# The World's First Sterilizable Flexible Organic Transistor

Brookhaven National Laboratory

Contacts: Karen McNulty Walsh [1], (631) 344-8350 or Peter Genzer [2], (631) 344-3174

The following press release on the world's first sterilizable organic transistor was issued jointly by the University of Tokyo, Japan Science and Technology Agency, and Princeton University. A key to its fabrication (establishing structure-function relationships) was work done at Brookhaven National Laboratory's National Synchrotron Light Source (NSLS) by scientists with Princeton and the National Institute of Standards and Technology. Working at NSLS beamline U7A, the researchers systematically characterized the structure of an organic transistor, proving that the material remains stable even at 150 degrees Celsius. This is an important step toward the development of medical devices that must be viable after high-temperature medical sterilization before implantation.

## The World's First Sterilizable Flexible Organic Transistor

### A path to the development of implantable devices

Tokyo, Japan — An international research team has succeeded in manufacturing on a polymeric film the world's first flexible organic transistor that is robust enough under high temperature medical sterilization process. The study is to be published online in Nature Communications on March 6, 2012.

In a serious aging society with a declining birthrate, electronics are increasing their importance in the health and medical area as more IT devices are being introduced. Upon this background, an expectation is getting higher on an organic transistor, which is a soft electronic switch. A flexible organic transistor can easily be manufactured on a biocompatible polymeric film, and this is the reason why it is expected to adopt it to a wearable health monitor without a stress, and/or implantable devices such as a soft pace maker. For practical implementation, it is crucial (1) to make the best use of its softness and biocompatibility, simultaneously (2) to decrease driving voltage down to a few V, and (3) to decrease the risk of infections by sterilization, for a security reason. Up until now, however, the existing organic transistors had huge obstacles towards the practical usage in the health and medical field. For example, typical driving voltage for displays is high (i.e. 20 to 80 V) and/or and it is not durable under high temperature sterilization.

The team has succeeded in manufacturing on a polymeric film an organic transistor that has high thermal stability and driving voltage of 2V at the same time. The new type organic transistor can be sterilized in a standard sterilization process (150 °C heat treatment) without being deteriorated in its electrical performances. The key to realize heat resistant organic transistor is in the forming technique of an ultrathin insulator film: The team develops a technique to form extraordinarily densely packed self-assembled monolayer (SAM) films, whose thickness is as small as 2 nanometers, on a polymeric film. This allows them to elevate substrate temperature up to 150 °C without creating pinholes through SAM films during the high temperature treatment. It is believed that ultrathin monolayer film like SAM degrades easily by thermal processes; however, it is unexpectedly demonstrated that densely packed SAM is stable at 150 °C or higher. This result is also proved by systematic characterization of crystallographic structures of SAM using a synchrotron radiation beam. Furthermore, by adopting a novel encapsulation layer comprising organic/metal composite materials and extremely thermally stable and high mobility organic semiconductors, the thermal stability of organic transistors is now improved up to 150 °C.

It should be benefited more from applying this heat-resistant organic transistor to long term implantable devices, or to some medical devices such as a smart catheter. With these applications, it is expected to broaden the usage of the transistor to medical apparatus such as thin film sensor that will detect tumors, inflammations, and or cancers.

The international team is led by Dr. Takao Someya, who is a professor of the University of Tokyo (President: Jyunichi Hamada, Ph.D.), a research director of ERATO (Exploratory Research for Advanced Technology) “Someya Bio-Harmonized Electronics Project” of Japan Science and Technology Agency (JST, President: Michiharu Nnakamura, D.Sc.), and a global scholar of Princeton University (President: Shirley M. Tilghman, Ph.D.), in collaborations with Associate Professor Tsuyoshi Sekitani of the University of Tokyo and Professor Yueh-Lin (Lynn) Loo of Princeton University. This joint research project was also carried out with the following institutions: Max Planck Institute for Solid State Research, Germany, National Institute of Standards and Technology, NIST, U.S., Hiroshima University, and Nippon Kayaku Co., Japan.

In consequence of a serious declining birthrate and a growing proportion of elderly, information technology (IT) devices are rapidly introduced in the health and medical area. One of the good examples is the internet connection of a healthcare device between a patient’s home and a hospital. The internet allowed a doctor to monitor patience’s heart rates and weights away from his/her home. The miniaturization of medical apparatuses such as endoscopes succeeded in minimizing patients’ burdens and/or invasiveness. In this way, in the medical and the healthcare field, electronics are increasing their importance. Indeed, in the health and medical market, electronics are expected to grow 120% every year successively until 2015.

In this background, an organic transistor, which is a flexible electronic switch, attracts much attention because it is easily manufactured on a biocompatible polymeric film. A biocompatible organic transistor would be suitable for applications to a stress free wearable health monitoring system and implantable devices such as a soft pacemaker. For practical implementation, it is crucial (1) to make the best use of its softness and biocompatibility, simultaneously (2) to decrease driving voltage down to a few V, and (3) to decrease the risk of infections by sterilization, for a security reason. Up until now, however, the existing organic transistors had huge obstacles towards the practical usage in the health and medical field. For example, typical driving voltage for displays is high (i.e. 20 to 80 V) and/or and it is not durable under high temperature sterilization.

The team has succeeded in manufacturing on a polymeric film an organic transistor that has world’s first 150 °C thermostability and simultaneously its driving voltage of 2V. The keys to realize the heat resistant organic transistor are (1) self-assembled monolayer (SAM) and (2) a sealing film, which are to be discussed later. The highly thermal stability that we had realized exploded the typical theory that an ultrathin monolayer film of nanometers in size was easily affected by heat. This result was also proved by the systematic analysis of precise crystallographic characterizations using a synchrotron radiation beam, which will be described in (3) in detail. Furthermore, the organic transistor has successfully been sterilized under a standard sterilization process (150 °C heat treatment) without being electrically deteriorated. This will be discussed in (4).

### (1) Highly thermostable self-assembled monolayer (SAM) gate insulator

A key technology towards the development of sterilizable organic transistor is the 2-nm-thick ultrathin self-assembled monolayer (SAM) film. To reduce a thickness of a gate insulator film is known as the effective way to reduce the driving voltage of an organic transistor. From the security reasons, it is necessary to thin down a gate insulator film to a few nanometers thickness in order to reduce the driving voltage down to 2V. The team employed SAM film for a gate insulator in the past. They attempted to optimize manufacturing process of SAM from heat resistance point of view. As a result, by substantially improving crystalline ordering of densely packed SAM films on a polymeric film, they succeed in forming an insulator film that does not create pinholes, the cause of a leakage current, even under a high heat treatment. This becomes possible by optimizing plasma condition during the shaping process of aluminum-oxide thin films on top of the polymeric film, resulting in a way to avoid the film from being damaged during a plasma process.

### (2) An encapsulation layer comprising organic and metal composite films

An improvement of thermal stability of a SAM gate insulator is not enough to accomplish the high thermal stability of an organic transistor. Normally, organic semiconductors that compose the channel layer in organic transistor are known to be easily degraded by heat. Thereby, an organic semiconductor, which is carefully chosen among heat resistant materials, is dinaphtho-thieno-thiophene (DNTT) in the experiment. Furthermore, after manufacturing an organic transistor, the transistor is completely covered by a flexible, heat-resistant encapsulation layer comprising organic and metal composite films (Figure 2). The encapsulation layer restrains DNTT from subliming with heat, and it prevents elements from substantial deterioration. Moreover, it is demonstrated that electronic characteristic of organic transistor remains practically unchanged even after dipped in the boiling water.

SOURCE [3]

**Source URL (retrieved on *03/04/2015 - 2:19pm*):**
http://www.ecnmag.com/news/2012/03/worlds-first-sterilizable-flexible-organic-transistor

**Links:**
[1] http://www.bnl.gov/bnlweb/pubaf/pr/mailto:kmcnulty@bnl.gov
[2] http://www.bnl.gov/bnlweb/pubaf/pr/mailto:genzer@bnl.gov
[3] http://www.bnl.gov/bnlweb/pubaf/pr/PR_display.asp?prID=1396