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Carbon Nanotube – Based Inks for Touch Sensor Applications

Carbon Nanotubes (CNT), a unique form of carbon, exhibit remarkable electrical, optical and mechanical properties. One result of those properties is the fact that specific types of Single –Walled Carbon Nanotubes (SWCNT), when printed in very thin films, are both highly electrically conductive and highly transparent to visible light. This makes them important candidates for applications, such as touch panel sensors, that require a Transparent Conductive Film (TCF).

Most TCFs are now based on a material called Indium Tin Oxide (ITO). In comparison, SWCNT products offer a number of advantages, not the least of which is reduced cost - of both raw material and processing. ITO is typically applied to a substrate through a sputtering or vacuum deposition process. This coats the entire substrate surface with an ITO film. But in applications such as Capacitive Touch Sensors, the ITO cannot cover the entire surface. It needs to be present in a specific pattern. Therefore, the coated substrate must go through expensive additional processing steps to remove the unwanted areas of ITO. This is referred to as subtractive patterning or photolithography.

SWCNT have been formulated into inks which are printable by standard commercial processes such as screen, gravure and flexography. Because these are relatively inexpensive processes, and because the desired pattern is built into the printing screen, plate or cylinder, CNT based inks print a TCF on a substrate in precisely the required pattern. No subsequent etching or other film removal steps are

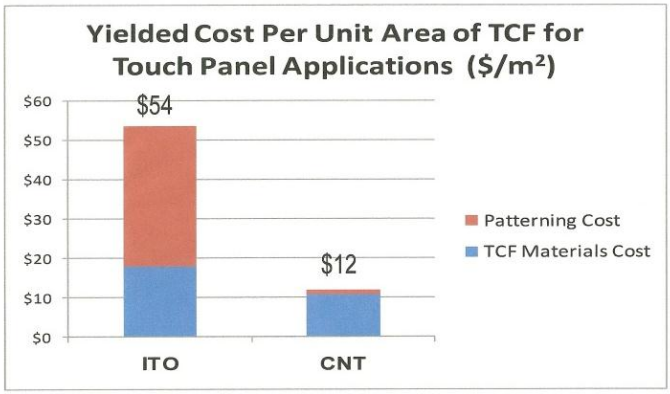
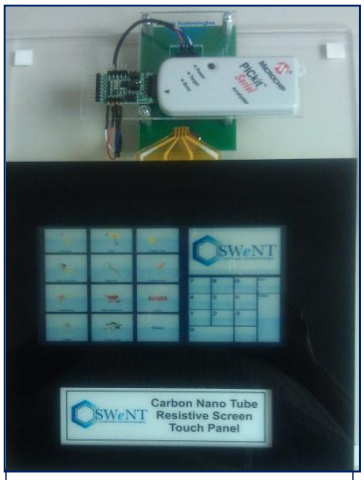


Figure 1

required. This is referred to as additive patterning. The potential cost savings for both the raw materials and the patterning are shown quantitatively in Figure 1.

The printing process offers the additional advantage that prototype preparation cycle times can often be reduced from a week or more to a single day.

In addition to the advantages described above, carbon nanotubes are far stronger and more flexible than ITO, are less reflective (an advantage in viewing the screen) and offer a more secure, price stable source of raw material.



An operating touch panel based on TCF made from Carbon Nanotubes.

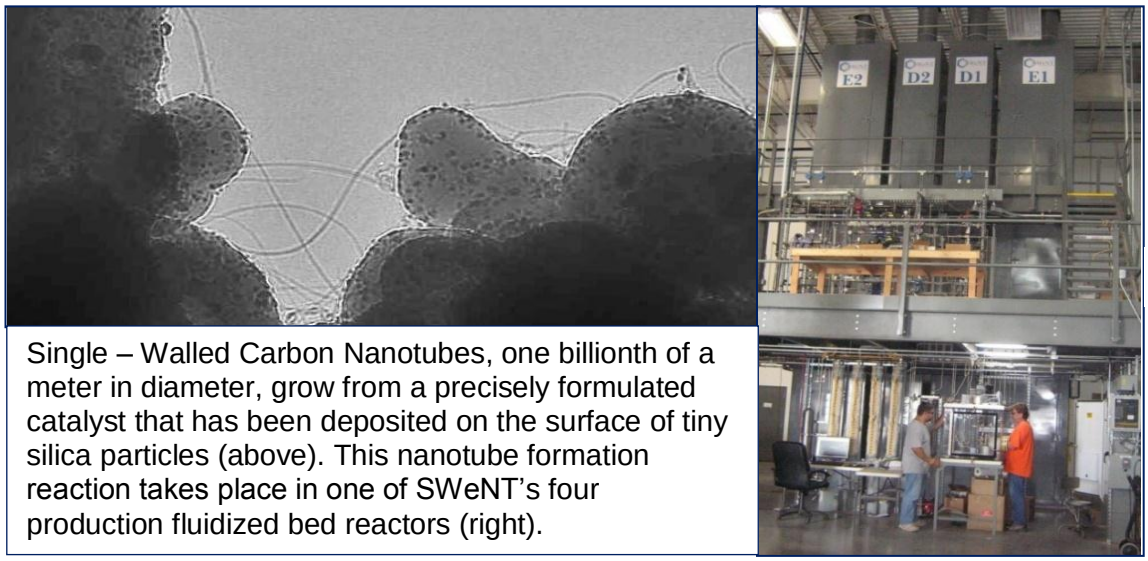
Figure 2

A few conductive organic polymers are also of interest as transparent conductors. However, SWCNT are typically more easily incorporated into printable form and their films, once printed, are more stable in conditions of high temperature and humidity.

SouthWest Nanotechnologies (SWeNT®), of Norman, Oklahoma, in collaboration with its partner, Chasm Technologies, of Canton, Massachusetts, has developed complementary technology platforms that make printed, transparent conductors, based on SWCNT, a commercially available technology…today. A demonstration touch panel based on these technologies is shown in Figure 2.

SWeNT is a leader in the production of Single - Walled Carbon Nanotubes and the first (and as of this writing) only, manufacturer to have been granted a Consent Order by the United States Environmental Protection Agency to produce and distribute SWCNT on a commercial scale.

Using technology developed at Oklahoma University, SWeNT nanotubes are produced in precisely controlled (+/- 1^{o}C) and readily scalable fluidized bed reactors. Silica and



Single – Walled Carbon Nanotubes, one billionth of a meter in diameter, grow from a precisely formulated catalyst that has been deposited on the surface of tiny silica particles (above). This nanotube formation reaction takes place in one of SWeNT's four production fluidized bed reactors (right).

Figure 3

catalyst are removed after synthesis. The resulting, high purity, carbon nanotubes are available in powder, dispersion, paste and printable forms. Figure 3 shows the growth of SWCNT from catalyst coated silica particles and the reactors in which this takes place.

Chasm Technologies is a consulting firm with expertise in coating, printing and other thin film technologies. They guide clients in bridging the gap from concepts and lab results to commercially viable processes. In cooperation with SWeNT, Chasm has developed inks, based on Single – Walled Carbon Nanotubes, which are printable using existing commercial technologies. SWCNTs have been printed in Chasm's laboratory on polycarbonate and PET films and on glass. See Figure 4.

A pilot scale, roll to roll printing line in Chasm's Canton, MA facility

Figure 4

The SWCNT that are incorporated into the inks are engineered to optimize the balance of electrical conductivity and visible light transmission in the printed film. This is accomplished by careful control of the tubes' diameters, lengths, chemistry and other properties.

SWeNT is continuing its Research and Product Development activities in the area of Transparent Conductive Films based on SWCNT. Figure 5 depicts the Resistivity / Light Transmission capabilities as of this writing for spray coated and screen printed TCF. A technical roadmap is in place to develop a product with a resistance of 300 Ω/square at 90% visible light transmission. (Gen 1)

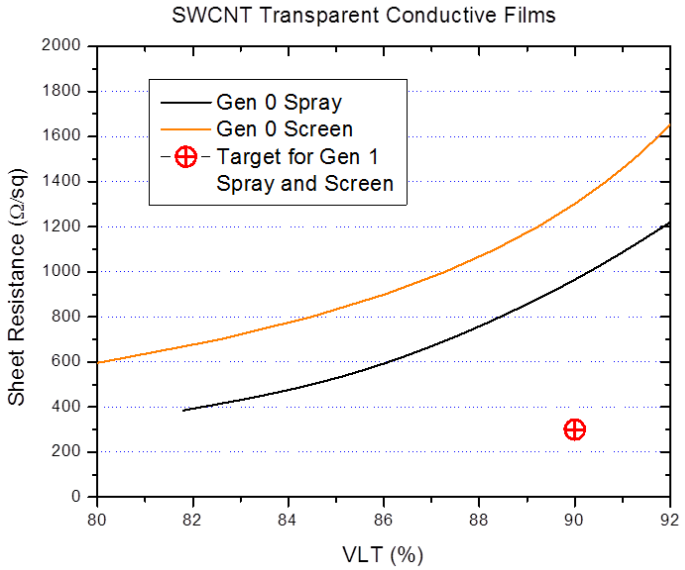


Figure 5

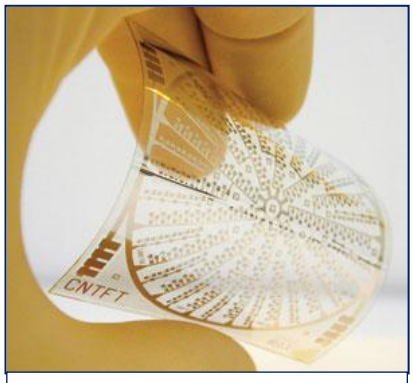
This will be achieved through further optimization of the nanotubes' properties as Chasm Technologies continues to optimize ink formulations to ensure maximum performance of the overall system.

Looking through a transparent, conductive film of SWCNT

Figure 6

A view through a SWCNT film is shown in Figure 6.

SouthWest Nano Technologies' commitment to printed Transparent Conductive Films for touch sensor applications is part of a broader commitment to the rapidly emerging field of printed electronics. While TCFs require electrically conductive nanotubes, SWCNT can also be produced as semi-conductors by carefully controlling the exact arrangement of carbon atoms in the tube wall structure. This opens the door to the use of carbon nanotube inks in a variety of other applications, including printed thin film transistors (TFT), Figure 7. SWeNT has recently entered an agreement with Panasonic Boston Labs to commercialize printed thin film transistors using single-walled carbon nanotube inks**.** The work will be funded by a $500,000 research grant from the State of Oklahoma.



Printed TFT

Figure 7

SWeNT's technology is readily scalable and our plant, located in Norman, OK was designed for rapid future expansion. We are ready to meet the carbon nanotube and CNT based ink requirements of the exciting field of printed electronics.

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