On-Demand Direct Printing of Conductive Circuit Pattern by Thermal Transfer Technology

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Abstract

In our R&D study, we found that antenna patterns printed on the film by thermal transfer ribbon bear the basic frequency characteristics as film antenna, which are used for inlet of IC tags, car navigation systems, etc. We are convinced that the manufacturing of film antennas can be more simple process and lower cost by using thermal transfer printing technology.

Introduction

These years, IC tag with RFID technology is the most featured device for the supply chain management, and it has already been used in some field, such as logistics. However, further cost reduction is required for IC tags to be spread more widely for its practical use. IC tag is processed from "inlet", which consists of IC chip with antenna formed on the PET film. Car navigation systems also adopt the film antenna, which is formed on the PET film and attached on the windshield. We have focused on these film antennas, and we propose on-demand direct printing method using thermal transfer technology as more simple and lower cost method of manufacturing the film antennas.

Layer Structure of Conductive Thermal Transfer Ribbon (Conductive TTR)

In terms of volume resistivity, Conductive TTR can be classified in 2 types, (1) Low conductive TTR: 3 x 10 (-2)Ω・cm, (2) High conductive TTR: 1 x 10(-3) to 10(-5)Ω・cm. Layer structure of each type of ribbon is shown in Figure 1 and 2.

Overcoat layer	0.3-1.0µm
Conductive layer	10-15µm
Undercoat layer	0.3-1.0µm
PET film	6.0µm
Backcoat layer	0.1-0.3µm

Figure 1. Low conductive TTR

Overcoat layer	0.3-1.0µm
Conductive layer	0.05-0.30µm
Protection layer	0.3-1.0µm
Undercoat layer	0.3-1.0µm
PET film	6.0-9.0µm
Backcoat layer	0.1-0.3µm

Figure 2. High conductive TTR

Function and Component of Each Layers

Function and component of each layer are shown in the following Table 1.

Table 1: Layer Function and Component

Conductive layer	To provide Conductivity Component: Low conductive TTR: Conductive carbon black High conductive TTR: Metals, e.g. aluminum, copper
Overcoat layer	To bond conductive layer to the receiving surface. Component: Resin, e.g. Polyester. Type of resin is changeable depending on the receiving substrates. It also can be curable to increase durability.
Protection layer	Curable layer to protect conductive layer from the heat damage during the thermal transfer process. Component: Acrylic resin
Undercoat layer	To help the release of conductive layer from the PET Film Component: Resin and Wax
Backcoat layer	Curable layer to protect PET film from the heat damage of thermal head, and to prevent sticking Component: silicone modified urethane polymer

Photo Images of Direct Printing by Thermal Transfer Printer

Photo images of antenna patterns printed by conductive TTR, CDCU-1000, is provided in Figures 3 and 4.

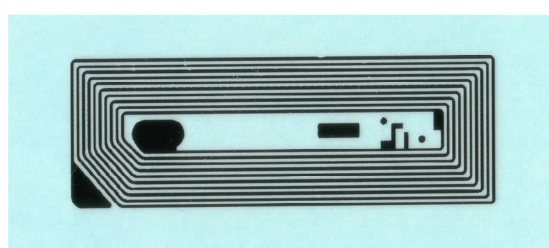

Figure 3. Antenna pattern of IC tag

<Figure 3. Print condition>
Printer: Yamazakura DIGICA
Resolution: 600dpi
Print speed: 40mm/s
Print energy: level18 (max20)
Receiving substrate: Osaka Sealing Printing, transparent PET label

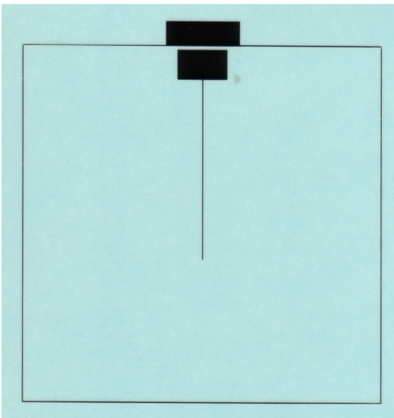

Figure 4. Antenna pattern of car navigation film antenna

<Figure 4. Print condition>
Printer: Tohoku Ricoh IP4630V
Resolution: 400dpi
Print speed: 30mm/s
Print energy: level 4 (max15)
Receiving substrate: Osaka Sealing Printing, white PET label

Frequency Analysis of the Film Antenna Printed by Conductive TTR

Figure 5 shows the gain and frequency of film antennas printed by conductive TTR. We can see basic function of antenna in printed antenna pattern.

Advantage of Thermal Transfer Method

Photolithography–Etching method is the current popular method for film antenna formation. We have compared the manufacturing process of Photolithography-Etching method and Thermal Transfer method.

Photolithography-Etching Method

PET film (with metal foil) → Photo resistant coating → Exposure (photo mask required) → Development → Etching → Pattern complete

Thermal Transfer Method

PET film → Direct printing by thermal transfer printer → Pattern complete

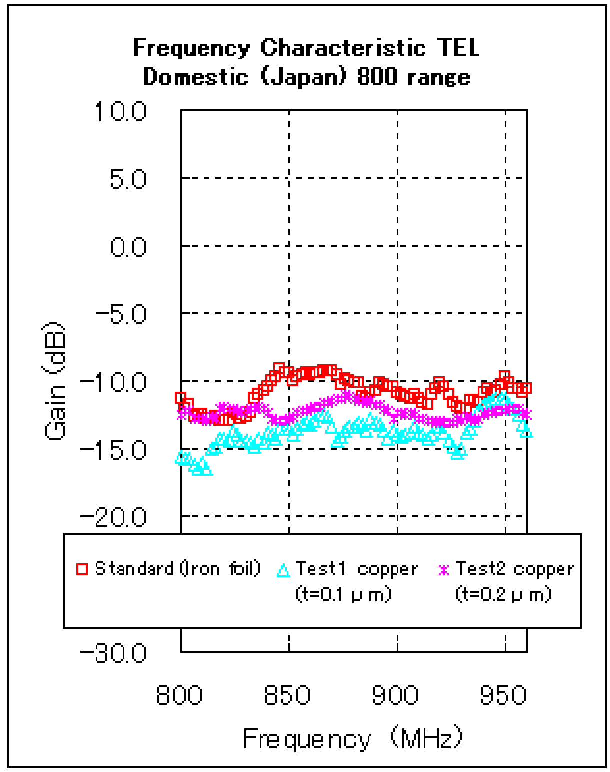

Figure 5. Frequency Characteristic

In photolithography-etching method, which includes exposure development process, photo mask is used for making antenna pattern. In some cases, gravure is used instead of exposure development, but it still requires making plate. On the other hand, in Thermal Transfer method, antenna pattern is formed within the computer on demand, and printed directly on the film substrate. Therefore, this method does not require the process of making plate, and especially advantageous at the process of antenna pattern designing in which modification of design happens frequently. In terms of environmental point, while “wet” process of photolithography-etching method requires the waste fluid management systems, “dry” process of thermal transfer method does not.

From these reasons, thermal transfer method can be the superior on-demand antenna manufacturing method, which enables less manufacturing process, less lead time, and meets the inquiry for small volume-various patterns. Comparison of 2 methods are show in Table 2.

Table 2: Layer Function and Component

Item	Photolithography-Etching	Thermal Transfer
Small volume	×	○
Short lead time	×	○
Environment	×	○
Cost	△	○

Application

Intended application of low conductive TTR is for the surface resistant range of more than a hundred Ω/□, e.g. circuit board of TV controller, or flexible connector. On the other hand, high conductive TTR is applied to the range of less than one hundred Ω/□, e.g. film antenna, or FPC.

Conclusion

We found that antenna patterns printed on the film by thermal transfer ribbon bear the basic frequency characteristics as film antenna, and its on demand printing method can reduce the manufacturing process and cost compare to the conventional photolithography-etching method. To increase the use of this method, our next challenge is to increase the thickness of conductive layer to over 0.3μm, which eventually reduces surface resistant to less than 0.3 Ω/\□. To clear this hurdle, we are currently working on developing the specialty thermal transfer printer, or testing electroless plating to increase the conductive layer thickness.

Acknowledgement

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References

1. Mark James, `Manufacturing Printed Circuit Boards Using Ink Jet Technology' (IS&T, NIP19, 2003)

Author Biography

Katsuhiro Yoshida received his BE in chemistry from Doshisha University (1987). His career as an engineer started from Fujicopian Co., Ltd. Since 2002, he has been working in the R&D Department at General Technology Co., Ltd. He has focused on thermal transfer ribbons in his career, especially interested in the possibility of specialty use, or wider application of thermal transfer ribbons.