Research Paper Engineering

Zno/Mg/Mgo Based Transient Electronics - Splinter After Use

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ABSTRACT

Over the years it is always the goal of Electronics Industry to build and develop durable electronic devices that last forever with dedicated and stable performance, but many new opportunities open up once you start thinking about electronics that could disappear in a controlled and programmed way. Transient Electronics is the name, represent an emerging class of technology whose key characteristics is that it physically disappear in whole or in part in a very controlled fashion after it served its targeted functions. The transient nature is based around coating the base electronic device in a material that will completely dissolve in bio-fluids or water after a known period of time. Because the coating takes a known length of time to dissolve in fluids. Off course this transient nature is not possible without certain special material called transient materials; special degradable polymer composite materials designed to quickly and completely melt away when a triggered is activated. Transient Electronics enable application range from biodegradable electronics, medical implants, secure electronics, to vanishing environmental sensors and zero-waste consumer electronics. The initial part of this article focuses on introduction to various transient material, functioning, and structure. The later part of the article emphasis on application of transient electronics in various promising fields.

KEYWORDS | Transient, SOI (Silicon on insulator),bio-fluids.

1. Introduction

It is the era of advanced electronics, conventional electronics are made to last indefinitely. Transient Electronics on the other hand offer the opposite behavior. They physically vanish over time in a well controlled manner and at a prescribed time, dissolving when they react with water or bio-fluids. A magnesium oxide encapsulation layer and a silk overcoat envelopes the base electronics, and thickness of encapsulation determine how long the system will take to disappear into the environment.

An interdisciplinary team of researchers from Northwestern University, the University of Illinois at Urbana-Champaign and Tufts University were the first to demonstrate "transient electronics". The materials tested by them are biocompatible, which is important for implantable electronics. Magnesium is a basic element found in the human body, and the materials used in some stents.

Fig -1: Transient Electronics Chips

1.1 Transient Materials

Today's material Silicon (Si), which under goes hydrolysis in basic aqueous condition is an easy choice but zinc oxide and certain organic semiconductors represents best alternatives. In all cases compatible conductive materials are also essential. By comparison to conductive polymers, conventional metals are more appealing due to their low resistivity, stable properties and well established roles in commercial devices. Materials and fabrication procedure are described for bio-degradable transistor and simple integrated circuits, the approach relies on an unusual type of silicon on insulator (SOI) wafer to yield devices that uses ultrathin sheets of mono crystalline silicon for semiconductor, thin film of magnesium for electrodes and interconnection, silicon dioxide and magnesium oxide for the dielectrics, and silk for substrate.

Si for Transient Electronics:
Si thickness: 35 nm (ultrathin, top SOI)
Dissolution time: 10 days
Required volume of water: 0.4 mL (~1 cm2)

Si for Conventional Electronics:
Si thickness: 700 mm (bulk wafer)
Dissolution time: 600 years
Required volume of water: 8 L (~1 cm2)

(ZnO), in particular, has a favorable combination properties, Including excellent transparency in the visible wavelength range, high electron mobility, and strong piezoelectric response. As a result, ZnO, in forms ranging from films to wires and rods, has been explored in sensing, catalysis, optical emission, piezoelectric transduction, and actuation. ZnO is biocompatible, and therefore suitable for devices that integrate on or in the human body. Here we introduce classes of ZnO based electronic devices that have, as their key attribute, the ability to dissolve completely in water or bio fluids. In this way, ZnO provides an alternative to silicon or organic semiconductors for physically transient forms of electronics and sensors, with expanded capabilities in energy harvesting, light emission and others.

2. Transient Electronics

Silicon which is the most abandoned material, as used conventionally, does dissolve in bio fluids but at a rate too slower

than what require or suitable for transient electronics. Hence we require nano- membranes (ultra thin sheets) of silicon, which are thin enough to melt with few drops of water. They used magnesium electrodes and interconnect magnesium oxide for gate and interlayer dielectrics to build various circuits and devices. These circuits are then encapsulated in silk layers, collected from silkworm cocoons, dissipation rate is modified by carefully controlling the crystal structure of silk, time scales ranging from few minutes to hours or days or even years.

2.1 Structure

The electrodes inside the silk are based on nanometers thick sheets or ribbons of silicon, called silicon nano membranes. The materials have been used to fabricate experimental devices such as transistor, diodes, complementary logic devices and photocells of flexible surface.

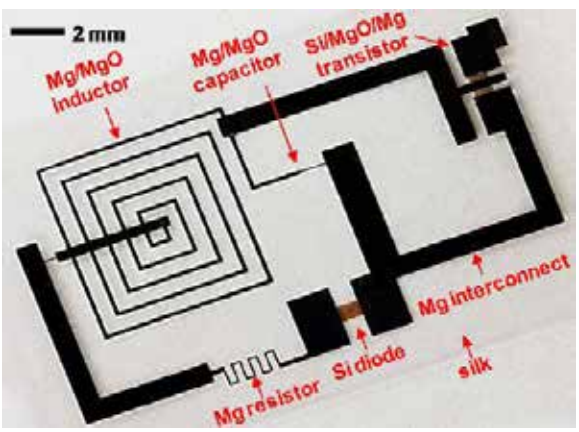

Fig:2 Transient integrated devices(Science Vol. 337)

As already mentioned in previous text, that it is possible to fabricate various basic transient electronics devices as shown in Fig.2, Mg/MgO inductor, capacitor, transistor, Mg resistor, Si diode. All are fabricated on silk base as a substrate. The figure also shows the Mg interconnect for connection. Fig. 3 also shows different view of integrated devices.

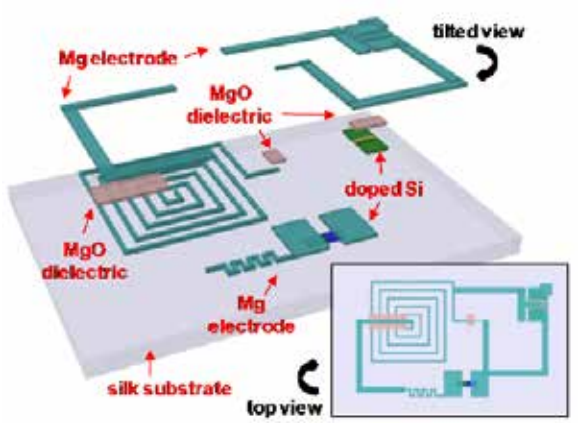

Fig:3 Cut way view of transient inductor

2.2 Disappearance behavior (courtesy Science 1200, Vol. 337):

The following figures show the disappear act of transient devices. The sample under experiment disappears within ten minutes depending upon programming.

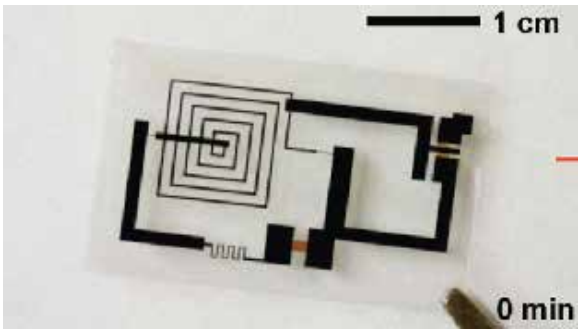

Fig: 4 Status at zero min.

Sample just immersed in water.

Fig: 5 Status after 5 min.

View of sample after 5 min.

Fig: 6 Status after 10 min.

This shows that after 10 min the entire electronics is disappeared. The time of disappearance may be modified by carefully controlling the crystal structure of silk.

3. Current Research Scenario

The researchers under John Rogers team, tested a host of such transient components like inductors, capacitors, resistors, diodes and transistor. All the components above said, disintegrated and dissolve when immersed in de-ionized water. They also report progress in making the devices with conventional manufacturing process. The researchers also demonstrated that transient electronics component including heater, sensors and power supply can operate in both water and a phosphate buffered salin liquid, which is very chemically similar to what is in the human body. They also implanted the transient electronics in a mouse model and shows that the heating device was effectively kill the bacteria.

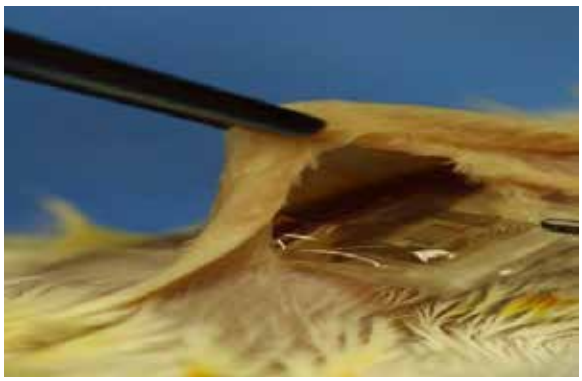

Fig. 6 Implantation in rat (courtesy Beckham Institute, University of Illinois).

The team was able to construct a very tiny biomedical implant in mice, which was used to eliminate a common complication with many surgeries. "That is the growing problem associated with surgery – surgical sight infection,".

Capable of receiving power wirelessly, the device creates local heating at levels that can kill bacteria that may be forming at the sight of surgery. However, the risk of infection from surgery is the most critical two weeks after the initial period – rendering the device unnecessary in just a short time. The device was programmed to start dissolving after that two-week period. When the researchers examined the mice three weeks after the device was originally implanted, they found that infection had been reduced and only a very faint traces of the implant remained.

4. Applications

Transient Electronics finds wide spread applications in various fields such as medical implants, pharmaceutical industry, environmental monitors, secure electronics and many more. Going beyond medical application, transient electronics inventions may revolutionize the entire electronics industry by developing devices that naturally degrade into the environment, there is less waste left behind and the environment is less harmed. One day they may totally transform the consumer electronics industry by producing zero-waste electronics gadgets.

4.1 Transient, Implantable Thermal Therapy Devices

One of the major applications of transient electronics is in medical implants, where it is used as to monitor organs conditions or as a drug dispenser.

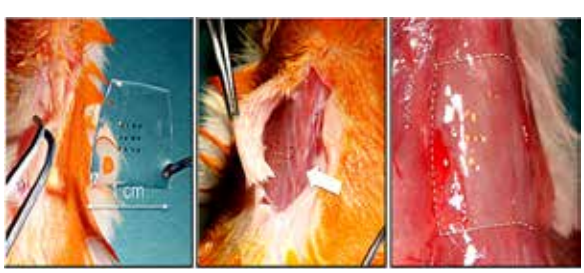

Fig.8 Si electronics on silk (w/ Tufts) (Courtesy Appl Phys Lett 95, 133701 (2009))

4.2 Secure Electronics

Transient Electronics devices can be used as secure integrated circuits which is disappear after their targeted functions so that crucial circuit information may be protected.

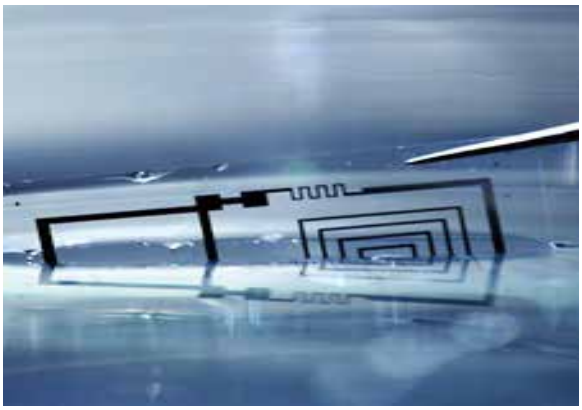

Fig.9 Transient Electronics Circuit

4.3 Military Sensitive Equipments

Transient Electronics finds wide application in military, from communication equipments to surveillance system all can used transient devices to hide very important information, incase these equipments/system left behind in militant's periphery during war situation.

Fig.10 Edible Colpitts RF Oscillator(Courtesy ILLINOIS UNIV.)

4.3 Transient Environment Monitor/Sensors

Environmental monitors such a wireless sensors that are dispersed after a chemical spill, that degrade over time to eliminate any ecological impact.

Fig.11 (Courtesy ILLINIOS UNIV.)

5. CONCLUSIONS

Transient Electronics devices are still in the beginning stages of development. Medical implants such as pacemakers and defibrillators have helped to revolutionize the industry. But researchers are currently more interested in the devices potential for medical care, like implantable sensors or drug dispensers, as military exploits and environment monitoring. The fact that

these devices enhance the quality of life greatly and also have a very minimal environmental impact is very promising for the future development of the technology. While there have been no human trials yet, the component materials of the system are found in implants that have been approved by government regulators for other medical uses. Hence by introducing transience, transient electronics based devices or sub-parts will become compost rather than trash. The technology may someday reduce the amount of e-waste. The vision would be to make a cell phone that's completely water soluble, or make certain components water soluble.

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