Existing and Emerging Opportunities in Printed Electronics For Printers

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Presentation Outline

- Summary of some new and existing technologies for printed electronics outside of traditional membrane switch manufacturing

- Discussion of requirements for understanding the technology of these applications in order to capitalize on them

Opportunities in Printed Electronics Outside of Membrane Switch Manufacturing

- Printed Disposable Medical Sensors made with Silver and Silver Chloride Inks (EEG, EKG, Defibrillator and Blood Glucose)
- Printed Flexible Heaters with Self Regulating Temperature Capabilities made using PTC Carbon Ink
- Printed Potentiometers and Rheostats using Carbon Ink
- Printing Radio Opaque Inks for Medical Devices
- Unique Display Panels

Printed Disposable Medical Sensors

Four Common Types of Disposable Medical Sensors

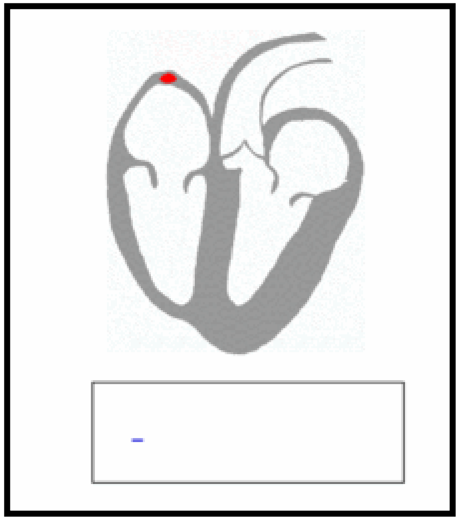
Electrocardiograph (ECG or EKG)
Electroencephalography (EEG)
Defibrillation
Blood Glucose

Printing a Disposable Medical Sensor is Similar to Printing a Membrane Switch

ECG and EEG sensors incorporate printed silver chloride and/or silver ink layers that interface with a liquid or semisolid gel to detect electrical impulses on the skin, as well as the time intervals between the impulses around the area of the heart or brain, and transmit these impulses along the silver ink trace back to the device for decoding. Defibrillation pads use these traces to carry an electrical charge from a device to the skin. Blood glucose sensors use silver ink traces to transmit electrical impulses generated by a complex chemical reaction to detect glucose (sugar) levels in blood. Usually, there is graphic printing on the opposite side of the substrate where the functional inks are printed.

ECG/EKG Sensors

Electrocardiograph (ECG or EKG) is a machine designed to read and record the small electrical impulses given off by muscles of the heart as they expand and contract. This is achieved using sensors attached to the skin surface to detect the electrical signals. Each heartbeat cycle produces 3 main electrical impulses. These electrical impulses or waves are known as "P", "QRS", and "T". The P wave is typically a small wave, QRS is a complex "pulse" and T is a wave similar to the P wave. The P wave is generated as blood flows through the atria (two upper chambers of the heart), the QRS pulse shows what happens to the heart as the blood travels across the ventricles (lower heart chambers) and the T wave shows how the ventricular muscle recovers once it is seen that electrical impulse and gets ready for the next contraction.

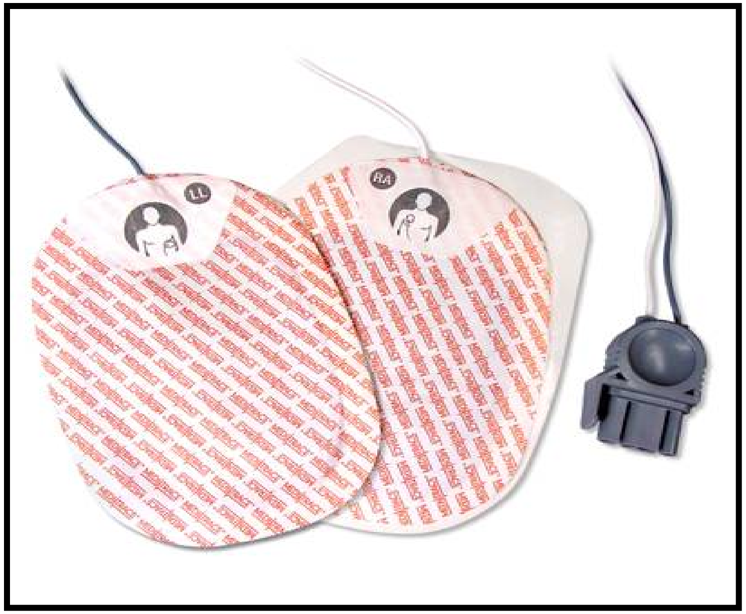


EEG Sensors

Electroencephalography (EEG) is similar to ECG in that it uses sensors to pick up electrical impulses on the skin surface, but it monitors activity in the brain. As brain neurons fire electrical impulses, these impulses travel along a chain of other neurons. The sensors of an EEG cannot pick up impulses from individual neurons, but the sensor can measures these large waves of impulses as they travel through millions of neurons.

Defibrillator Pads

These are "reverse driven" sensors in the respect that they are used to pass an electrical charge from a device into a patient's body, through the skin in the heart area, in order to try to shock the heart into contracting and starting to pump.



Blood Glucose Sensors

These sensors are used to quickly and accurately measure amount of blood sugar by placing a drop of blood onto the disposable sensor and inserting it into the device. The glucose level in the blood is detected through a complex chemical reaction with material on the sensor.

Within the test strip, the blood is mixed with glucose oxidase, which reacts with the glucose in the blood sample, to create gluconic acid. Another chemical within the test strip, called ferricyanide, then reacts with the gluconic acid to create ferrocyanide. The electrode, within the test strip, then runs a current through the blood sample and the ferrocyanide influences this current in such a way that the concentration of blood glucose within the sample can be accurately measured within a fair margin of error. The silver or carbon ink trace printed on the sensor carries an electrical signal to the device which then displays the level of blood sugar on an LCD screen.

Specification for Medical Sensors

AAMI
Association for the Advancement of Medical Instrumentation

Disposable ECG electrodes

ANSI/AAMI EC12:2000/(R)2010

Requirements for Medical Sensor Printing and Assembly

- **Electrical test requirements greater than required for membrane switches**
  --DC Offset Voltage (DCO): After a 1-minute (min) stabilization period, a pair of electrodes connected gel-to-gel shall not exhibit an offset voltage greater than 100 millivolts.
  --Impedance (ACZ): The average value of 10-hertz impedance for at least 12 electrode pairs connected gel-to-gel, at a level of impressed current not exceeding 100 microamperes peak-to-peak, shall not exceed 2 kilohms. None of the individual pair impedances shall exceed 3 kilohms.
  --Defibrillation recovery rate: Pair connected gel-to-gel, 5 seconds after each of four discharges of 200 volts. mV/s is tested by: During 30-sec interval following polarization potential measurement.
  --ACZ Impedance: At end of cycle – post defibrillator overload
- **In some applications, sensor testing adopts methods from specifications for other types of sensors because of a lack of specific procedures to use.**
- **Actual printing of medical sensors is similar to a membrane switch: silver ink traces followed by silver/silver chloride and then UV dielectric. Graphics are often printed on the back side of circuit substrate.**

Requirements for Medical Sensor Printing and Assembly (continued)

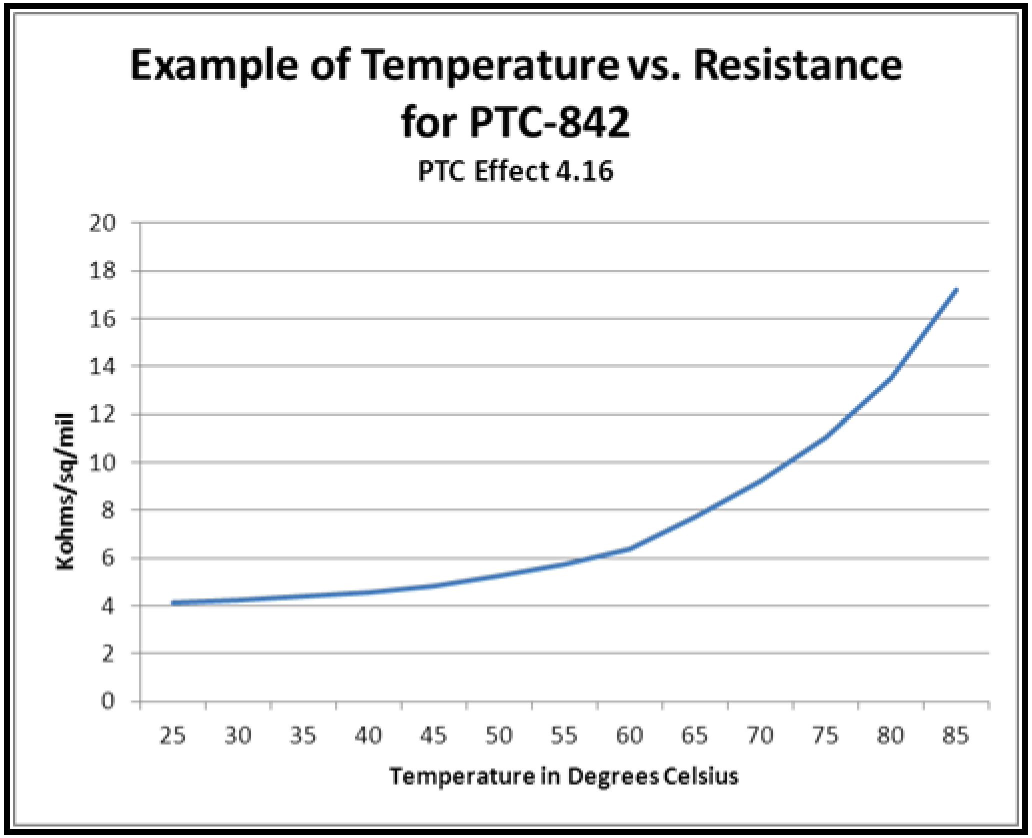
- **New requirements for long term testing include accelerated heat aging to simulate 24 months packaged storing without loss of electrical performance when electrode is powered. Speculation is that there may even be a push for 36 months. As these shelf life requirements are extended, the discrepancy between how well accelerated aging testing can mimic actual ambient packaged shelf life of a sensor appears to be more significant.**

- **Typical sensor development cycle involves adjusting the silver to silver chloride ratio to get the proper electrical response from the sensor and device, and then making sure that the ink polymer binder is compatible with the materials contained in the gel used with the electrode.**

- **Actual skin impedance varies from a hundred to hundreds of thousands of ohms based on skin color, tanning or lotions used. While it is possible to make a low impedance electrode, it is pointless to limit the impedance to less than that of skin. The problem is that high impedance electrodes may not work on some patients.**

Printed Self Regulating PTC Heaters

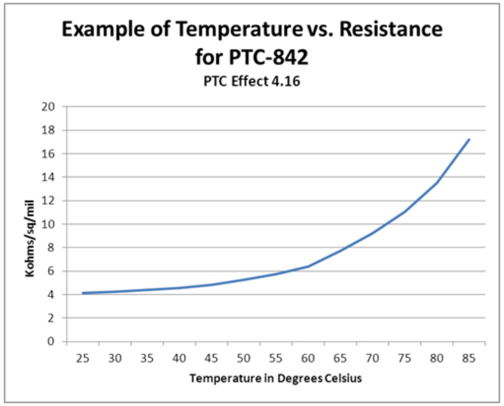
How PTC (Positive Thermal Coefficient) Inks Work

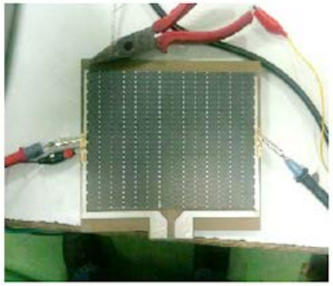


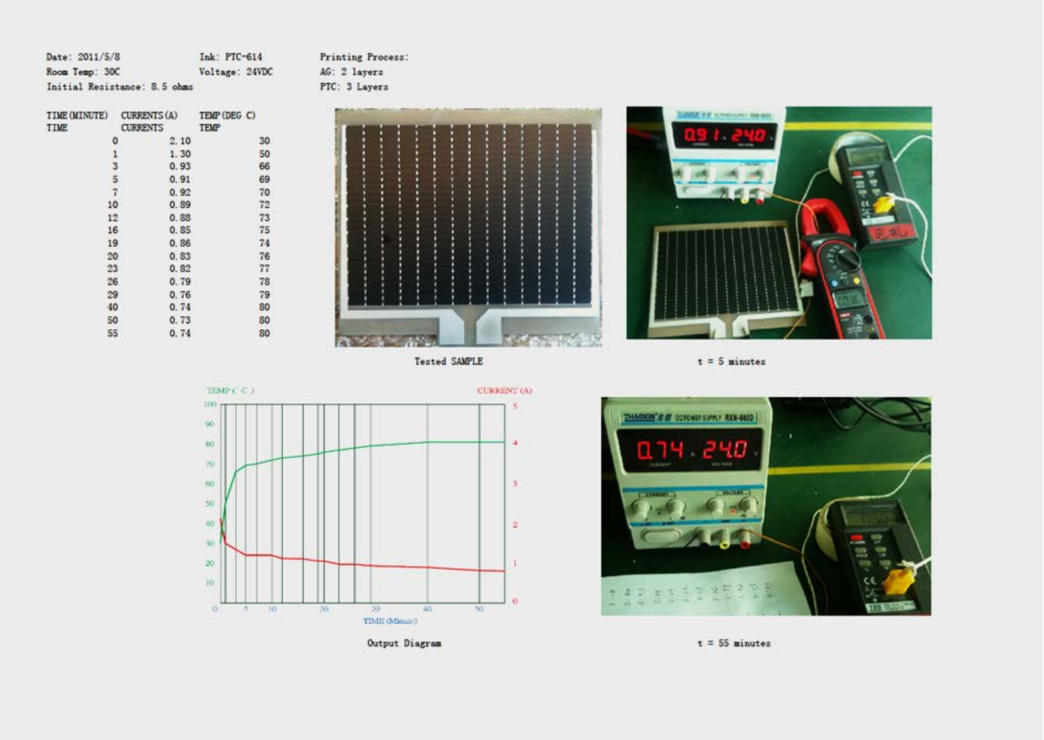
Requirements for Printed PTC Heaters

- **Automotive is driving current development, with heaters used in interior and exterior mirrors for many years, and GM has just launched PTC printed technology for seat heaters on one current car platform.**
- **Properties of inks (baseline resistance, PTC ratio) along with circuit design pattern of heater dictate heater performance.**
- **Key requirements are heater surface and seat surface maximum temperature, response time for seat surface temperature, and impact of surface temperature by a jacket placed on seat.**
- **Seat design, lamination and assembly of heater and location of placement in molded seat bun also contribute to overall performance.**
- **Actual printing of PTC heaters is a two step process involving printing of silver ink bus bars followed by printing of PTC carbon heater elements. Overprinting with insulating material may be used in place of film lamination to protect circuit.**
- **Emerging area of development is using large printed heaters as radiant heat sources for residential and commercial construction.**

PTC Heater Example







Date: 2011/5/8
Room Temp: 30C
Initial Resistance: 8.5 ohms

Ink: PTC-614
Voltage: 24VDC

Printing Process:
AG: 2 layers
PTC: 3 Layers

TIME (MINUTE)	CURRENTS (A)	TEMP (DEG C)
TIME	CURRENTS	TEMP
0	2.10	30
1	1.30	50
3	0.93	66
5	0.91	69
7	0.92	70
10	0.89	72
12	0.88	73
16	0.85	75
19	0.86	74
20	0.83	76
23	0.82	77
26	0.79	78
29	0.76	79
40	0.74	80
50	0.73	80
55	0.74	80

Tested SAMPLE

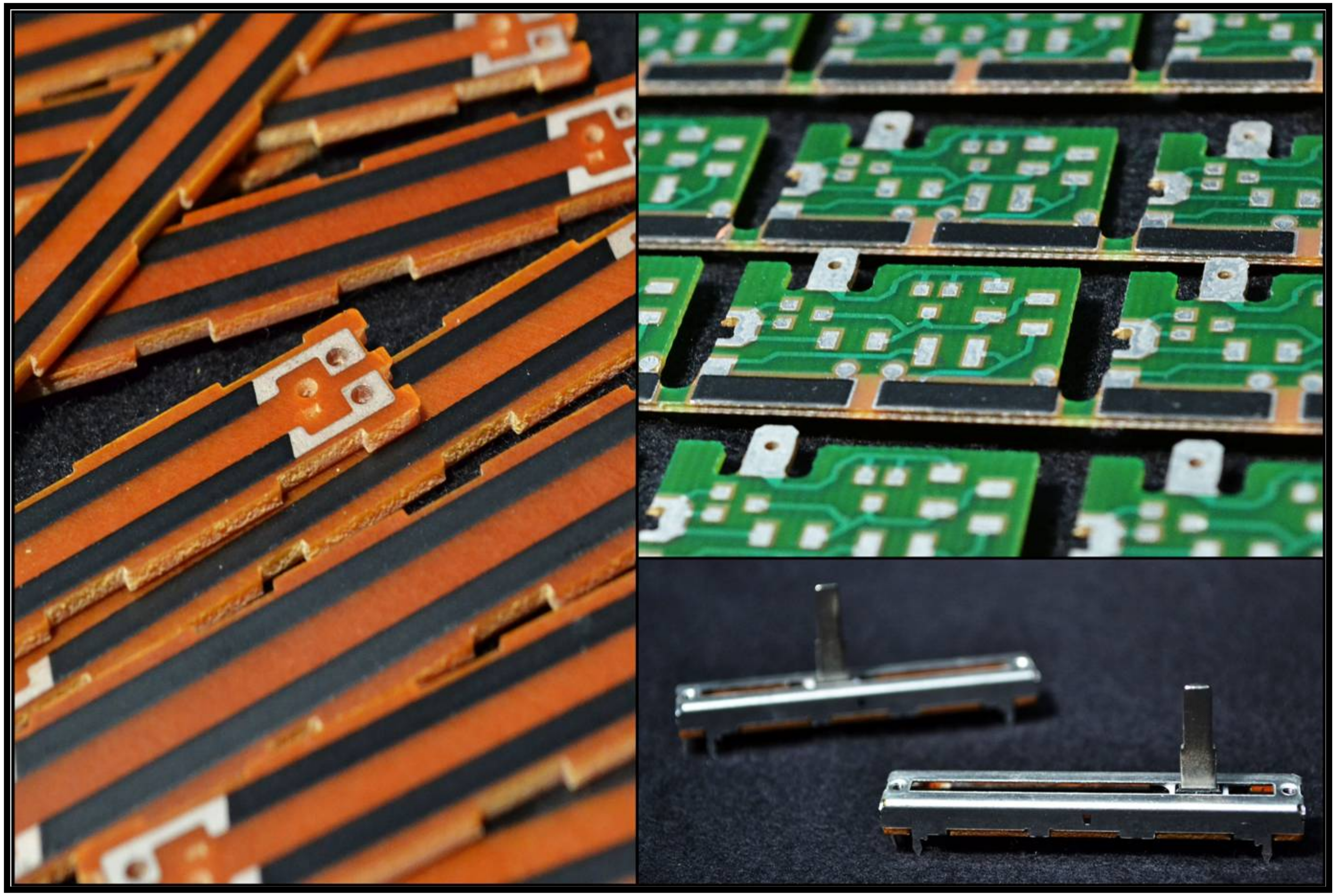
t = 5 minutes

TEMP (°C)
CURRENT (A)
TIME (Minute)

Output Diagram

t = 55 minutes

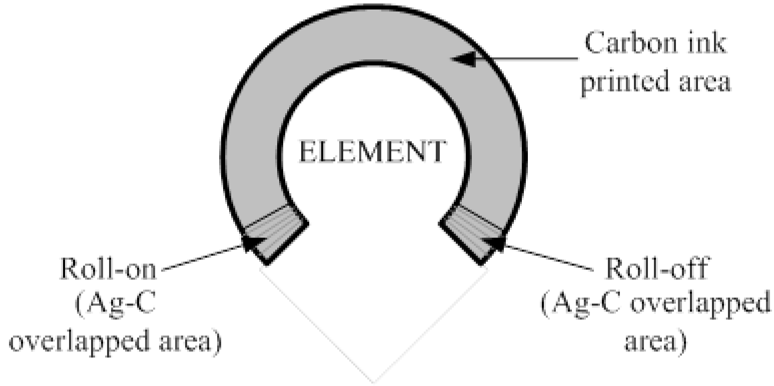
Printed Potentiometers and Rheostats

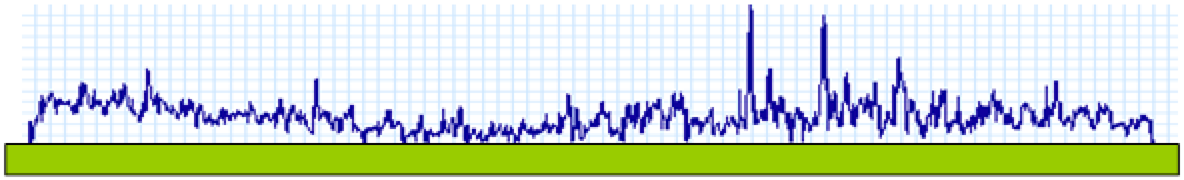


Requirements for Printed Potentiometers and Rheostats

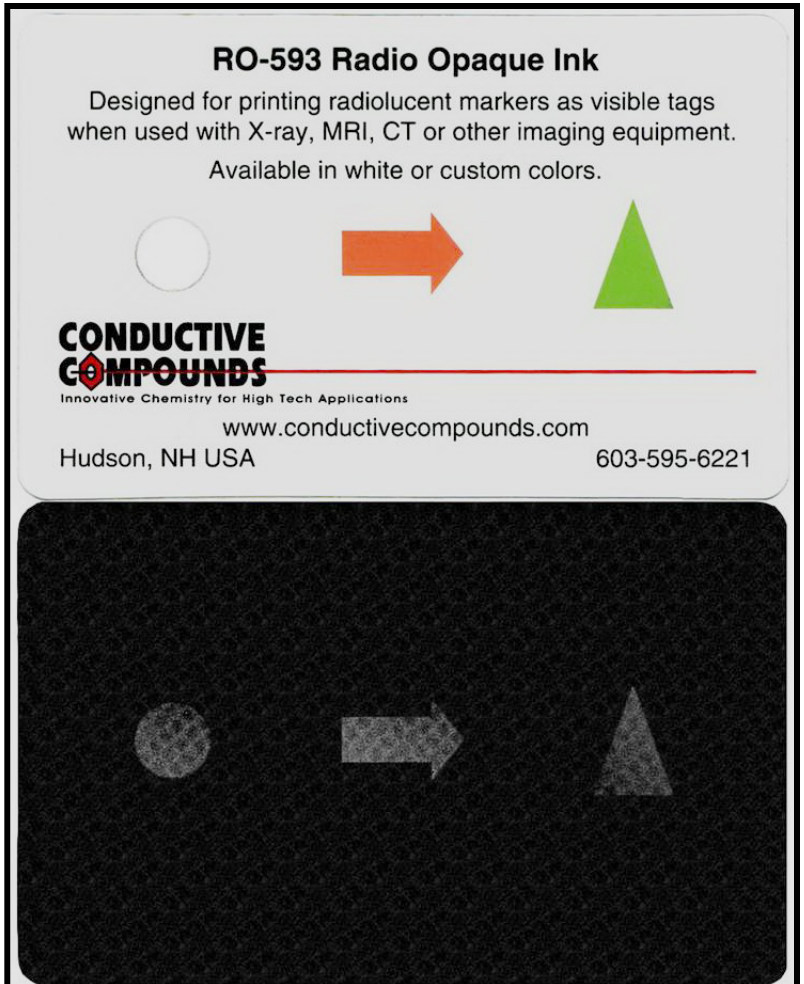
- Requires use of specialty carbon inks with high abrasion resistance and electrical stability over time with exposure to heat and humidity (examples are Acheson Minico inks and Conductive Compounds, Inc. VRI inks)
- Expectation is 1 million plus cycles of mechanical abrasion with minimal electrical noise output and Contact Resistance Variation (CRV), and smoothness of electrical output.
- Printed substrates are almost universally FR-4 circuit material, although some work is being done with flexible polyimide films.
- Print requirements are two layers – silver first and carbon next, but curing temperatures are higher than traditional membrane switch printing, often as high as 200 ^{o}C.

Printed Potentiometers and Rheostats





Radio Opaque Inks for Medical Devices



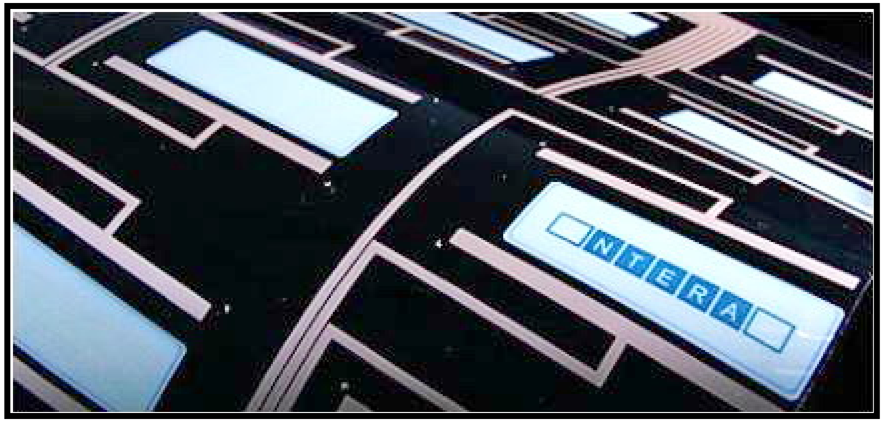
- RO Inks are simply inks that can be detected by either x-ray or MRI scans
- Used as disposable tags, and can be pad printed or dispensed onto medical devices
- Single layer pad or screen printing, and drying similar to silver inks for membrane switches.
- Can be coated or dipped onto devices as well

Radio Opaque Ink Stent Dipping

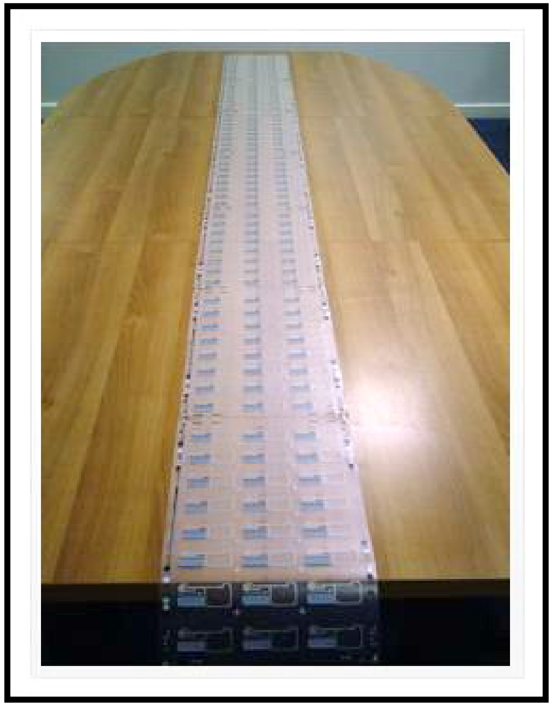
Specialty Display Panels

- **Traditional printed electroluminescent display technology has been established for many years. Most of the new and emerging printed display applications using “printable OLED” type inks are protected by IP or the critical OLED inks are used for captive manufacturing.**

- **One new technology allows membrane switch printers to print functional, printable, flexible interactive monochromic displays that operate on low voltage and can be incorporated into a wide variety of advanced functional printing applications.**



Functional Interactive
Monochromic Graphics



Roll Printable
Flexible Displays

Printed Thin Flexible
7 Segment Displays