As electronic equipment becomes smaller and lighter, FPCs, which are wiring material with a high degree of freedom in design and excellent flexibility, are in greater demand.

In addition, such electronic equipment becomes more functional and operates at a higher speed, as well as becoming smaller and lighter. Therefore, it is now essential to take proper measures against electromagnetic noise. In such a situation, demand for electromagnetic noise suppression of FPCs incorporated into electronic equipment is also growing rapidly. Up to the present, for electromagnetic noise suppression, FPCs have been shielded by laminating copper foil or conductive paste. Or, components such as a rectangular ferrite core or EMI filter have been installed to FPCs. However, it is difficult to apply the shielding method using a lamination structure to the drive section on FPCs because this method degrades the flexibility of FPCs. Also, the shielding method installing noise suppression components is a problem from the viewpoint of the mounting space because mobile equipment is being downsized rapidly.

The cross-sectional structure of the SF-PC1000 is shown in Fig. 1. With the main body of the SF-PC1000, highly heat-resistant PPS film 9 µm in thickness is used as the base film. A metallic deposition layer 0.1 to 0.15 µm in thickness is formed on this base film and then a thermosetting conductive adhesive layer is formed on the metallic deposition layer. As described above, the SF-PC1000 has a three-layer structure.

Taking into consideration the working efficiency and processability during the bonding process to an FPC, a reinforcement film is laminated to the base film side, and a mold release film for protection is laminated to the adhesive side. These films are removed while processing the FPC, and finally the three-layer structure (base film/metallic deposition/conductive adhesive) is only added to the FPC, as

Our company has developed and commercialized the SF-PC1000 of ultra-thin electromagnetic shielding film especially intended for flexible printed circuit applications (hereafter referred to as FPC), which can give shielding performance without degrading flexibility intrinsic to FPCs. The SF-PC1000, featuring thinness and high flexibility, is more and more widely used in mobile equipment that is required to be downsized and more functional, such as cellular phones, notebook PCs and digital cameras.

Our company has developed and commercialized the SF-PC1000 (Photo 1) of ultra-thin electromagnetic noise shielding film that can give shielding performance without degrading the flexibility intrinsic to FPCs. This article introduces the structure and characteristics of the SF-PC1000 and its most frequently used applications.
shown in Fig. 2. The metallic deposition layer is joined with the ground circuit of the FPC through the conductive adhesive and works as a shielding layer. Electrical insulation between the metallic deposition layer and the outside is achieved with the base film. The specifications and functions of each layer are shown in Table 1. Moreover, the SF-PC1000 can be applied to both sides of an FPC. In this case, the front and rear metallic deposition layers are electrically joined with each other through the conductive adhesive, allowing both sides of the FPC to be shielded, as shown in Fig. 3.

The features of the SF-PC1000 are shown below.

- Thin and lightweight despite its three-layer structure. The total thickness is 32 μm.
- Provides excellent adaptability, flexibility, and suppleness.
- Provides excellent shielding characteristics in a wide band range.
- Reflow-soldering is applicable. (Lead-free soldering is also applicable.)
- Can be pressed simultaneously with a cover-lay film.

Table 1 Specifications and functions of each layer

<table>
<thead>
<tr>
<th>Item</th>
<th>Specifications</th>
<th>Functions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mold release film (with adhesive) Removed during the production process.</td>
<td>PET with adhesive (#25) Thickness: 62 μm</td>
<td>Protects the conductive adhesive layer and prevents its contamination during the transportation and production process.</td>
</tr>
<tr>
<td>Base film</td>
<td>Heat-resistant engineering plastic: PPS Thickness: 9 μm</td>
<td>Ensures electrical insulation between the metallic deposition layer and the outside. Can be reflow-soldered due to high heat resistance.</td>
</tr>
<tr>
<td>Metallic deposition</td>
<td>Surface resistance: 100 mΩ or less Thickness: 1.000 to 1.500 Å (Reference value)</td>
<td>Works as a conductive layer to provide shielding performance. Keeps shielding characteristics of 60 db or more in a wide band range.</td>
</tr>
<tr>
<td>Conductive adhesive</td>
<td>Thermosetting conductive adhesive Thickness: 23 μm Adhesion strength: 3.0 N or more 2</td>
<td>Works as a conductive layer to electrically join the metallic deposition layer (shielding layer) with the ground circuit of the FPC, and as an adhesive layer to bond the SF-PC1000 to the FPC body.</td>
</tr>
<tr>
<td>Reinforcement film (with adhesive) Removed during production process.</td>
<td>PET with adhesive (#50) Thickness: 48 μm</td>
<td>Improves ease of handling and ease of punching during the production process.</td>
</tr>
</tbody>
</table>

1. The values described in the specifications columns are typical values.
2. The adhesion strength of adhesive layer against polyimide (Kapton 100 H, 25˚C x 40 to 60%RH)

**Typical Characteristics**

**Bending endurance (Flexural endurance)**

The result of the MIT flexural endurance test shown in Fig. 4 is shown in Fig. 5. Although the flexural endurance of an FPC shielded by the SF-PC1000 is shorter than that of an FPC only, the endurance (number of bends) exceeds 10 thousand times when the radius of curvature is 0.8 mm. Thus, the SF-PC1000 has achieved a level where it can be practically used as the shielding material for a drive section. The test conditions are shown in Table 2.

Table 2 MIT flexural endurance test conditions

<table>
<thead>
<tr>
<th>Item</th>
<th>Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Speed</td>
<td>175 times/min.</td>
</tr>
<tr>
<td>Tension</td>
<td>5 N</td>
</tr>
<tr>
<td>Test atmosphere</td>
<td>Room temperature (25˚C)</td>
</tr>
<tr>
<td>Test pattern</td>
<td>12 mm width, L/S = 0.12/0.1</td>
</tr>
</tbody>
</table>

**Fig. 4 MIT flexural endurance test**

**Fig. 5 MIT flexural endurance characteristics**
Shielding characteristics

The shielding characteristics measured by the KEC method are shown in Fig. 6. The shielding characteristics are even more excellent in the order of copper foil, shielding copper paste for FPCs (NF2000 of DD paste offered by our company), and the SF-PC1000 according to the difference in electrical characteristics. However, in high-frequency bands of several hundred MHz or more, the difference in shielding characteristics between these three shielding materials is minimal, and there is not a great difference between the SF-PC1000 and the shielding copper paste for FPCs. The required level of the shielding characteristics varies depending on the equipment to which the FPC is installed. However, since the SF-PC1000 keeps shielding characteristics of 60 dB or more in the frequency range of up to 1 GHz, it can be said that the SF-PC1000 displays the shielding effects in a wide variety of equipment.

Ground joint resistance

In order to allow the SF-PC1000 to display its shielding characteristics fully, it is necessary to stably join the metallic deposition layer, which is the shielding layer, with the ground circuit of the FPC. The joint resistance between the metallic deposition layer and ground circuit varies depending on the number and diameter of connection holes made in the ground circuit of the FPC. The relationship between the diameter of connection holes and joint resistance is shown in Fig. 7 and 8. By using the largest area possible to join the metallic deposition layer with the ground circuit of the FPC, a stable joint can be made. When a large area cannot be used for design convenience, joint stability can be improved by joining them at multiple points. As well, it is desirable that the copper foil on the FPC connected should be a gold-plated one that is electrically stable.

Processing Process

The example of the standard processing process for the SF-PC1000 is shown in Fig. 9.

1. Punching
   Punch or half-cut the SF-PC1000 according to the shape of the FPC and remove the mold release film on the adhesive surface.

2. Pre-fixing
   Fix the SF-PC1000 to the FPC at a temperature of 120 to 130˚C.

3. Thermal pressing
   Bond the SF-PC1000 to the FPC by thermal pressing. The standard pressing conditions are shown in Table 3. Since the pressing conditions for the SF-PC1000 are the same as the standard pressing conditions used during the production process of FPCs, the SF-PC1000 can be bonded to the FPC without using special equipment or conditions. Moreover, it can also be pressed together with a cover-lay film. This increases productivity.

4. Removing reinforcement film

5. Processing the outward form of the FPC
As equipment becomes more functional and operates at increasingly and higher speeds, the necessity of electromagnetic noise suppression becomes crucial. In addition, with the development of networking, mobilization of electronic equipment is accelerated. In such a situation, the shielding materials are required not only to provide excellent shielding characteristics but also to be “thin” and “lightweight” in order to satisfy the requirements of mobile equipment. Therefore, we expect that demand for the SF-PC1000 is steadily increasing. When functional material is made to a film-type product, generally it is difficult to supply the product in a small lot and in a short delivery period. The more globalized electronic equipment industry strongly requires a decrease in stock articles and reduction in lead-time. Our company is working on developing new products by extending the development concept of the SF-PC1000 and is making full efforts to establish a supply system that enables frequent, small-lot production.

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