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Effects of Chemical Dopants on the Electrical Conductivity of Carbon Nanotubes for Novel use in Wire Applications

Carbon nanotubes (CNTs) are being investigated as an alternative to conventional metallic conductors. Individual CNTs have measured conductivities around $1x10^8$ S/m, but conductivities this high in bulk materials have not yet been achieved. Of the numerous strategies employed to increase the bulk conductivity of CNTs, chemical doping is a prominent pathway. The present work focuses on doping efficacy and dopant stability as part of making multifunctional wires that are both electrically conductive and mechanically strong. In addition, an investigation of conductivity as a function of purification was performed to understand how material processing impacts the conductivity. CNT sheet material was doped with a series of compounds of varying structure and functionality, including metal halides, nitrates, hydroxides, acids, halogen gases, and ionic liquids. Of the chemical dopants investigated, potassium tetrabromoaurate salt, gold (III) chloride, and iodine gas showed the greatest increases in electrical conductivity, with iodine gas reaching $2.98x10^5$ S/m, 8 times higher than the average purified sheet value. Metal halides, bases, and ionic liquids all showed limited doping results on the CNT sheet material. A qualitative analysis of the extent of dopant plating was performed, and it was found that the CNT samples immersed in the gold halide and alkali gold halide solutions showed the highest extent of dopant plating, while most other dopants did not have a visible change after doping. Densified CNT wires were fabricated using each of the top three dopants and tested for both electrical conductivity and mechanical strength. The wire doped with potassium tetrabromoaurate was able to withstand the most stress, while a control sample densified with deionized water was able to withstand the least amount of stress. Potassium tetrabromoaurate and iodine gas were selected for additional environmental experiments because they exhibited the highest potential for multifunctionality. Doped sheets were soaked in deionized water and aqueous sodium chloride and changes in electrical conductivity of each sample were measured before and after soaking. The iodine doped samples had an initial decrease in conductivity after a 15 minute soak, after which conductivity remained stable over a 5 week soaking period. The general trend for the potassium tetrabromoaurate doped samples in both deionized water and saltwater was a continuous decrease in electrical conductivity. These experiments served as a preliminary assessment of CNT wire stability for conventional cable applications, and demonstrate the viability of this developing technology. The present work indicates that potassium tetrabromoaurate and iodine gas dopants have emerged as the best for the fabrication of multifunctional wires.