SWCNTs in Magnetic Recording

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Contributor: Marianna V. Kharlamova

Applications in magnet-recording devices rely on the combination and emergence of unique properties of single-walled carbon nanotubes (SWCNTs) and encapsulated materials. The entry "SWCNTs in magnetic recording" focuses on applications of filled SWCNTs in magnetic recording.

Keywords: Magnetic Recording ; Single-walled carbon nanotubes (SWCNTs) ; magnetization

1. Introduction

The range of materials that can be filled inside Single-walled carbon nanotubes (SWCNTs) encompasses simple substances [1][2][3][4][5][6][7][8][9][10][11][12][13][14][15][16][17][18], molecules [19][20][21][22][23][24][25][26][27][28][29][30][31][32][33][34][35][36][37][38][39][40][41][42][43][44] and chemical compounds [45][46][47][48][49][50][51][52][53][54][55][56][57][2][58][59][60][61][62][63][64][65][66][67][68][69][70] with an equally wide range of chemical and physical properties. If magnetic materials or substances are filled inside SWCNT the magnetism in such nanostructured composites can qualitatively differ from that of the macroscopic bulk. Applications in magnet-recording devices rely on the combination and emergence of unique properties of SWCNTs and encapsulated materials [71][72][73][74][75][76][77].

In Reference [73] a composite of Fe nanowires inside SWCNTs was prepared and its ferromagnetism at room temperature was detected. Reference [75] reported that the magnetization of Fe-filled SWCNTs exceeds that of pristine SWCNTs. A study employing X-ray magnetic circular dichroism and the superconducting quantum interference device of Fe encapsulated inside metallicity-sorted SWCNTs revealed the differences in the orbital and spin magnetic moments of the iron for SWCNTs with different conductivity type [74]. In Reference [71], it was found that small Ni clusters featured superparamagnetism at room temperature. Authors of Reference [78] measured the transport properties of Co cluster-filled SWCNTs. The cobalt nanoparticles encapsulated in SWCNTs were found to be ferromagnetic.

Figure 1 shows single traces of conductance (G (e^2/h)) (e – the charge of electron, h – the Plank's constant) measured as a function of gate voltage (V_g) and sweeping in-plane magnetic field ($\mu_0 H$) (μ_0 – the vacuum permeability, H – the magnetic field) [78]. The cobalt-filled SWCNT device was measured at T = 40 mK. The field was swept at a constant rate in either direction between -2.5 to +2.5 T. The conductance evolves in a continuous manner as the field is swept (H_{sw}) unless the sweeps go through mirrored critical field values (Figure 1a-c) at $\mu_0 H = \pm\mu_0 H_{sw} = \pm1.28$ T in each sweep direction. The forward and backward conductance trace show at their respective critical fields a symmetrical sudden jump (ΔG_{sw}). The peculiar conductance traces correspond to a pronounced hysteresis, centred around $H = 0$. The sign and amplitude of the symmetric conductance jumps are shown in Figure 1d and depend strongly on V_g but they are always observed at the same critical fields ($\mu_0 H_{sw} = \pm1.28$ T) [78].

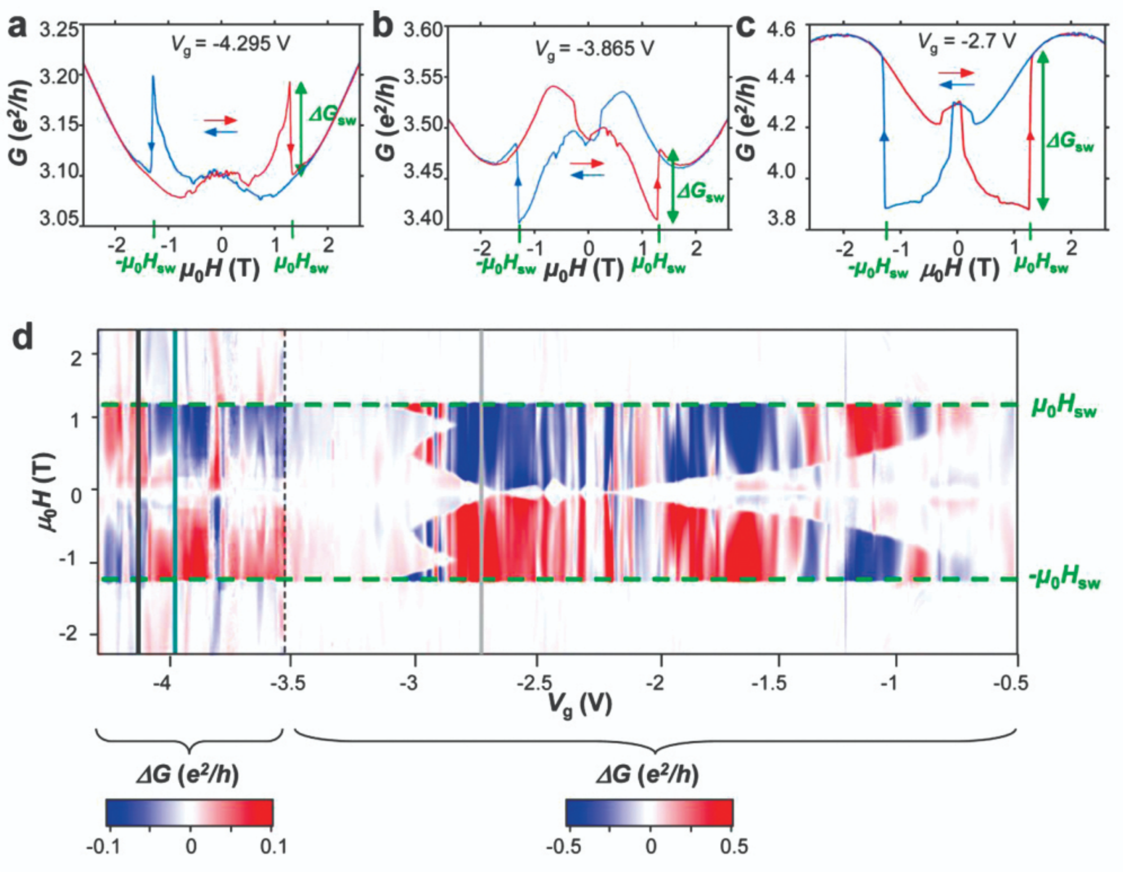

Figure 1. Conductance hysteresis loops of cobalt-filled carbon nanotubes at 40 mK. (a-c) Differential conductance dI/dV as a function of in-plane magnetic field $\mu_0 H$ for selected gate voltages. The field was at an angle of 25° with respect to the nanotube axis. The red and blue arrows in (a-c) indicate the field sweep direction. (d) The changes in amplitude and sign of the jumps for different V_g. Note the two different conductance color scales above and below V_g = -3.5 V. Reprinted with permission from [78]. Copyright 2011 American Chemical Society.

2. Properties

The magnetic properties of filled SWCNTs were also explored by calculations [14][79][80][81]. Local-spin-density-functional theory was applied to calculate the electronic and magnetic properties of Fe nanowires inside SWCNTs [14]. Larger magnetic moments as compared to the bulk Fe were revealed for the encapsulated Fe. The authors of reference [81] carried out *ab initio* calculations on the magnetic properties of Fe-filled SWCNTs. They suggested that the relative diameters of the nanowire and the SWCNT would decide the magnetic ordering in the nanowire. The magnetic ordering in freestanding Fe nanowires and Fe-filled different SWCNTs were calculated from first principles [80]. The freestanding Fe nanowires did show ferromagnetic ordering, but for the nanowires inside a SWCNTs antiferromagnetic ordering became preferable.

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