SUPPORTING INFORMATION

Rapid Electromechanical Transduction on a Single-Walled Carbon Nanotube Film: Sensing Fast Mechanical Loading via Detection of Electrical Signal Change

Wonjoon Choi [1], Jinkee Hong [2*]*

1 – School of Mechanical Engineering, Korea University, Seoul 136-713, Korea

2 – Department of Plant and Environmental New Resources, College of Life Science,
Kyung Hee University, Republic of Korea

AUTHOR INFORMATION

Corresponding Author

*E-mail : wojchoi@korea.ac.kr, jkhong@khu.ac.kr

1. Synthesis of SWNT films

Briefly, 0.005–0.01 wt% HiPco SWNTs were dispersed in deionized (DI) water with 1.0 wt% sodium dodecyl sulfate (SDS) as a surfactant. The prepared solution was homogenized for one hour at 6500 rpm and sonicated for 10 minutes in a cup horn sonicator. After room temperature ultracentrifugation at 30,000 rpm, the resulting solution was decanted. The vacuum filtration method was used to fabricate the conductive SWNT films on diverse membranes. The decanted SWNT solution was filtered while applying a vacuum to the bottom of the membrane. The thickness and transparency of the SWNT films were controlled by adjusting the amount of decanted SWNT solution. Thick, non-transparent and thin, transparent films were synthesized on mixed cellulose ester and anodisc membranes (0.2 μm pore size and 47 mm diameter, Millipore), respectively. For the fabrication of a thick-nontransparent film with a thickness of 3–5 μm, 150 ml of decanted SWNT solution was used, whereas 150 ml of a 30X diluted solution was used to produce a 100- to 200-nm-thick thin, transparent film. A 3 M NaOH solution was used to dissolve the anodisc membrane. Additionally, a free-standing SWNT film was acquired by dissolving the mixed cellulose membrane in acetone.

2. Equipment and set up

An Agilent E5272 medium-power source/monitor unit was used to record the characteristics of the SWNT film without deformation as a reference condition. A Melles Griot 17PAZ015 piezoactuator and 17BPI101 controller were built and connected with a LG FG 7005 function generator that supplied the electrical signal to move the piezoactuator up and down (Figure 1c). A B & K precision 4012A function generator supplied a constant electric field to the SWNT film, and the voltage change between the two Cr/Au electrodes was recorded in real time, while the vertical movement of the piezoactuator precisely induced the deflection of the SWNT film through the large hole of the holder (Figure 1c, Figure 1d). Additionally, a two channel source/monitor unit or oscilloscope recorded the current change at the same time, and the resistance changes were calculated with Ohm's law.

3. SWNT films on PDMS

Based on the pre-test results, the diameter of the SWNT film and the thickness of the PDMS substrate were approximately 37 mm and 7 mm, respectively, because the area of the SWNT film should be large enough to make contact with moving particles or projectiles and the PDMS substrate has to be sufficiently thick to withstand heavy mechanical impact. The average resistance of the thin, transparent SWNT films used for the conductiometric detection of the mechanical loading was 10 –12 kΩ. The morphology of the macroscopic SWNT film on the PDMS substrate was quite stable and recovered to its original condition after forcible deformation including bending, unfolding, and torsion. Copper conductive tape was attached to the SWNT film as electrodes, and fixed in holders constructed with optical parts and a table. In this setup, the function generator supplied the electrical signal to the film and the oscilloscope recorded the input-output signals.

4. Set up for high speed projectiles

The SWNT film was fixed in holders and an airsoft gun was placed in another holder. For safety reasons, the SWNT film on the PDMS substrate and its holder were located inside a transparent and thick polycarbonate chamber. To prevent damage to the SWNT network by direct contact with the moving projectiles, the back of the PDMS substrate without SWNTs was placed facing the airsoft gun, while the deformation of the PDMS on the front was transferred to the SWNT film. A high-speed camera (CPL-MS70K, Canadian Photonic Labs, 20,000 frames/sec) simultaneously recorded the movement of the projectile and the deformation of the PDMS substrate in real time. The function generator was the source of the constant electrical signal on the SWNT film, whereas the oscilloscope detected the changes in the input and output electrical signals.