Ultrahigh Conductive Materials for Electric Machines

Dr. Quanfang Chen
Professor
Mechanical and Aerospace Engineering Department
University of Central Florida
Quanfang.Chen@ucf.edu
Electrical Conductors and Energy Loss by Resistive Heating

Electric power generators → Electric power grid → Various motors and their applications → Copper windings

Copper interconnects → Electrical cables → Computers
Issues about Conductors

- Currently Cu or Al are main players
- Resistivity of Cu is $1.7 \mu \Omega/m$, Al is $2.7 \mu \Omega/m$
- Joule (resistive) heating $Q=I^2Rt$, proportional to $I$ and $R$
- Electric machines’ efficiency is proportional to the current $I$, large current densities are preferred
- Large current wastes more energy due to Joule heating
- More heating needs more energy for cooling
- Thermal mechanical a threat for reliability
- How to increase the thermal and electrical conductivities at room temperature?
Performance of Ultraconductive Copper/CNT Nanocomposite

Comparison of electrical conductivity

- Conductivity >200%

- Resistivity reduced >50% of Cu

- Conductivity >200% of copper
- Strength >300% of copper
- Thermal conductivity >180% of copper
- Addition of CNT < 1%
- Cost of Cu/CNT < 4% more of copper

Tensile testing of Cu/CNT
Thermal Conductivity of Cu/CNT

Schematic diagram of the thermal conductivity measurement setup and an optical image of the Pt heater

Thermal conductivity of Cu/CNT versus CNT addition in electrolyte (actual CNTs in Cu/CNT is < 1%)
Today’s standard copper refining is electrochemical.

Copper cathode deposited

Copper plates removed from cathodes

Schematic of single co-deposition cell

Copper/CNT plate at UCF
Manufacture of Wires and Cables

Solid round shape wire conductors

Other shaped conductors

The manufacturing process from casting to the finished machined and wrapped bushing

How PIC Cable is Made

Plastic pellets

10- or 17-gauge copper wire

Insulated wire

Test strand

Wire draw

Anneal

Cool

Insulated wire

Test strand

Fiberglass

Insulated wire
Thank you for your attention!