

## NOTE

# Development of Printable Electronics for Circuit Formation

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## Introduction

### 1.1 What is Printable Electronics Technology?

Conventionally, printing is to recreate characters, paintings and pictures on papers or others with ink. Lately, printed electronics (PE), technology for creating electronic circuits and electronic components by use of printing technology, has been intensively researched and developed.

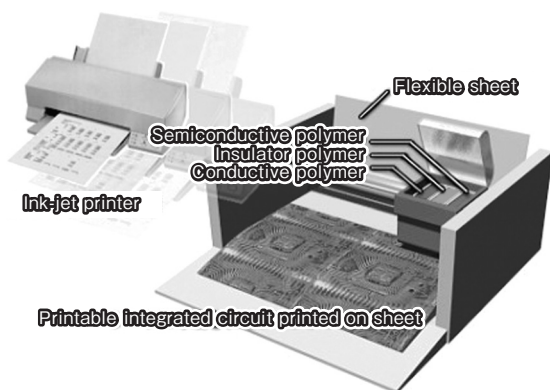


Fig.1 PE Technology <sup>(1)</sup>

### 1.2 Advantage of PE Technology

The PE technology has following major advantages.

#### • Flexibility in production

In the conventional way of producing electronic devices, electronic components are soldered on the printed wiring board on which circuits have been formed. In the method by the PE technology, material for electronics circuits is printed. There are various printing methods. Ink-jet printing with no use of a printing plate is capable of easily changing production models in response to change of a program, being suitable for high-mix low-volume production. On the other hand, relief printing and intaglio printing are capable of high-speed printing, being suitable for high-volume production like newspapers. As above, the PE is capable of responding appropriately to customer needs.

#### • Downsizing, weight saving and flexibility (ease of flexing)

A general electronic component consists of elements, electrodes and a package to protect inside from the external environment. By the PE technology, an electronic component consists of the material having an element function formed on a circuit, and of the printed protective film covering the formed element, instead of a package.

We expect this method will allow the electronic devices to be smaller and lighter. Moreover, using a thin film instead of a printed circuit board will allow superior products in flexibility.

#### • Green product

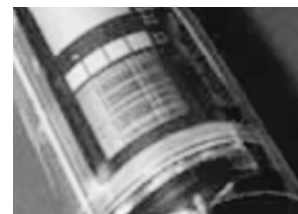
In order to form circuits on the major printed circuit boards used in conventional electronic devices, chemicals are used for etching unnecessary parts on the circuit boards entirely covered by copper foil. In many cases, solder is used to mount the electronic components. By the PE technology, only the necessary amount of material is used for printing on the parts for circuit formation. This reduces large amount of waste chemicals and material. Besides, material for electronic components to be formed in much lower temperature than a solder melting point is under development. Using such material lowers the temperature required for production processes. This contributes to reduction of waste and consumption energy during production.

### 1.3 Expand of PE-application Market

The research and development of the PE technology in the West has preceded other countries. In Japan, the research and development activities are more active than before, and Printed Electronics Association was launched in 2010 as well. At present, the competitors of the PE technology are spread all over the world. This is because the market taking advantage of the PE technology has a great potential for huge growth, as seen in the products, such as a solar cell [Fig. 2 (a)], a display [Fig. 2 (b)], an electronic paper and RFID.



(a) Solar cell <sup>(2)</sup>



(b) Display <sup>(3)</sup>

Fig.2 Example of Product Using PE Technology

\* (1) Excerpt from website of SCIENCE GRAPHICS. Co., Ltd.

\* (2) Provided by Dr. Nogi, an associate professor of the Institute of Scientific and Industrial Research, Osaka University

\* (3) Excerpt from website of AIST (Advanced Industrial Science and Technology)

**2 Examination of Applicability of PE Technology to FUJITSU TEN Products**

**2.1 Advantage of FUJITSU TEN Products with PE Technology Feature**

FUJITSU TEN that mainly manufactures and sells in-vehicle electronic devices has to address endless challenges to downsize and reduce the weight of products. Therefore, new PE technology is expected to help to solve the challenges in some way. If we create a new printed board using a flexible PET film instead of the conventional printed circuit board, the new product will be lighter, of course, and have fewer restrictions on the shape of the product. This will expand the availability of the product to be installed in the limited space in a vehicle, which used to be a difficult space for installation. This will also give us a chance to provide various types of design. Moreover, this technology may enable us to develop an unprecedented product, by finding a new installation position. As above, the PE technology has potential for new product development by a new method. In order to examine the application of the PE technology to our products, we have started with creating an antenna that we can evaluate in the performance only of its conductor circuit. We have collaborated on this examination with the Institute of Scientific and Industrial Research, Osaka University, which precedes the research in the PE technology.

**2.2 Antenna to be Formed**

We have selected PET film as base material of the antenna, and have adopted an ink-jet printer that does not use a plate for printing, so as to meet diversification of future needs. The antenna to be formed will be attached on a vehicle windshield to receive broadcasts and GPS signals.

**3 Examination of Circuit Formation by Ink-jet Printing**

**3.1 Ink for Circuit Printing**

There are basically two types of conductive inks for circuit formation by the PE technology: a highly-conductive metallic type; and a readily-synthesized organic type<sup>1)</sup>. Silver nanoparticle ink that uses nanoparticles of silver, as small as several or dozens of nanometers in diameter, is highly conductive among the metallic inks (Fig. 3).

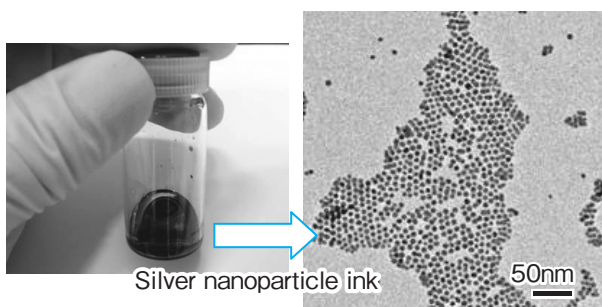


Fig.3 Examined Silver Nanoparticle Ink

The silver nanoparticle ink heated at approx. 100°C provides conductive property as high as bulk silver. Because of using the PET film having heat resistance performance of approx. 100 °C, we have used the silver

nanoparticle ink that is capable of forming at 100°C, for the examination of conductive circuit formation.

**3.2 Circuit Formation by Ink-jet Printer**

To achieve 50 μm of the circuit width that is equivalent to the circuit width of a high-density printed circuit board, we have printed the circuit by use of an ink-jet printer with silver nanoparticle ink on the PET film. After printing, we have found that the ink bleeds as wide as 650 μm (Fig. 4). Therefore, we addressed the problem.

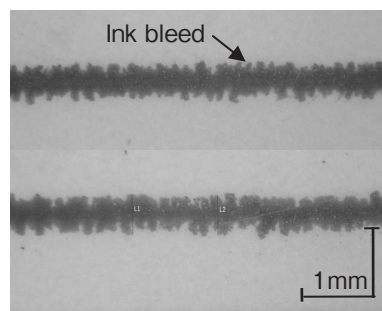


Fig.4 Ink-Bleeding Pattern without Absorbing Layer

To suppress the ink bleed, the characteristics of bleeding expanse shall be controlled by use of appropriate ink or appropriate material on which the circuit is printed. We have examined the change of surface property of the material on which the circuit is printed so as to suppress the ink bleed without changing the ink characteristics. There are several methods for changing the surface property: a method to apply a porous layer on the surface so as to absorb ink solvent; another method to control surface energy by irradiating plasma; and another method to make the surface finely-undulate so as to obtain water repellent effect<sup>1)</sup>.

This time we have selected the method to apply the porous layer because the treatment on the material on which the circuit is printed is relatively easy. Fig. 5 shows the results regarding bleed of the circuit widths on various levels of the surface roughness created depending on porous treatment conditions. We have succeeded in obtaining desired printing result where the ink has been absorbed in the porous layer, showing a line thinner than 50 μm of targeted circuit width, unlike the former result showing a broadened line (Fig. 6).

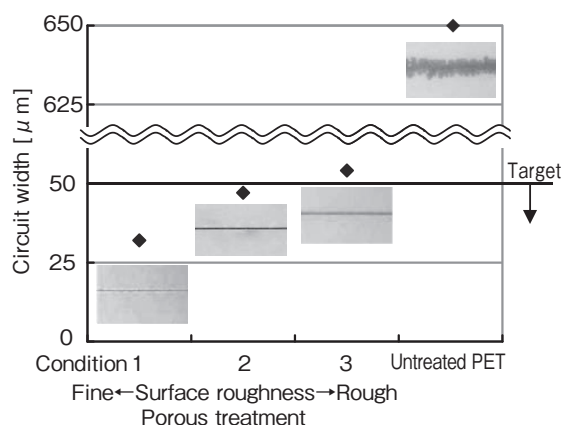


Fig.5 Bleeding-Suppression Effect by Porous Treatment

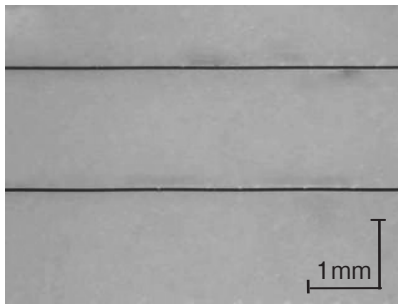


Fig.6 Bleeding-Suppressed Pattern with Absorbing Layer

### 3.3 Formation of Antenna Circuit

We have formed the antenna that has been printed with the silver nanoparticle ink by the ink-jet printer on the PET film on which the porous surface treatment has been applied (Fig. 7).

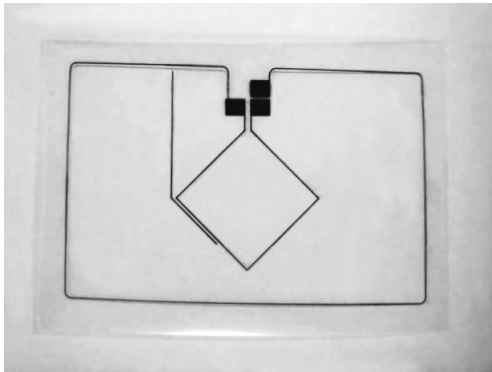


Fig.7 Successfully printed Antenna

We have checked that our product equipped with this antenna behaves properly in receiving broadcasts and GPS signals.

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## Conclusion

In line with current active research and development of the PE technology, FUJITSU TEN has started with examination of circuit formation for an antenna by use of the PE technology. Further, we will develop printing technology for a finer circuit or for the material serving the function of an electronic component, so that we will provide a breakthrough product and a green product.

Lastly, we would like to express our heartfelt thanks to everyone involved for this development in Suganuma laboratory and in Nogi laboratory of the Institute of Scientific and Industrial Research, Osaka University.

### Reference

- 1) Printed Electronics Technology, written by Katsuaki Suganuma and Hiroshi Tanaami, published by Kogyo Chosakai Publishing Co., Ltd. in 2008

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