ELECTRONICS

Flexible Flat Cable with Low-Profile, Easy-Bonding Interconnection

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Connectors are widely used to connect flexible flat cables (FFCs) with printed circuit boards (PCBs). In recent years, demand for a direct connection of FFCs with PCBs has been increasing due to the downsizing of electronic devices such as wearable components. An anisotropic conductive film (ACF) can be used for such a connection, however, there exist some difficulties in the bonding operation and the shelf life. We have developed a low-profile, easy-bonding interconnection that eliminates the need for connectors and is highly reliable. This achievement was made possible with our original conductive paste and high-resolution printing technologies.

Keywords: FFC, direct connection, circuit board, conductive paste, adhesive

1. Introduction

Flat flexible cables (FFCs) are widely used for internal wiring within electronic products for their flexibility and thinness. Sumitomo Electric Industries, Ltd. commenced research into flat cables as a new wiring material for electronic devices in 1965, launching this as a business in 1969 with sales of Sumicard FFC commencing in 1977.

A connector is usually used between an FFC and a printed circuit board, however, demand for direct connection has been rising as electronic devices become increasingly smaller and thinner, as represented by new wearable devices. An anisotropic conductive film(1) (ACF) is a common connecting material used for direct connection. However, the ACF requires cold storage, and prefixation on the circuit board is necessary before crimping it permanently. Such restrictions prompted the search for alternative connecting materials that are easier to handle. In order to respond to such industry needs, Sumitomo Electric has developed a directly connectable FFC that offers both low profile and easy connection. This paper discusses the details of the new product.

2. Development Concept

Figure 1 shows the structure of Sumitomo Electric's new direct connection FFC, in which the strips of conductive paste are laid on the conductor located at the terminal of the FFC, and adhesive is set in the spaces between the strips of the paste. After the FFC has been bonded to the circuit board using a thermocompression method, the conductive paste transmits electrical signals and the adhesive ensures secure contact (Fig. 2). Since the connecting materials are premounted on the FFC terminal, the FFC can be bonded to the board with simple operation—positioning and thermocompression. The cable does not require prefixation to the board prior to actual bonding. Sumitomo Electric's exclusive, highly conductive paste spread over the electrodes on the circuit board keeps the contact resistance low, and the adhesive provides close fitting and high insulation properties, ensuring both good connection reliability and insulation. Both the conductive paste and the adhesive can be stored at normal temperatures, providing easy management without the need for cold storage, which is necessary for ACFs.

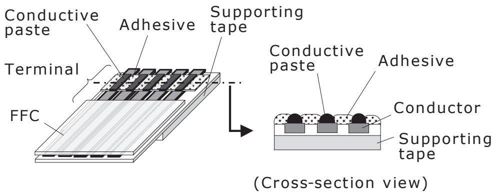


Fig. 1. Direct Connection FFC

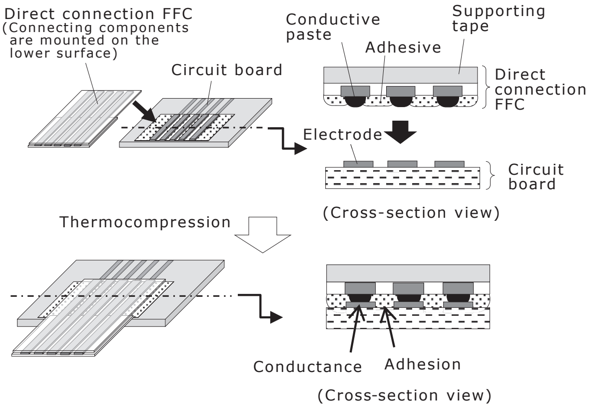
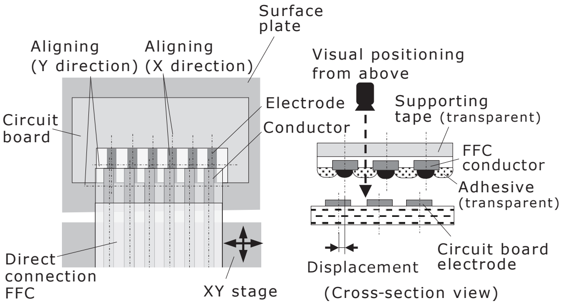


Fig. 2. Connection to the Circuit Board

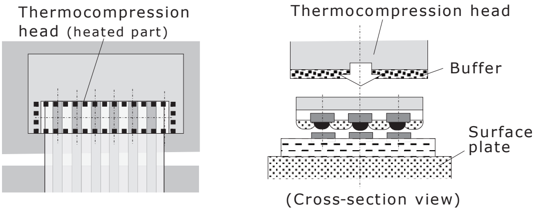
3. Connectivity Performance

3-1 Connection method and conditions

The FFC can be connected to a circuit board using a commercially available thermocompression bonding machine. First, the electrodes on the circuit board are aligned with the conductive points on the FFC terminal, as shown in Fig. 3. This alignment can be visually confirmed in an easy manner from above the FFC as it uses a transparent reinforcement sheet and adhesive. Next, apply the heating element over the FFC to connect the cable and the board. Table 1 shows the standard thermocompression conditions. Thermocompression can be performed at temperatures as low as 140 ± 10°C with a pressure of 1.8 ± 0.6 MPa in as short a period as 10 seconds. A further benefit is that the required pressure for bonding is much lower than the standard 3 MPa required for an ACF.



(1) Aligning



(2) Thermocompression

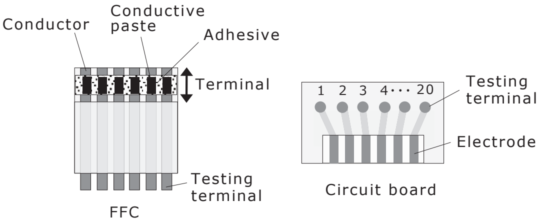
Fig. 3. Thermocompression Procedure

Table 1. Standard Conditions for Thermocompression

	Standard conditions
Temperature	140 ± 10°C (Actual temperature)
Pressure	1.8 ± 0.6 MPa (Area subject to thermocompression)
Duration	10 seconds
Compression head width	4 mm
Buffer	0.2 mm-thick silicone

3-2 Assessment of connection reliability

To assess the FFC's connection reliability, we used an FFC with a conductor of 0.3 mm in width and 0.2 mm pitch formed into a gold-plated 20-conductor terminal, and a rigid circuit board made of glass epoxy circuit board (Fig. 4). The FFC and board were bonded under the standard thermocompression conditions shown in Table 1, and then placed in an environmental test chamber at 60°C and 95% RH to measure the changes in connection resistance over time (Fig. 5). The results in Fig. 6 show that the connection resistance



FFC	Conductor width and pitch	0.3 / 0.2 mm
	Number of conductors	20
	Terminal length	4 mm
	Terminal thickness	0.2 mm or less
	Conductor thickness	0.035 mm
	Conductor plating	Gold plating
Circuit board	Material	Glass epoxy
	Electrode width and pitch	0.3 / 0.2 mm
	Number of electrodes	20
	Electrode length	4 mm
	Electrode thickness	0.018 mm
	Electrode plating	Gold plating
	Board thickness	1 mm

Fig. 4. Test Material and Components

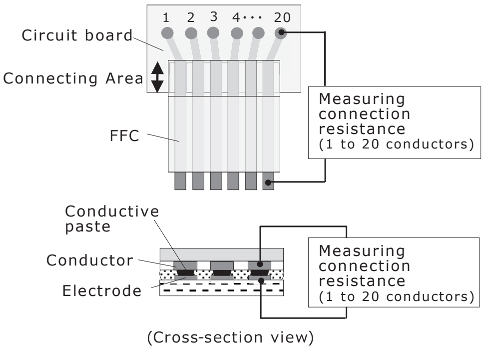


Fig. 5. Measuring Connection Resistance

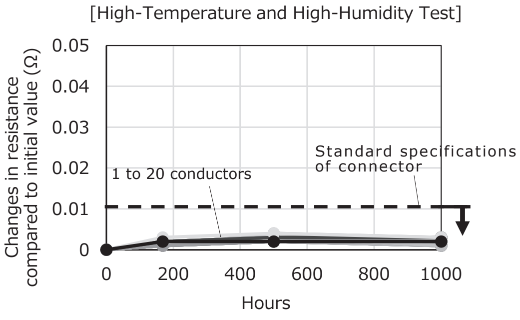


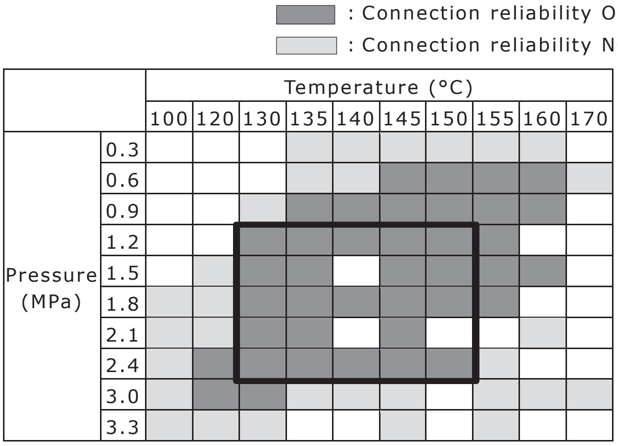
Fig. 6. Assessment Results of Connection Reliability (High-Temperature and High-Humidity Test)

changed by no more than 0.01 Ω compared to the initial value even after 1,000 hours, confirming that the direct connection is as stable as a connection using a connector. Table 2 also shows the range of tests performed, including 1,000 hours in an 85°C high-temperature environment, 1,000 hours in a –40°C low-temperature environment, and thermal shock tests with 1,000 cycles of 30 minutes in –40°C environment and another 30 minutes in an 85°C environment. In each test, the connection resistance showed no changes greater than 0.01 Ω, confirming that the connection was very stable.

Table 2. Test Results of Connection Reliability Assessment

	Test conditions	Results
High-temperature and high-humidity test	60°C 95% × 1000 hr	Changes no greater than 0.01 Ω (Fig. 6)
High-temperature test	85°C × 1000 hr	Changes no greater than 0.01 Ω
Low-temperature test	-40°C × 1000 hr	Changes no greater than 0.01 Ω
Thermal shock test	85°C 30 min ⇔ -40°C 30 min × 1000 cycles	Changes no greater than 0.01 Ω

We also assessed the relationship between various thermocompression conditions and connection reliability, and the results showed that a stable connection can be achieved in a wide range of conditions from 130°C to 150°C and 1.2 to 2.4 MPa (Fig. 7). This means that quality control can be relatively straightforward.


■ : Connection reliability OK
▒ : Connection reliability NG

Pressure (MPa)	100	120	130	135	140	145	150	155	160	170
0.3				▒	▒	▒	▒	▒	▒	
0.6				▒	▒	■	■	■	■	▒
0.9			▒	■	■	■	■	■	■	
1.2			■	■	■	■	■	■		
1.5		▒	■	■		■	■	■	■	
1.8	▒	▒	■	■	■	■	■	■		
2.1	▒	▒	■	■		■			▒	
2.4	▒	■	■	■	■	■	■	▒		
3.0	▒	■	■	▒	▒	▒		▒	▒	▒
3.3	▒	▒	▒			▒		▒		

Fig. 7. Relationship between Connection Reliability and Thermocompression Conditions

3-3 Assessment of insulation performance

The FFC's insulation performance was also assessed using an item equipped with a conductor 0.3 mm in width and 0.2 mm pitch formed into a gold-plated 20-conductor terminal (the same specifications as in 3-2), connected to a circuit board. In this test, 5 V was applied between the even and odd conductors of the FFC, then the sample was placed in the test chamber at 60°C and 95% RH to monitor the change in insulation resistance over time (Fig. 8). As a result, it was found that the insulation resistance remained at more than 100 MΩ after 1,000 hours, which is equivalent to a connection using a connector (Fig. 9). Thus, we confirmed that the FFC was able to retain high insulation without possible migration.[*4] The relationship between insulation performance, misalignment of the FFC (in the x direction), and applied voltage was then assessed. Insulation was maintained when an electrical voltage of 5 V was applied to the connection with a misalignment of 100 µm or less; 10 V electrical voltage to the connection with a misalignment of 90 µm or less; and 15 V electrical voltage to the connection with a misalignment of 80 µm or less (Fig. 10). This means that the misalignment tolerance is relatively large, and, therefore, thermocompression management is straightforward.

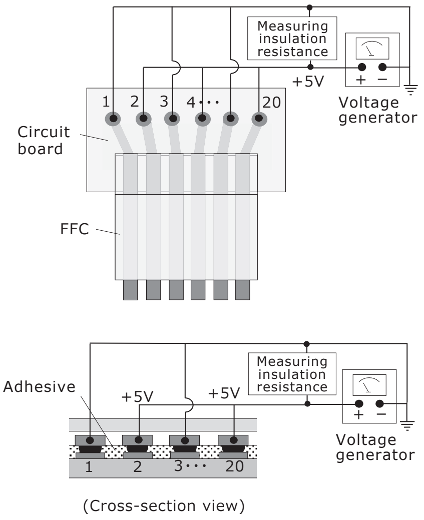


Fig. 8. Measuring Insulation Resistance

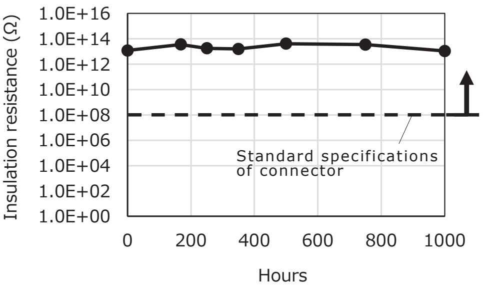


Fig. 9. Results of Insulation Performance Assessment

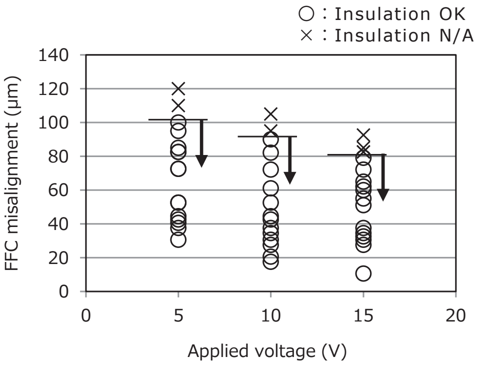


Fig. 10. Relationship of Insulation, Misalignment, and Applied Voltage

3-4 Connecting the FFC to a 100-electrode circuit board

The greater the number of electrodes (conductors) on a circuit board, more difficult it is to establish a stable connection, as the temperature and pressure at the time of thermocompression are likely to vary and misalignment is also likely to occur. Also, the larger connection area requires a higher pressure for bonding, possibly causing deformation of the circuit board. We assumed that Sumitomo Electric's FFC should retain connection stability even when the number of conductors is increased, as it has a wide tolerance in terms of both connection conditions and misalignment, and requires only a low pressure for thermocompression. We were able to verify this assumption, as follows.

An FFC with a gold-plated 100-conductor terminal and conductor 0.3 mm in width and 0.2 mm pitch was connected to a circuit board under the same conditions as 3-1. We then carried out the same connection reliability assessment as 3-2 and the same insulation resistance assessment as 3-3. The assessment results showed that both connection resistance and insulation resistance after the 1,000-hour experimental period were equivalent to the initial values, demonstrating that a stable connection could be secured for up to 100 conductors. Based on this result, a wide range of applications—including those requiring a large circuit board—can be envisaged.

4. Storage Stability

Finally, we assessed the FFC's storage stability. Samples that had been stored for six months, one year, and eighteen months at normal temperatures were connected to a circuit board under the same conditions as 3-1, and we then carried out the same connection reliability assessment as 3-2 and the same insulation resistance assessment as 3-3. The assessment results again showed that both connection resistance and insulation resistance after the 1,000-hour experimental period were equivalent to the initial values, confirming that the FFC has excellent storage stability. Unlike ACFs, this FFC does not require refrigeration, making storage management straightforward.

5. Conclusion

Utilizing Sumitomo Electric's conductive paste and fine printing technologies, we developed a direct connection FFC offering a low profile and easy connection capabilities. We confirmed that the FFC requires simple bonding operations—aligning and thermocompression—thanks to the pre-mounted connection materials at the FFC terminal. The assessment results showed that both connection resistance and insulation resistance after the 1,000-hour test period were equivalent to the initial values, validating its high connection stability. The assessments also demonstrated the FFC's wide tolerance to variable connection conditions and misalignment, as well as its high connection reliability and insulation when attached to a 100-electrode circuit board. In the storage stability assessment, it was demonstrated that samples stored for more than a year after production at normal temperatures were able to form stable connections. All of these features indicate that the FFC will find a wide range of applications in the electronics area.

Table 3. Direct Connection FFC Specifications and Connection Conditions

Specifications	Conductor width and pitch	0.3 / 0.2 mm
	Number of conductors	Up to 100
	Therminal length	4 mm
	Terminal thickness	0.2 mm or less
	Conductor thickness	0.035 mm
	Conductor plating	Gold plating
Connection conditions	Temperture	140 ± 10°C (Actual temperature)
	Pressure	1.8 ± 0.6 MPa (Area subject to thermocompression)
	Duration	10 seconds
	Thermocompression head width	4 mm
	Buffer	0.2 mm-thick sillicone
	Misalignment tolerance	0.1 mm or less (applied voltage of 5 V in the insulation test)

- Sumicard is a trademark or registered trademark of Sumitomo Electric Industries, Ltd.

Technical Terms

- ∗1 FFC: Flexible Flat Cable. An extremely thin cable in which multiple rectangular conductors are laminated within an insulation material.
- ∗2 Anisotropic conductive film: A film in which fine conductive metal particles are dispersed in a thermosetting resin.
- ∗3 Conductive paste: A mixture of conductive metal powder and adhesive binding resin, offering electrical conductivity and able to adhere to different surfaces.
- ∗4 Migration: A phenomenon in which insulation performance deteriorates due to the movement of metal ions within an insulating material between voltage-charged electrodes.

Reference

(1) H. Toshioka et al., “Development of Anisotropic Conductive Film for Narrow Pitch Circuits,” SEI Technical Review, No.73 pp.40-44 (2011)

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