MICROWAVE PHOTORESISTANCE SPECTROSCOPY OF SINGLE-WALLED CARBON NANOTUBES

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Introduction

Since their discovery in 1991, carbon nanotubes (CNTs) have been the focus of intensive research for many potential applications, including sensing, textile, chemistry, biology and electronics, to name a few. CNTs are rolled up sheets of graphitic carbon with minimum diameter of 1.2 nm and are available in single-walled and multi-walled forms. Because of their perfect one-dimensional crystalline structure, CNTs exhibit unusual physical, chemical and mechanical properties, for example, the exotic Luttinger liquid behavior in electrical transport properties. Recently, there has been tremendous interest in using CNTs as channels of field-effect-transistors (FETs) since these have the potential to replace the Si CMOS technology in microelectronic industry. The RF response is of great importance to evaluate this novel nano-device. However, it is very challenging to characterize the RF performance of CNT transistors since the impedance of CNTs is mismatched with the standard 50 Ω input of RF instrumentation, hence the present, initial investigation looks at photoresistance of the CNT device under microwave radiation.

Experiments

We have successfully developed a novel CNT-FET with a poly-Si bottom gate structure. The device has a gate length of 1 μm and achieves a unity gain frequency f_T of 2.5 GHz and a maximum oscillation frequency f_{max} of > 5 GHz. In this microwave photo-response experiment, we study the quasi-dc electrical transport properties of single-walled CNTs under high-frequency (RF and microwave) excitations at dilution refrigerator temperatures using NHMFL microwave capability.

Results and Discussion

Figure 1(a) summarizes our findings on quasi-metallic single-walled CNTs under microwave radiation. The resistance of CNTs at B=0 is almost at constant value of 300 kΩ independent on microwave radiation from 50 MHz up to 20 GHz. A negative resistance peak emerges at 5 GHz when B field is a fraction of 1 tesla and becomes more pronounced with the increase of B field. The $\Delta R/R_0$ is about 5% as B reaches 18 T. Possible harmonic features are also observable, for example around 10 GHz. The effect becomes more pronounced on increasing microwave power as shown in Fig. 1(b). More experiments are needed to clarify the origin of the sensitivity of the device to microwave radiation.

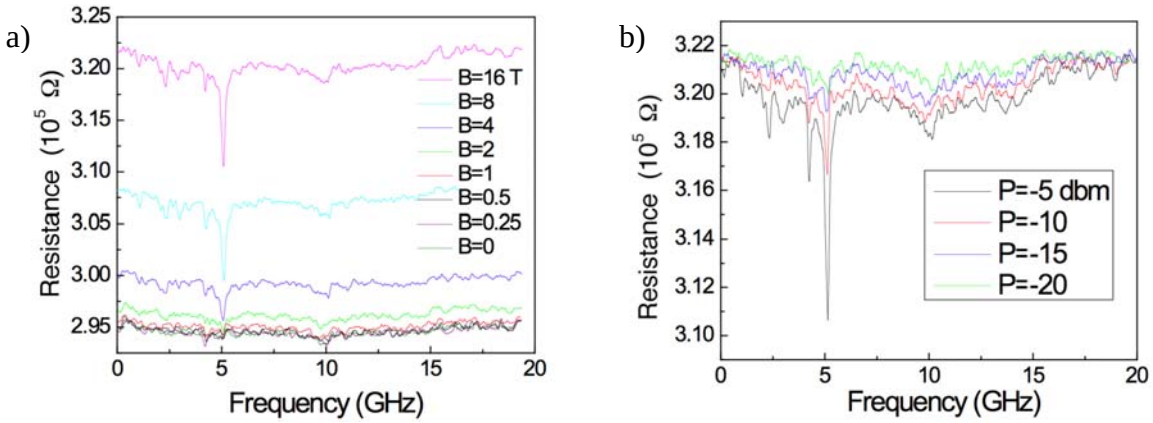

Fig. 1. Single walled CNT under microwave radiation resistance vs. microwave frequency (a) at various magnetic fields. and -5 dBm applied at top of cryostat (b) at 16 T for various power levels, in dBm at top of cryostat. Only a small fraction of the power applied couples into the sample, which was in mixture at a temperature of about 60 mK.