Research Article

Advances in Nanoscience and Nanotechnology

Optical and Electrical Properties of Transparent Carbon Nanofilm Sandwiched between Transparent Alumina Determined Using a Touch Technique

C Hsu*, JY Lu, SC Zhang, and ZL Xie

Department of chemical and materials engineering, Lunghwa University of Science and Technology, Taiwan, Republic of China.

***Corresponding author**
C Hsu, Department of chemical and materials engineering, Lunghwa University of Science and Technology, Taiwan, Republic of China, E-mail: chenhsuemail@yahoo.com.tw

Submitted: 01 Feb 2018; **Accepted:** 07 Feb 2018; **Published:** 20 Feb 2018

Abstract

This study investigated the optical and electric properties of carbon nanofilms for capacitive application. The carbon nanofilms were sandwiched between alumina layers, and the specimens were covered with SiO_2 nanofilm. Aluminum patterns were inscribed and used to determine the contact location. The optical and electrical properties of the transparent nanofilms were measured as the specimen was used as a touch panel. Light transmittance, film thickness, spacing, voltage, resistance, and electrical current were measured. Finally, an LCR meter was used to measure the inductive capacitance points. Glass was used as the substrate in this study. Carbon graphite was sputtered onto a metastable aluminum nanofilm, which was then cured. This carbon transits from an excellent conductivity (sp^2-bonded) to an insulating (sp^3-bonded). Metal can be transparent at the nanoscale, and its metastability can be sustained for a few hours. Graphite was sputtered onto aluminum nanofilm, and the carbon layer contained weak dipoles, resulting in weak capacitance. Consequently, sp^3 bonding was dominant after curing. The transparency and capacitance of the samples was related to the thickness of and pattern in the aluminum layer.

Keywords: Optical, Electric, Carbon, Al nanofilm, Transparence

Introduction

Carbon materials are known to have a wide range of conductivities, from the sp^2 conduction of materials such as graphene to the sp^3 isolation of diamond, with mixed sp^2 and sp^3 bonding also possible [1,2]. The conductivity of a material determines its applications. Touch technology is one of the applications that uses carbon materials with mixed sp^2 and sp^3 bonding. Normally, touch screens comprise indium tin oxide (ITO) film sandwiched between conducting electrodes. The resistivity and capacity can therefore be measured according to the touch screen structure.

There are several methods for using touch panels, which are described as follows [3,4]. The two main structures, resistive and capacitive, are frequently used in touch technology. In the structure of resistive touch technology, when a stylus or finger makes contact with the touch panel, the upper and lower electrodes conduct and the system determines the touch position. To achieve a multipoint location, the upper and lower board of the ITO film grew stripes for XY paste. As a result, when touching the intersection, IC determined touch position.

The structure of capacitive touch panels is either double-sided or single-sided. When manufacturing for stability, the goal is to design a thin device. The surface has a capacitive structure, provided by the voltage applied at the four corners of the screen and the resultant formation of a uniform electrical field on the glass surface. Metal induced crystallization of random structure [5]. Surface topography determined by metal deposition [6]. Using the human body and the electrical field between the electrostatic responses generated by changes in the capacitance, the input coordinates can be detected. The distribution of the electrical field is projected and induces capacitance between the finger and the electrode operating as the projection capacitor. Therefore, the capacitance of materials is easily measured by the touch technique.

Materials and Methods

The goal of this research was to create a transparent level with a width of less than a few hundred nanometers. Plasma sputtering was used to produce the thin films. We used glass as the substrate and then employed aluminum, carbon, and silicon dioxide to produce simple transparent capacitors. A transparent aluminum coating with excellent conductivity was used as the electrode material. A transparent carbon graphite layer was used between the electrodes, could withstand high voltages, and had extremely low inductance and capacitance. The upper electrode was covered with a silicon dioxide coating to prevent the aluminum from oxidizing. A diagram of the specimen's structure is presented in Fig. 1. A pattern was inscribed into the lower aluminum electrode using an infrared pulse laser machine. An LCR meter was then used to measure the resistance and capacitance. The electrical capacitance was measured using a copper rod with a 6 mm diameter. Changes in the capacitance were measured in the X and Y directions as measuring pads located as shown in Fig. 2. Therefore, we could accurately determine changes in the capacitance. Our test specimens included eight pads. The pattern inscribed using the laser machine was of a grid in the X and Y directions, with a scanning rate of 1000 m/s, a power output of 80 W, and a focal length 23.5 cm.

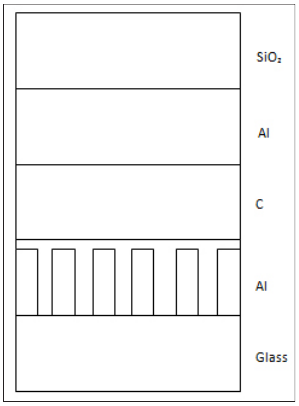


Figure 1: Structure of the specimens.

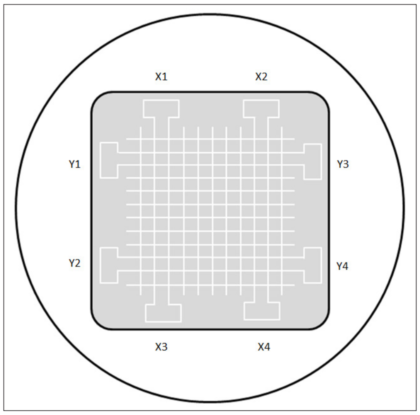


Figure 2: Pad arrangement in X and Y directions.

Results and Discussion

Thickness and Resistance

A typical image of a specimen with a spacing of 5 mm is presented in Fig. 3. This image shows a specimen with a completely engraved nanofilm and an isolated cell. The Al nanofilm was as finished plane and transparent. The typical thicknesses of the layers in the structure are presented in Table 1. The electrodes had a thickness of approximately 100 nm, and the carbon layer was slightly thicker. The cover layer was highly transparent. The total thickness of a specimen was approximately 650 nm, which is within a transparent range.

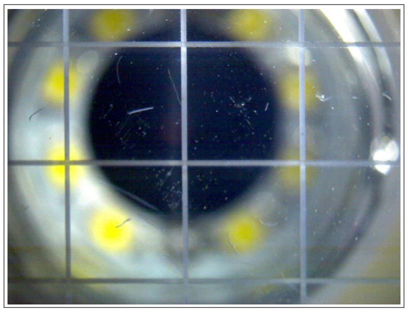


Figure 3: A typical specimen with a 4 mm pitch.

Table 1: Typical thicknesses of layers in the structure for an Al deposition time of 30 s.

layer	Materials	Sputtering time (s)	Thickness (nm)
1st	Al	30	103.38
2nd	120	120	143.21
3rd	Al	30	101.76
4th	SiO_2	SiO_2	304.66

Fig. 4 plots the total thicknesses of the fabricated specimens with spacings 4, 5, and 6 mm. The thickness of all specimens was thus within 650 nm.

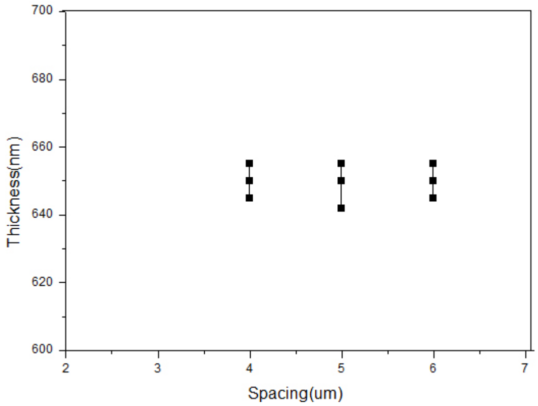


Figure 4: Thicknesses of the specimens with spacings of 4, 5, and 6 mm.

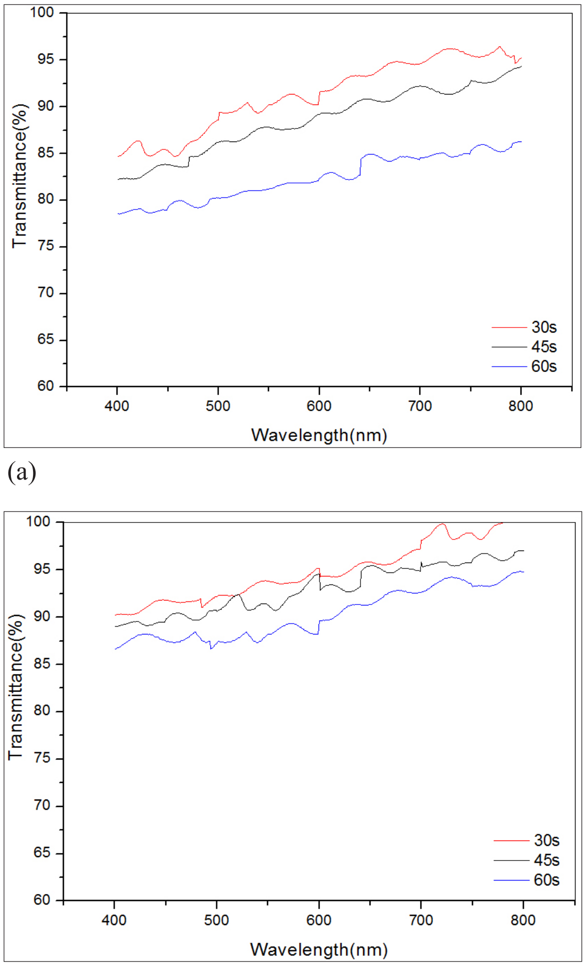
The resistance of the separate layers was measured (Table 2). Although the resistance of the Al electrode was increased slightly, Al was suitable for use in a touch screen. Rather than being a conductor, the Al electrodes had high resistance, which revealed that they were not pure aluminum. Carbon had diffused into the Al layer, which caused the conductivity to decrease. The electrical resistance of the carbon layer revealed that the carbon layer was almost an insulator. Most of the bonding in the carbon transformed from sp^2 bonding into sp^3 bonding. The cover layer comprising SiO_2 remained an essential insulator.

Table 2: Resistance of layers at various spacings.

Resistance (Ω) Spacing (mm)	Al	C	Al	SiO_2
4	202.36	1.5474M	215.97	2.3047M
5	241.94	1.4675M	218.15	2.5487M
6	221.64	1.899M	233.66	2.1124M

Transmittance

Before drawing patterns, the transmittance of the specimens was measured (Fig. 5[a]). Low reflectivity was detected, with a range of 75%–95%. The average light transmission rate was 87.18%. The wavelength increased when the transmittance increased. After drawing the patterns, the light transmission rate was 95.66%. The transmittance of blue light increased by more than 5.8% and the transmittance of red light increased by 3.1%. This revealed that the transmittance of the specimens was higher after the drawing.



(a)

(b)

Figure 5: Transmittance of specimens (a) before engraving and (b) after engraving.

The transmittance of each layer was measured and is presented in Fig. 6. The transmittance increased for all layers when the wavelength increased. The transmittance of blue light was primarily affected by the two Al layers, rather than by the carbon or cover layer (SiO_2). The transparent Al layer persistently displayed high adsorption of metals. The isolator (transparent carbon) showed mild adsorption.

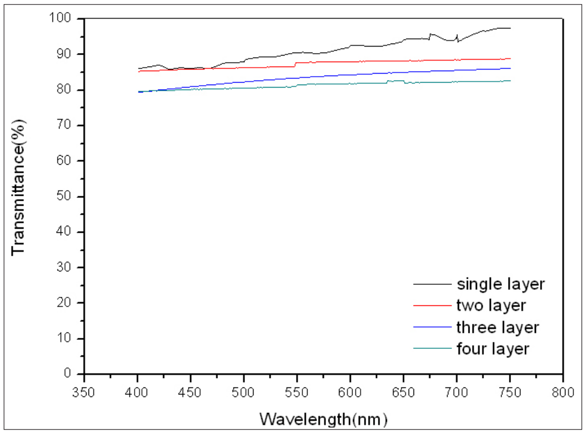
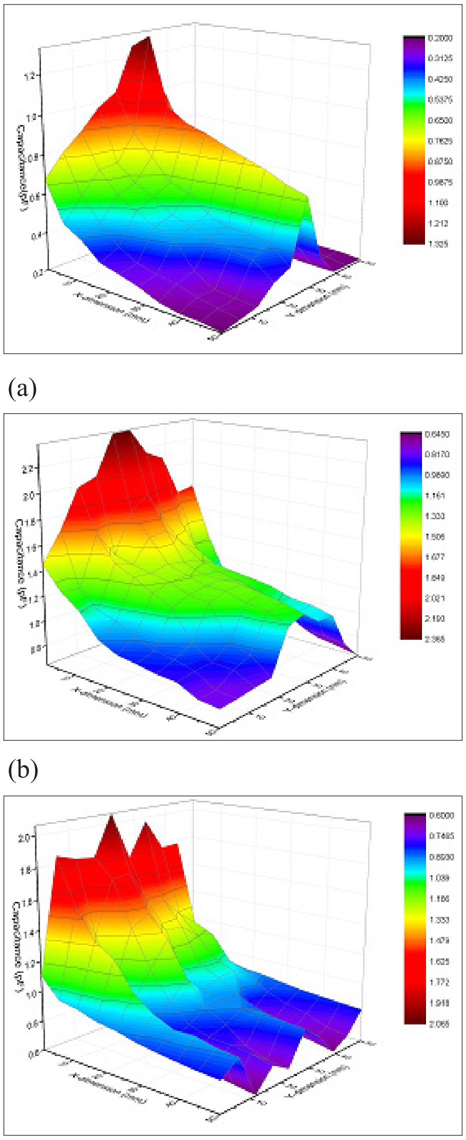


Figure 6: Transmittance of each layer.

Electrical Testing and Capacitance Changes

The capacitance of the specimens with various thicknesses was measured according to the pad location shown in Fig. 2. The capacitance results are displayed in Fig. 7. Overall, the left-hand side exhibited higher capacitance than the right-hand side. The central area showed higher capacitance than the external area. Increasing the specimen thickness increased the capacitance to a limit, which was close to intermediate capacitance.

The increased thickness of the specimens was primarily due to the Al layer increasing in thickness. In this instance, the Al layer was no longer a conductor but a resistor, which can be regarded as an insulator. The resistance was caused by the presence of electric dipoles, which induced an electric charge on the upper Al layer. The largest insulator was the carbon layer, which favored the charges in the Al layer. Therefore, when the thickness of the resistor increased, the capacitance increased.



(a)

(b)

(c)

Figure 7: Capacitance (pF) of the various specimens obtained using an Al deposition time of (a) 30; (b) 45; and (c) 60 s for the same spacing (5 mm).

A fixed Al deposition time of 45 s and spacings of 4, 5, and 6 mm were used to fabricate specimens, and the capacitance of each specimen was measured. The capacitance of the specimens with various aluminum layer thicknesses spaced at 5 mm is shown in Fig. 8. As shown, the smaller the pitch, the larger the capacitance.

Increasing the spacing of the specimens eventually caused a decrease in thickness of the Al layer. The capacitance was determined by interference of the Al resistance. Interference increased as the amount of engraving increased. Therefore, the capacitance of the engraving resistance increased as the degree of engraving increased.

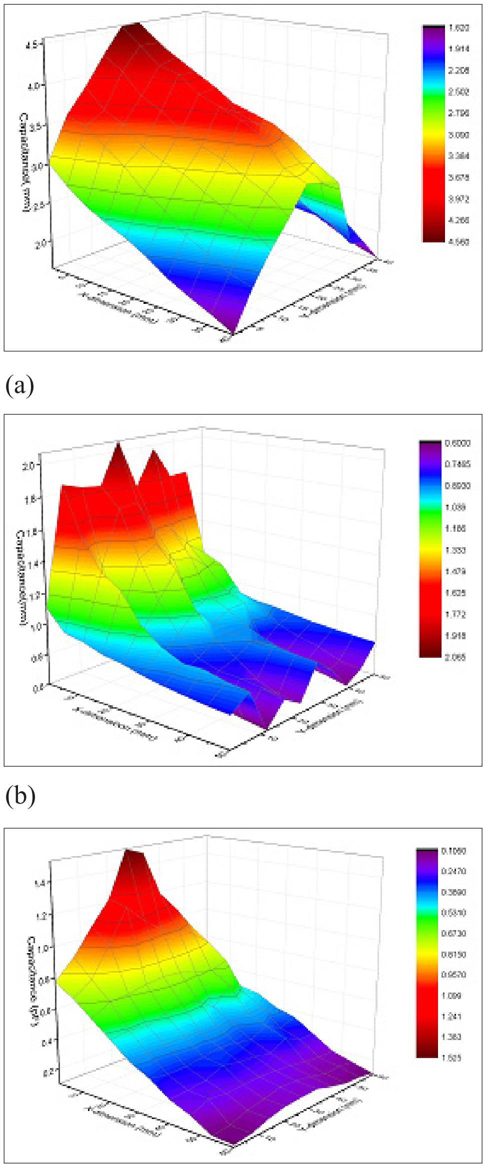


Figure 8: Capacitance (pF) of various specimens obtained using an Al deposition time of 45 s and spacings of (a) 4, (b) 5, and (c) 6 mm.

Fig. 9 shows the profile of a typical specimen. The carbon layer was sandwiched between the Al layers. The nontransparent metal adsorbed visible light. However, the Al layer became transparent when its thickness was less than 0.1 µm. The electrons in the metal excited to a high Fermi level (unoccupied status). Transmittance primarily decreased because of the transparency of the Al. The Al was more easily excited than the carbon nanofilm. The Al layers controlled the overall transmittance.

Atom diffusion at the Al–C interface played a vital role in the experiments. The diffusion occurred during sputtering and curing. Carbon atoms diffused into the upper and lower Al layers, which increased the overall resistance. The diffusion flux was proportional to the carbon gradient with displacement and was equal to

$$J = -D\frac{\partial c}{\partial x} = -1.38D \qquad (1)$$

The structure of carbons is determined from the substrate for depositing carbon. In this study, Aluminum acted as the substrate. The remaining carbon transformed from being sp^2-bonded to sp^3-bonded. The insulator of the remaining carbon layer exhibited electrical dipoles, which induced capacitance. The induced charges interfered with themselves when a spacing of 4, 5, or 6 mm and a line width of 0.02 µm were employed. As the spacing was increased, the capacitance increased.

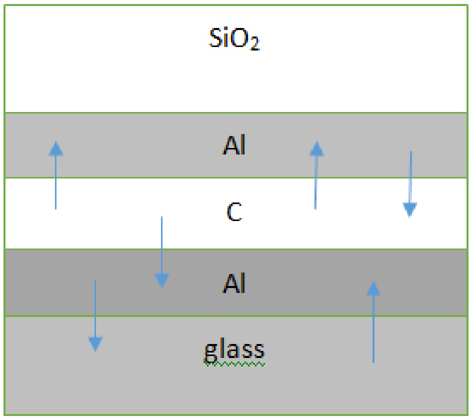


Figure 9: Profile of a specimen

Conclusion

A touch device composed of Al electrodes, carbon, and SiO_2 was fabricated. The optical and electrical capacitance of the carbon layer was investigated using a touch technique. The transmittance increased when the wavelength was increased. When the film thickness was decreased, the transmittance of blue light after engraving increased to a maximum intensity of 7%. The Al electrodes played a vital role in the transmittance. As the thickness increased, the light transmittance decreased and the capacitance increased. As the engraving line spacing was decreased, the capacitance increased [7].

References

1. Wang X, Zhi L, Müllen K (2008) Transparent, Conductive Graphene Electrodes for Dye-Sensitized Solar Cells, Nano Lett 8: 323-327.
2. Hwang EH, Adam S, Das Sarma S (2007) Carrier Transport in Two-Dimensional Graphene Layers, Phys. Rev. Lett 98: 186806.
3. Pepper W (1981) Touch panel system and method, United States Patent 4: 293,734.
4. Blouin F (1999) Touch Pad Panel with Tactile Feedback United States Patent 5,977, 867.
5. Hultman LG (2010) Metal induced crystallization of amorphous

silicon, Surface Engineering, Surface Instrumentation & Vacuum Technology, Vacuum 84: 828-832.

6. M Yonehara, K Kihara, Y Kagawa, H Isono, T Sugibayashi (2005) Journal of Japan Institute of Light Metals 1: 15-19.
7. Robertson AE, Hultman LG, Hentzell HTG, Hörnström SE, Shaofang G (1998) Metal induced crystallization of amorphous silicon, Journal of Vacuum Science & Technology A: Vacuum, Surfaces, and Films 4: 4618.