The Magnetoresistance of Carbon Nanotube Fibers in Pulsed Magnetic Fields up to 60T

Lekawa-Raus, A.; Bulmer, J. (University of Cambridge); Balakirev, F.; Rickel, D. (NHMFL)

Introduction

Understanding the electrical transport mechanisms of carbon nanotubes (CNT) fibers and its dependence on their morphology is of paramount importance for the use of these materials in any electrical applications.[1] Two methods are widely used to explore the transport mechanisms in CNT assemblies.[2] These are the measurements of resistance with temperature and magneto-resistance (MR) analysis. Both of them give complimentary information about the charge carrier transport in CNT networks. Up to now the magneto transport measurements have been well explored on this type of material only up to 10 T.[3,4] In this work we have performed MR measurements up to 60 T.

Experimental

The fibers used included mixed chiralities as well as pure fibers containing 95% of armchair (metallic) CNTs. The latter samples, recently produced in our laboratory, have the highest control of the structure ever attained.[5] The interesting part of this research is the fact that the fiber contains only two chiralities. This indicates that the results we obtained show the change in resistance is specific to these chiralites and not the standard magneto-resistance related to the network.

The samples were tested at magnetic fields up to 60 T with the field perpendicular to the nanotube axis. Measurements ranged over temperatures from 110K to 1.5K. The magneto resistance was measured using a digital locking technique at 28 kHz with excitation currents at 30,100,177 and 310 microamperes. The currents were directed along the nanotube axis.

Results and Discussion

The figure below shows a summary of the MR measurements up to 60T. The magnetic fields directed perpendicular to the long axis of the fiber revealed changes in the fiber resistance that are very dependent on the morphology of the test samples. There are clear differences between the samples with nanotubes of mixed chiralities and the chirality controlled ones. We have observed for the first time that the samples with metallic features which may were further reinforced by acid doping to obtain the lowest possible localization of charge carriers can still show positive MR but it is observable at extremely high magnetic fields and is highly suppressed in magnitude. The results presented need further analysis and theoretical interpretation. Nevertheless, they are already an important step forward in the understanding of the highly interesting transport mechanisms in CNT fibers and pave the way to the applications of these structures as the conductors of the future.

Conclusions

We have measured the MR of CNT fibers in pulsed magnetic fields up to 60T. It has been the first time that the MR for standard fibers was compared to the one of highly controlled metallic fibers. It has also been the first time that the fields used were up to 60T. The results obtained show clear differences between the samples and very interesting features at the highest fields. These results will be highly important for the understanding of transport phenomena in CNT fibers and their potential applications as electrical wires.

Acknowledgements

Funding support or this research was provided by the National Science Foundation through the NHMFL, the European Research Council (under the Seventh Framework Program FP7/2007-2013,ERC grant agreement no. 259061) and the Royal Society.

References

[1] A. Lekawa-Raus et al. Adv. Funct. Mat. 24, 3661 (2014).
[2] A. Lekawa-Raus et al. Carbon, 84, 118 (2015).
[3] J. Vavro et al. Phys. Rev. B, 71, 155410 (2005).
[4] K. Yanagi et al. ACS Nano, 4, 4027 (2010).
[5] R. Sundaram et al. Adv. Mat. 23, 5064 (2010).