# Copper-Clad Stretchable and Flexible Film

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## 1 Abstract

In recent years, wearable devices that track vital signs and that can be worn under, with, or on top of clothes or skin, have been attracting a lot of attention. Among wearable devices, the market for stretchable devices in particular is expected to grow. In light of such circumstances, we have developed a new material to be used to manufacture such devices. This new material consists of elastic film that is laminated with copper foil and is resistant to high temperatures. The elastic film has excellent mechanical properties: it is capable of elongating by 550% and has a recovery rate of 94%. In addition, this material is resistant to both the chemicals and the heat associated with the subtractive process and the $N_2$ reflow process. Furthermore, the material has a low dielectric constant (Dk) of 2.3 at 10 GHz, and a dielectric dissipation factor (Df) of 0.0030 at 10 GHz. Both of these properties are important for flexible substrates used in high-frequency devices.

## 2 Characteristics of the Product

- The film offers stable conductivity, with little change in the film's wiring resistance even when it is stretched.
- The film's low dielectric constant and low dielectric dissipation factor mean that energy conservation can be expected in high-frequency regions.
- The film is compatible with existing processes for forming and mounting circuits, so you do not need to invest in new facilities or equipment.

## 3 Background of the Development

Recently, the Internet of Things (which is commonly referred to as "IoT" and describes a state in which various things are connected via the internet) has attracted a lot of attention, and wearable devices[1), 2)] are being developed as a new type of device. In light of these trends, wearable devices not only need to provide the same functions as conventional devices, but also need to be comfortable. This requirement has led to studies on the application of stretchable devices to curved surfaces (such as a human body).[3)] As the conductor for such stretchable devices, the use of a stretchable, conductive paste has been examined. However, because such pastes typically contain a metal filler to ensure conductivity, repeated straining of the paste leads to an increase in its resistance value, which poses an issue.[4)] Although a flexible print circuit board can be used to stabilize the resistance value, it is difficult to miniaturize such circuit boards or to make them conform to a particular shape. For these reasons, we attempted to develop a new wiring material for stretchable devices that maintains a stable resistance value even when subject to repeated bending or straining, and that can be made to conform to a particular shape.

## 4 Technical Details

### 1. Design concept of the stretchable wiring material

In order to be used as a conductor in stretchable devices, the base material must be highly malleable, must maintain a stable resistance value when stretched, and must be sufficiently heat-resistant to enable the mounting of parts. To satisfy these requirements, we developed a stretchable wiring material by integrating technologies used in print circuit boards and composite materials. To make the conductor stretchable, we used multiple layers consisting of a layer of etched copper foil in a meander structure, and a base layer of a stretchable and highly heat-resistant film made from a combination of elastomer and thermosetting resin.

### 2. General properties of the stretchable wiring material

**Table 1** shows the general properties of the stretchable wiring material. The base material can elongate by 550% before breaking, and has a 94% recovery rate after being elongated by 50%. Furthermore, the material's resistance to the chemicals used during wiring forming and its superior heat resistance make it suitable for use in conventional etching and soldering processes.

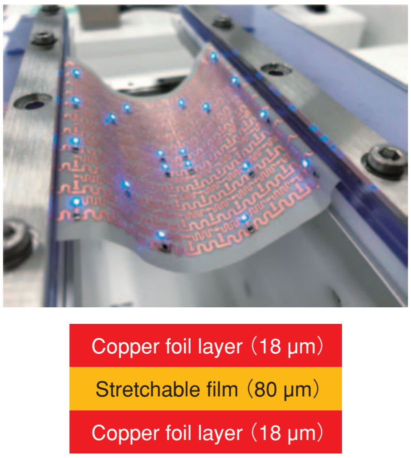


Figure 1 A sample device (upper) and structure of copper-clad stretchable and flexible film (lower)

Table 1 Properties of the elastic film used for the copper-clad stretchable and flexible film

| Item | | Property | Note |
|---|---|---|---|
| Tensile elongation | | 550% | Film thickness: 100 μm |
| Tensile modulus | | 5.0 MPa | |
| Recovery rate | | 95% | |
| Peel strength (copper foil) | | > 1.0 kN/m | 90° peel |
| Dielectric constant (Dk) | | 2.3 | At 10 GHz, using the cavity perturbation method |
| Dielectric dissipation factor (Df) | | 0.0030 | At 10 GHz, using the cavity perturbation method |
| Breakdown voltage | | 7.0 kV | Film thickness: 80 μm |
| Heat resistance | | No change | 260℃, 10 s, 10 cycles in an $N_2$ atmosphere |
| Chemical resistance | NaOH | No change | After a 24 h immersion test |
| | $Na_2CO_3$ | No change | |
| | Copper etchant | No change | |

**Figure 2** shows the correlation between the change observed in the wiring resistance of the base material (after forming), and its rate of elongation. These results indicate that, even when the base material is elongated by 90%, the resistance changes by no more than 5%. Similarly, **Figure 3** shows the change observed in the wiring resistance when the base material was repeatedly stretched by 10%. These results indicate that, even after being stretched 15,000 times, the stretchable wiring material shows little change in wiring resistance. Furthermore, the material has a low dielectric constant (Dk) of 2.3 at 10 GHz and a low dielectric dissipation factor (Df) of 0.0030 at 10 GHz.

Based on these results, we believe this new stretchable wiring material can be applied to various types of stretchable devices.

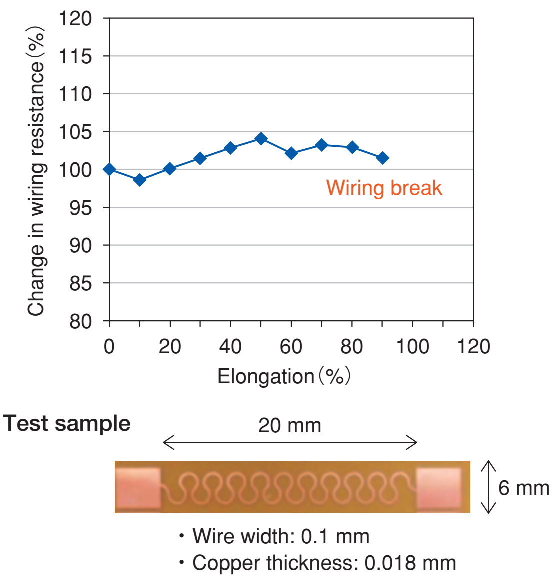


Figure 2 Change in wiring resistance when stretched

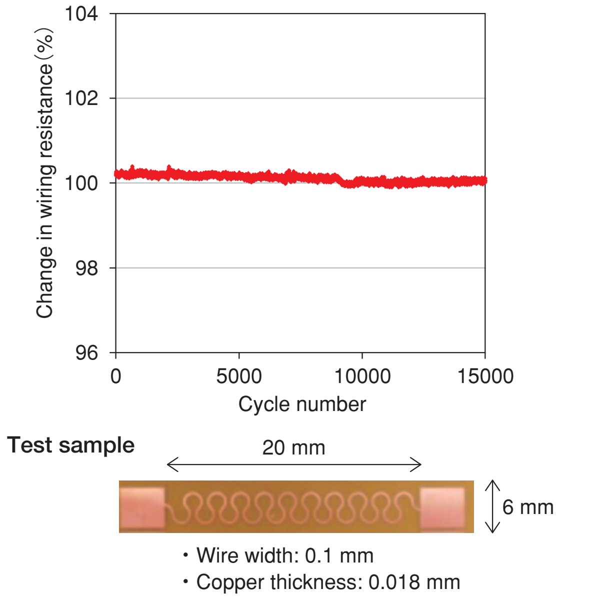


Figure 3 Change in wiring resistance during stretching test cycles under a 10% tensile strain

## 5 Future Business Development

・Development of low thermal expansion materials.
・Development of highly adhesive, stretchable materials for wire insulation.
・Development of semi-stretchable, highly flexible wiring materials for high-frequency (5G) applications.

**【References】**

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