Metal(Cu,Al)/CNT Composite Wires for Energy Efficient Motors

Contract Number: DE-EE0007864

University of Central Florida

Project Period: 5/01/2017 – 10/31/2020

PI: Dr.Quanfang Chen

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Overview

Project Title: Metal(Cu,Al)/CNT Composite Wires for Energy Efficient Motors

Timeline:

Project Start Date: 05/01/2017

Budget Period End Date: 10/31/2019

Project End Date: 10/31/2020

Barriers and Challenges:
- Dispersion and interfacial bonding between CNTs and metal matrices
- Oxidation and protection of metals
- Densification of metal/CNT composites

AMO MYPP Connection:
- Energy efficient electricity transmission and distribution
- Energy efficiency of electrical machines

Project Budget and Costs:

Budget	DOE Share	Cost Share	Total	Cost Share %
Overall Budget	$1,000,000	$367,440	$1,367,440	26.9%
Approved Budget (BP-1&2)	$777,683	$330,135	$1,107,818	29.8%
Costs as of 3/31/19	$504,987	$330,135	$835,122	39.5%

Project Team and Roles:
- Prof Quanfang Chen (PI), Material design and synthesis and characterization
- Prof Yuanli Bai (Co-PI), material deformation and wire fabrication

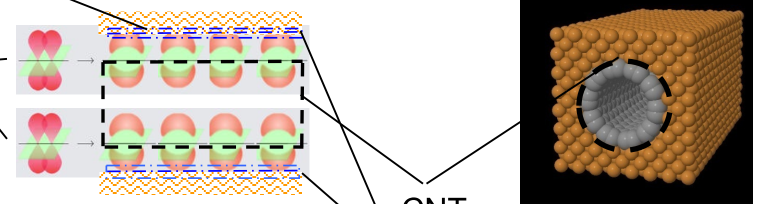
Project Objective(s)

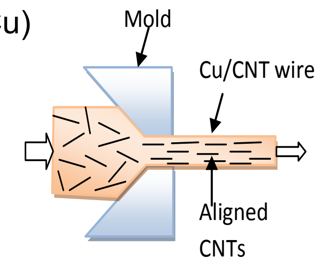
- Motors in manufacturing sector consumes significant amount of electricity due to resistance of conductors, How to increase Cu/Al conductance is very important to meet AMO's goal on energy consumption (reduce energy consumption by 50% in 10 years).
- Objectives: To reduce energy consumption by 33% of Cu or Al wires with metal/CNT composite wires to increase thermal/electrical conductivity by 50%.
- Approach: Quantum Mechanics material design guided material synthesis
- Challenge: CNTs and metals are dissimilar materials with poor "wetting" and large difference in density.

Technical Innovation

- The current R&D on metal composites are fabricated by mixing CNTs with metal powders or mixing with CNTs with molten metal.
- Limitations
    - Tangled CNTs
    - No “wetting” of CNTs with metals
    - Separation in melting due to large difference in densities.
- Proposed Approach: Develop pre-separated and pre-bonded CNTs with metal encapsulations
- Al/CNT and Cu/CNT wires with metal encapsulated CNTs
    - CNTs are pre-separated and pretreated
    - Metal encapsulation to retain separation and interfacial bonding

Technical Approach





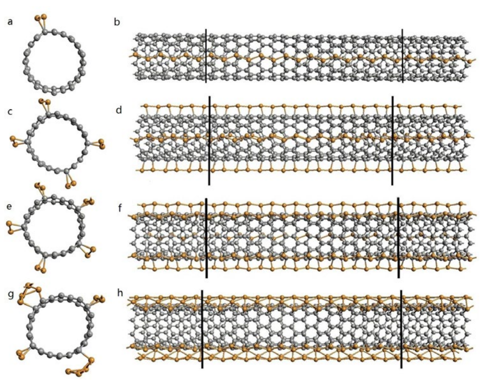
$$\sigma = \frac{ne^2 d}{mV_F}$$

Electrical conductivity

$$K = \frac{\pi^2 n d k_b^2 T}{3mV_F}$$

Thermal conductivity

$$\frac{K}{\sigma} = \frac{\pi^2 k_b^2 T}{3e^2} = L$$ Lorentz Constant



$$G = G0 * T$$

G-Electrical conductance
T-Transmission coefficient

- Electrical conductivity and thermal conductivity are dependent
- Both are proportional to the free electron density and mean free path
- Conductance is proportional to the transmission coefficient T
- Quantum mechanics based material design (UCF Chen's group)
- Guided material synthesis (UCF Chen's group)
- Deformation and wire fabrication process (UCF Bai's group)

Results and Accomplishments

- The quantum calculation shows significantly increased electrical conductivity with proper metal encapsulation
- Different metal encapsulated CNTs were synthesized
- Al/CNT and Cu/CNT composite are fabricated with powder metallurgy
- Increased electrical and thermal conductivities are obtained
- Al/CNT and Cu/CNT wires are fabricated

Transition

- Technology readiness (TR) level of 4-5 anticipated by the end of the current project
- Recruitment of further development funding beyond 10/2020