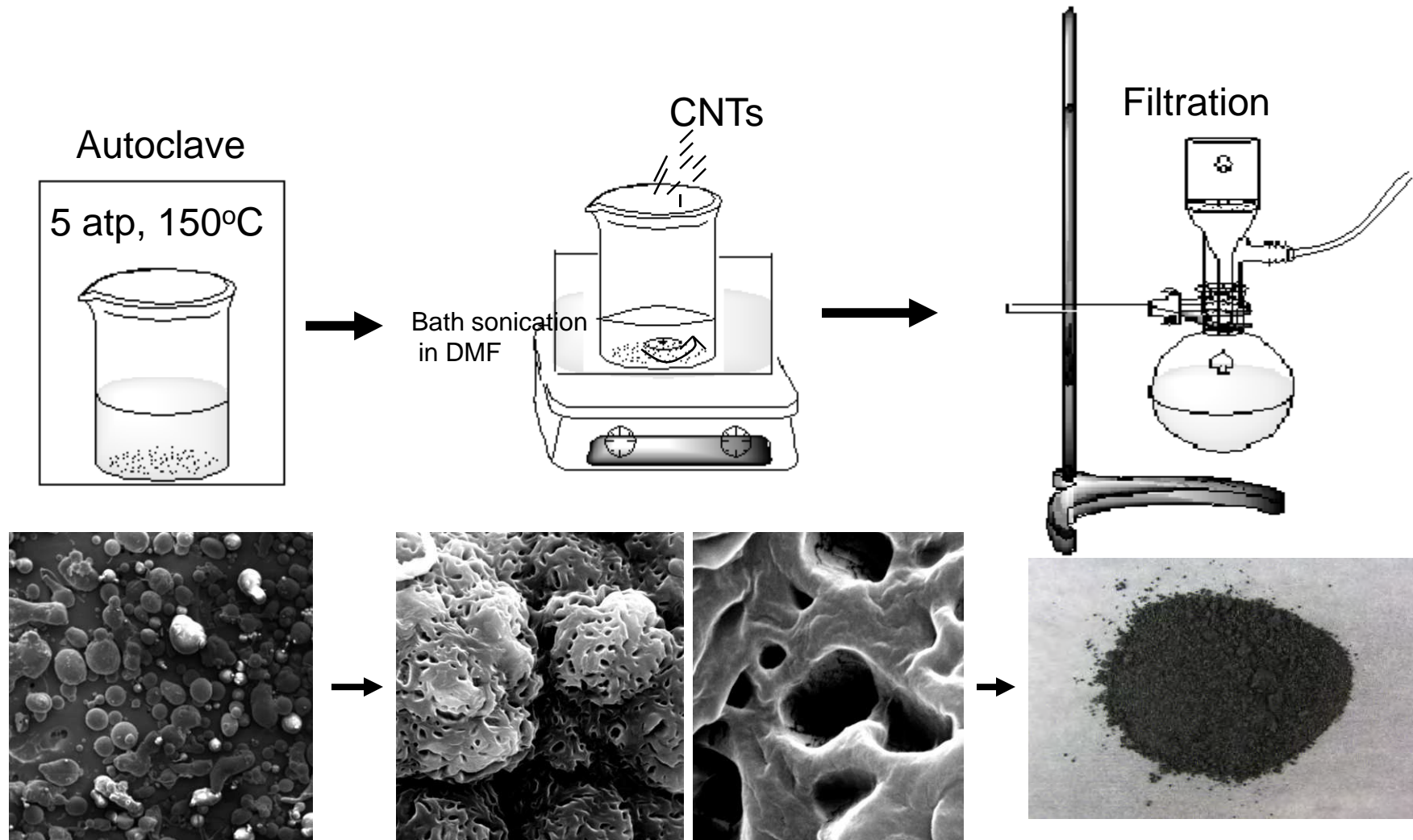


Masterbatch of the composite

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Dispersing CNTs in the MDPE matrix



Manufacturing fibers

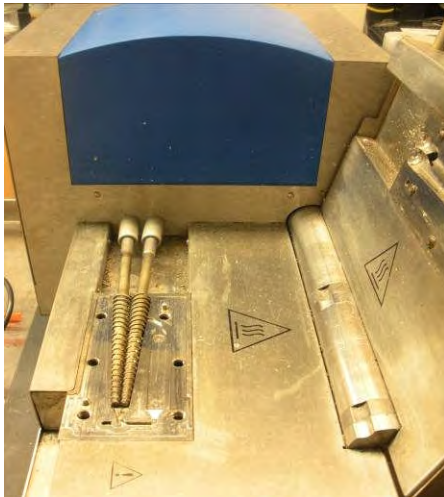
- Solution spinning
 - Relatively slow
 - Removing solvent is required
- Electrospinning
 - Fiber size is small (nano-micro size in diameter)
- Melt spinning
 - High production
 - Produced fibers suitable for macro applications

Melt spinning

1) Injection Molding
3 g size



2) Haake Mini lab
10 g size



3) Haake Extruder
100 g size



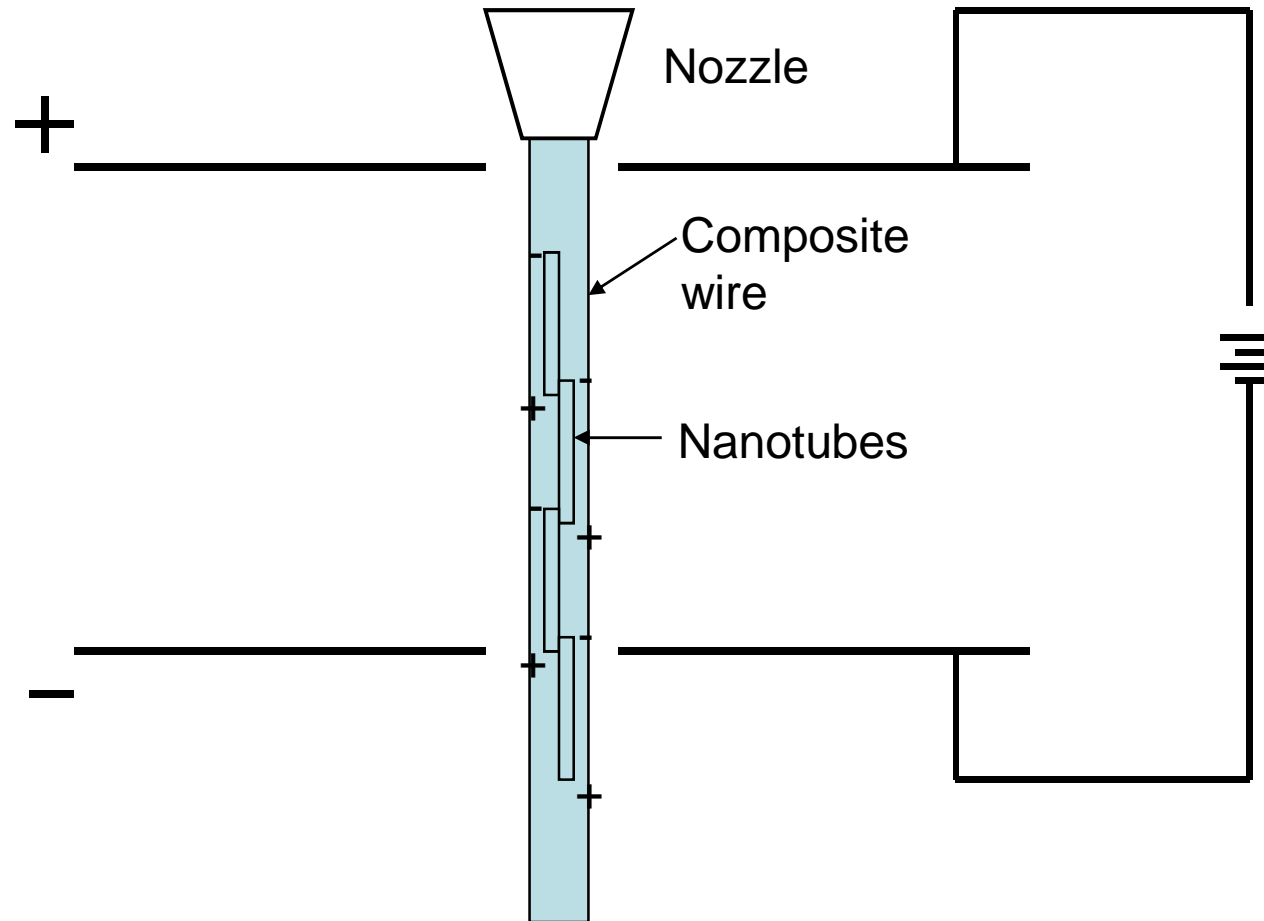
4) M-scientific Extruder
200 g size



In-situ and post treatments

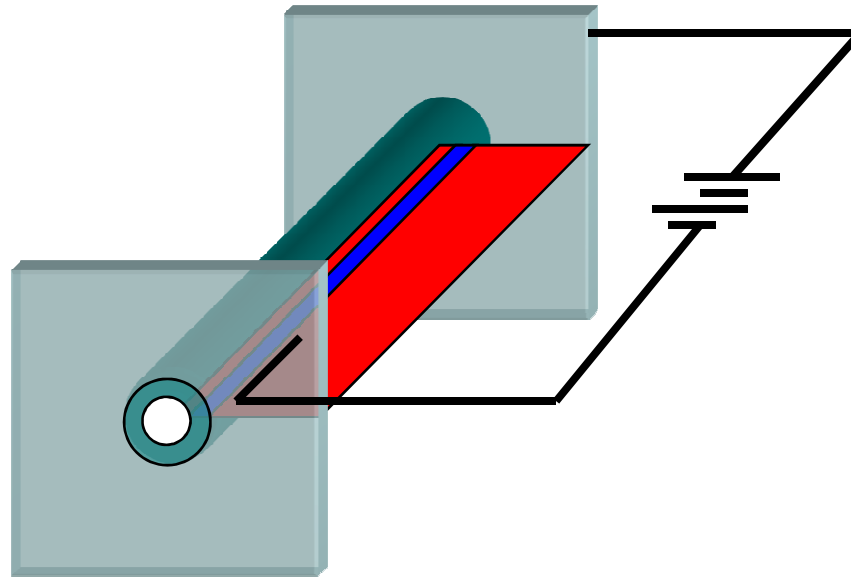
- In-situ electrical field assists alignment
- Post treatments
 - Annealing
 - Doping
 - Passing current
 - Hydrostatic pressure

2 functions of the electrical field

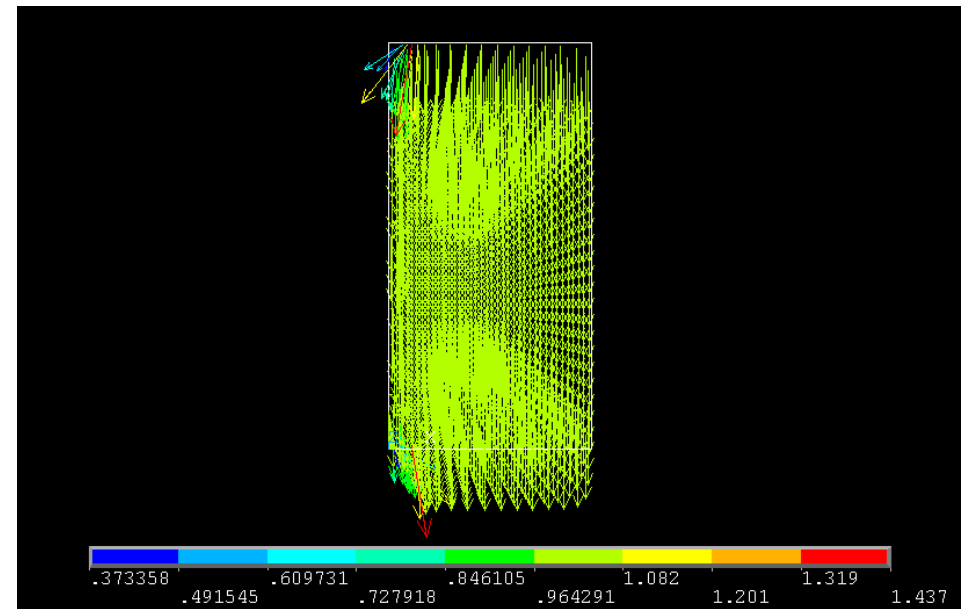
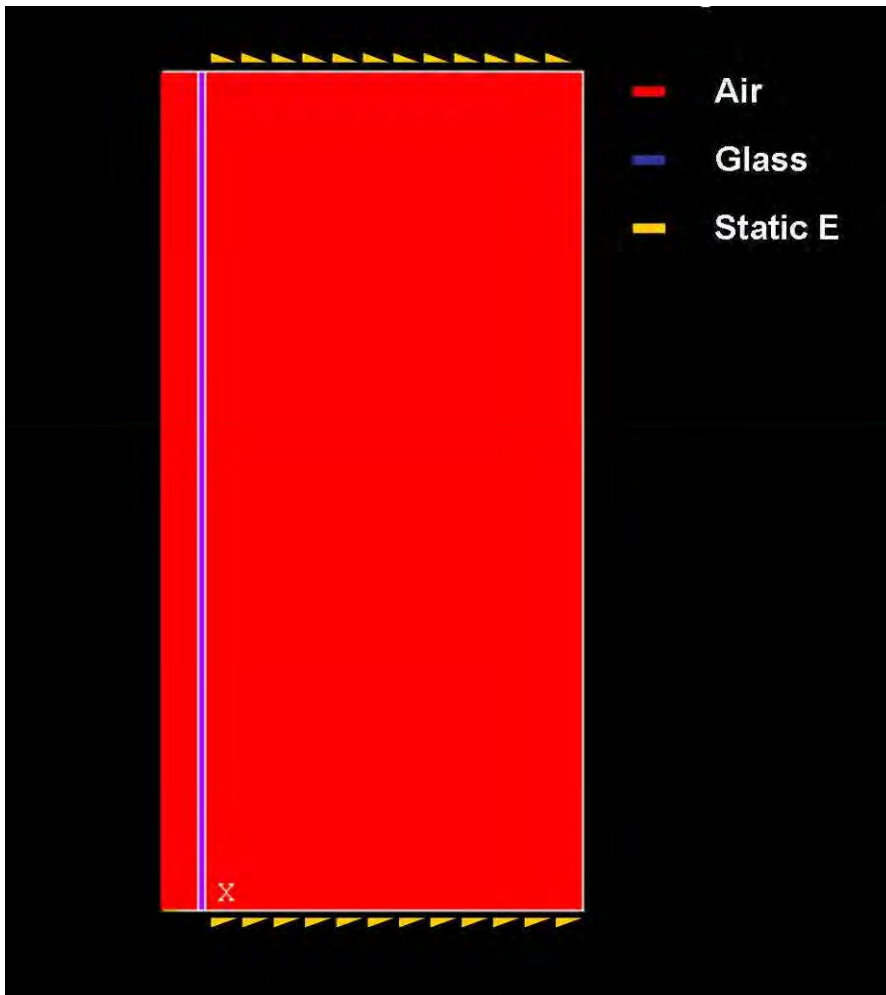


- ❖ NTs are dipolarized by the external electrical field.
- ❖ The opposite charges bring NTs closer and enhance alignment.

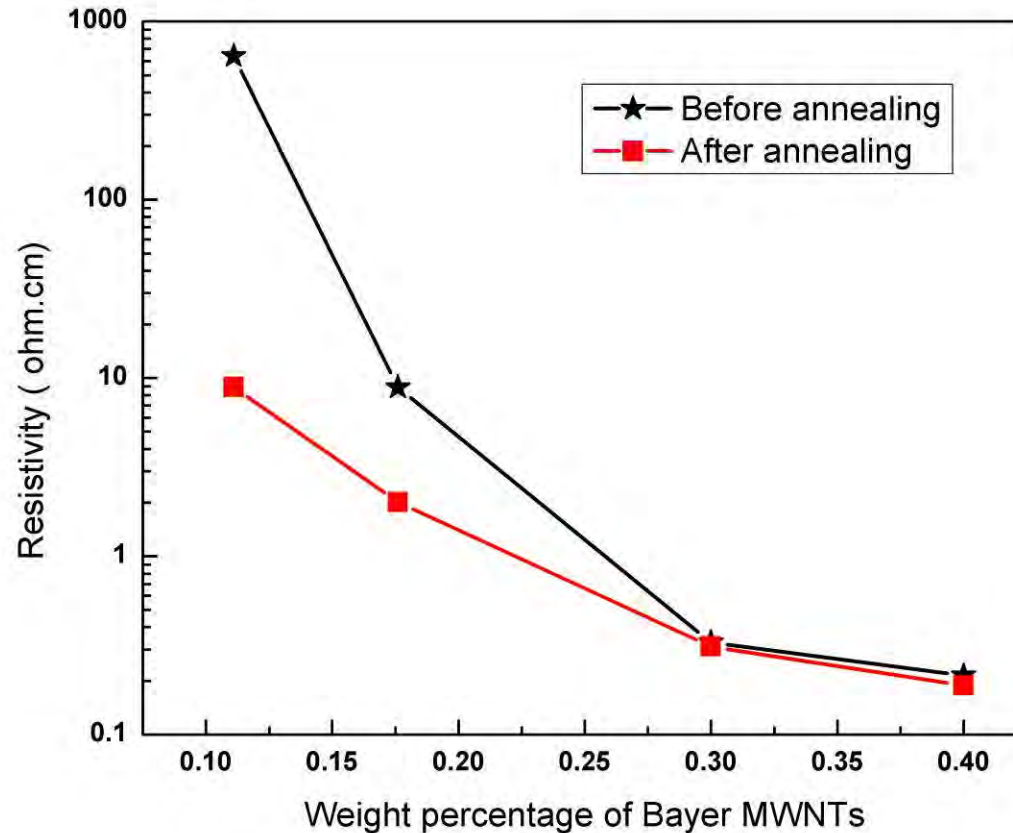
Electrical field setup design



Finite element analysis

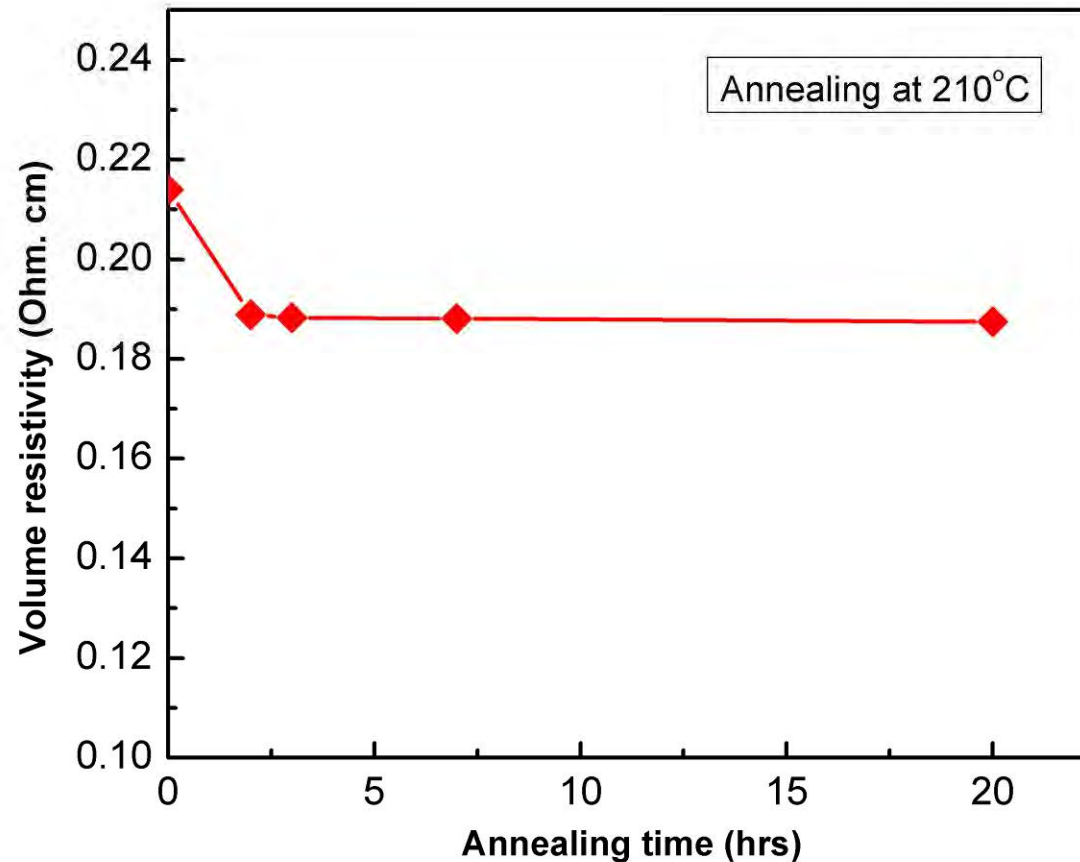


Annealed vs. unannealed



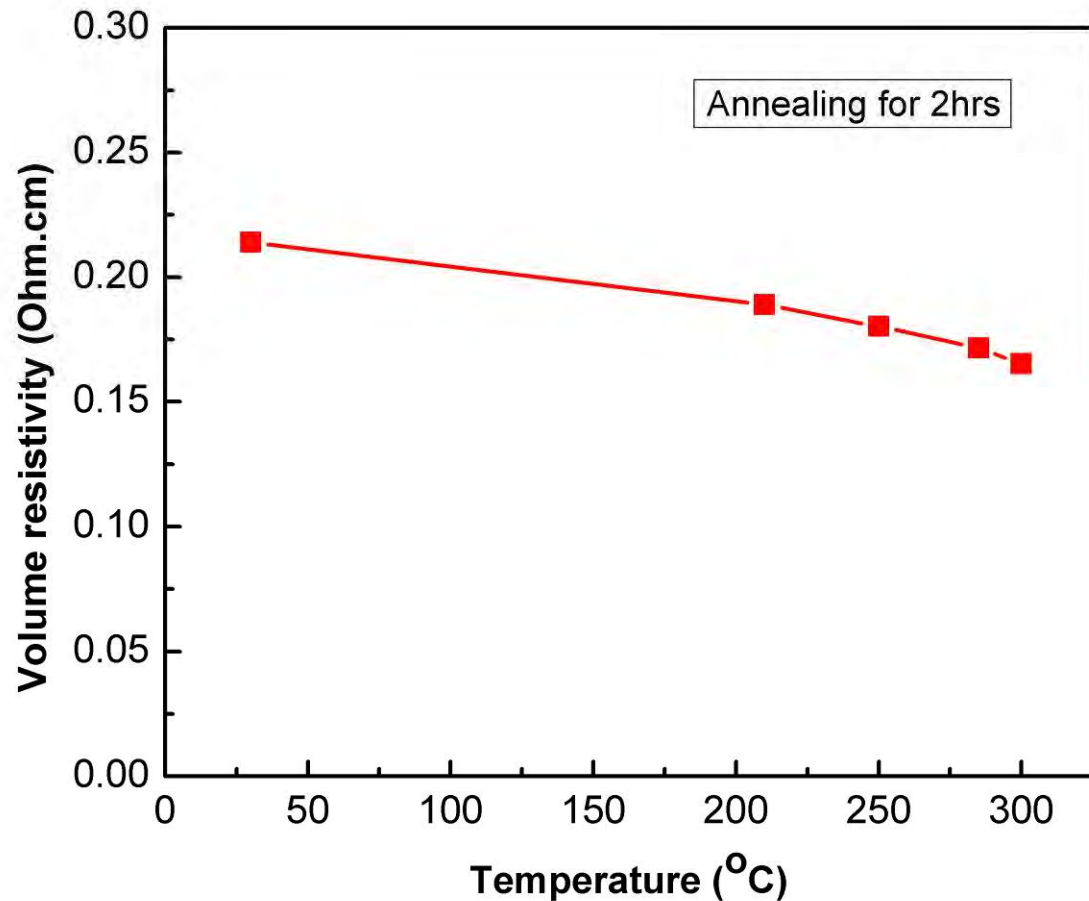
The annealing effect on improving the conductivity is more pronounced in the Low loading ratio region. The effect dims when the loading ratio reaches 30 wt% and Beyond.

Annealing time effect



Annealing time longer than 2 hrs does not help in improving the conductivity.

Annealing temperature effect



As annealing temperature increases, the conductivity of composite wires increases slightly.

Iodine doping

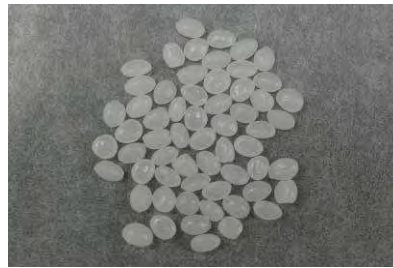


Sublimation temperature of iodine is $113.7\text{ }^{\circ}\text{C}$
The doping was taken place at $130\text{ }^{\circ}\text{C}$ for 8 hrs.

The resistivity has been reduced by a factor of 3.
Original: $4.17 \times 10^{-1}\text{ ohm.cm.}$
After doping: $1.41 \times 10^{-1}\text{ ohm.cm.}$

Other than Iodine doping, SOCl_2 and Li doping
Have been studied.

Steps to Manufacture the PNU



HDPE Pellets

Grinding
→



HDPE Powder

Incipient
wetting
→



Mixing
↓



Hot pressing
↓



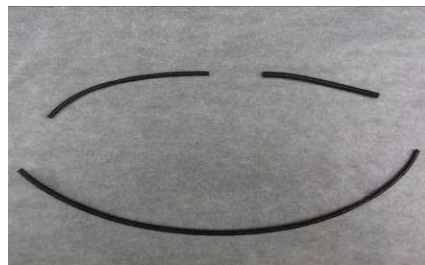
Cutting
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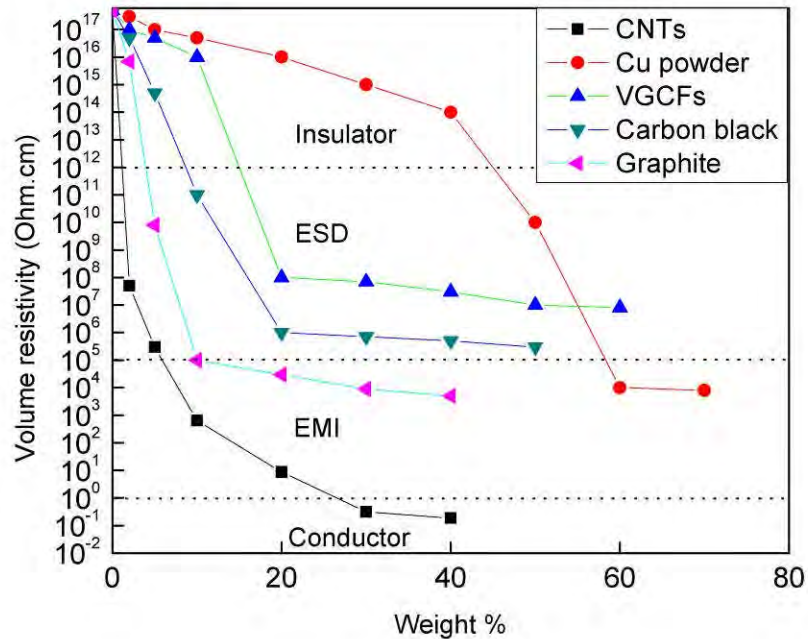
Extrusion
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*Schematics
of
Processing
Procedures*

Conclusion

- Progress achieved



- Semi-continuous conductive composite wires have been successfully fabricated.

Outcome

- Key processing steps have been identified.
- Scale up the quantity of materials processed by melt spinning.
- Device for the electrical field use has been produced.
- Annealing is an effective post-processing step for low loading samples.
- Doping reduces the resistivity.

Demonstration setup

