1 & 2DM Conference and Exhibition
January 29-30, 2019

Atsuko Sekiguchi
Rajyashree Sundaram, Guohai Chen, Takeo Yamada, Don Futaba, Kenji Hata
CNT Application Research Center, National Institute of Advanced Industrial Science and Technology, Central 5, 1-1-1 Higashi, Tsukuba 305-8565, Japan

atsuko-sekiguchi@aist.go.jp, rajyashree-meenakshisundaram@aist.go.jp

Lightweight high-performance Cu/Carbon Nanotube composites

We present high-performance copper-matrix carbon nanotube composites (Cu/CNT) lighter than copper [1-3] as promising copper-substitutes. Compared to copper, our composites are at least 2/3rd as light and show competitive room-temperature electrical resistivities, higher temperature- and current-stabilities, and at par mechanical strengths. Our data suggest that composite performances may depend on microstructure (Cu spatial distribution) and CNT attributes. For instance, our Cu/SWCNT composites show room-temperature electrical resistivities (ρ_{RT}) as low as 3.3 × 10^{-6} Ohm cm (~ × 2ρ_{RT}Cu) and temperature coefficient of resistivity (TCR) as low as 4.4 x 10^{-4} /K (~10% Cu_{TCR}). In contrast, our Cu/MWCNT show higher ρ_{RT} (× 10 ρ_{RT}Cu) and TCR (50% Cu_{TCR}). Besides ρ_{RT} and TCR, the current carrying capacity of our composites is higher than Cu. In addition to electrical performances, the composite mechanical and thermal expansion properties are also favorable. Our composites show mechanical strengths (~ 300 MPa) similar to annealed and drawn commercial Cu wires. The composite's coefficient of thermal expansion (CTE) is ~ 4-7 ppm/K, which is more similar to Si (~3 ppm/K) and lower than Cu (~17 ppm/K).

We have fabricated these Cu/CNT composites as microscale pillars and macroscopic wires, which are additions to planar Cu/CNT microlines and sheets reported by our group previously [4-6]. We believe our array of Cu/CNT composites show immense potential to fulfill a growing demand for lightweight electrically conducting Cu-substitutes. The macroscopic Cu/CNT wires could replace heavy copper electrical wiring in aircrafts and automobiles to achieve better fuel efficiencies and reduced CO_2 emissions. Our composite's temperature-stable resistivity (TCR < Cu) specifically makes it a reliable conductor for high-temperature operation e.g., in motor windings. Meanwhile, our microscale Cu/CNT structures with CTE ~ Si could serve as better interconnects than Cu in high-power electronics, facilitating the development of smaller and more powerful next-generation devices.

References

[1] Sundaram R, Yamada T, Hata K, Sekiguchi A, Sci. Rep., 7(1) (2017), 9267.
[2] Sundaram R, Yamada T, Hata K, Sekiguchi A. Mater. Tod. Commun., 13 (2017), 119.
[3] Sundaram R, Yamada T, Hata K, Sekiguchi A. Jpn. J. Appl. Phys., 57(4)(2018), 04FP08.
[4] Subramaniam C, Yamada T, Kobashi K, Sekiguchi A, Futaba DN, Yumura M, Hata K, Nat. Commun., 4(2013), 2202.
[5] Subramaniam C, Yasuda Y, Takeya S, Ata S, Nishizawa A, Futaba D, Yamada T, Hata K, Nanoscale, 6(5) (2014), 2669.
[6] Subramaniam C, Sekiguchi A, Yamada T, Futaba DN, Hata K, Nanoscale, 8(7)(2016), 3888.