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Electron Probe Microanalyzer EPMA-8050G

Application News

Cross-Sectional Mapping Analysis of IC Cards

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User Benefits

- The EPMA can be used for a wide range of applications including defect analysis, quality improvement, and research and development of IC cards.
- The EPMA enables the visualization of IC chip wiring patterns and their compositional elements.

■ Introduction

IC cards are used in industries such as finance, transportation, and services. There are two types of IC card—contact type cards such as credit cards, ETC cards, and non-contact type cards such as those used as IC transit cards.

An IC (integrated circuit) is a device consisting of transistors wired together with metal interconnect. As the ICs have become smaller, the width and thickness of the wires have been shrunk to several 100 nm. On the other hand, the total wire length now exceeds several 100 m. If any of these wires are broken or make poor contact, the IC will not function. In addition, if a crack or the like occurs during mounting of the board, it will lead to failure. Therefore, it is very important to evaluate the reliability and structure of materials and to examine the manufacturing process.

This paper introduces an example of mapping analysis of a cross-section of a contact type IC card and the wiring pattern of the IC chip using a Shimadzu EPMA-8050G (EPMA™) electron probe microanalyzer.

■ Element Analysis of Contact Type IC Cards

A contact type IC card consists of a card substrate such as polyethylene terephthalate (PET) on which an IC chip is mounted. On the surface of the card is a contact terminal that contacts a dedicated reader/writer to supply operating power. The contact terminal is made of gold (Au) about 0.1 µm thick that is formed by electroplating on a 1 to 3 µm nickel (Ni) layer.

Below the terminal is a board called a copper-clad laminate (CCL). The most common and versatile material used as a substrate in IC cards is called Glass Epoxy Resin (FR -4).

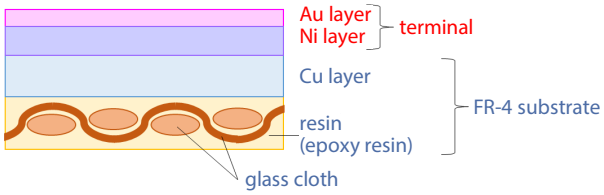

Fig. 1 Structure of the Terminal and FR-4 Substrate in the IC Card

Fig. 1 shows the structure of the terminal and FR-4 substrate in an IC card. FR-4 has a structure that consists of a layer made by thermally curing glass cloth impregnated with epoxy resin and coated with copper foil. The glass cloth consists of oxides such as SiO_2, Al_2O_3, and CaO, which prevent wire misalignment or void formation during press processing because, unlike plastic, it does not deform even at high temperatures. Epoxy resins are thermosetting polymers having multiple epoxy groups in their molecular chains. They are required to possess a wide range of properties, especially flame retardance, to prevent wires and components from catching fire at high voltages. To achieve this, bromine-based flame retardants may be added to the epoxy resin. Copper (Cu) adheres poorly to epoxy resin. Therefore, to improve the adhesiveness, rough surface treatment, which creates irregularities of a few µm in-depth, is applied to the copper surface contacting the epoxy resin or a modifier containing sulfur in the molecular chain is added to the resin.

Fig. 2 shows a cross-section of the IC card. Oxygen (O), aluminum (Al), silicon (Si), and calcium (Ca) were observed in the glass cloth, and carbon (C), oxygen (O), and bromine (Br) from the epoxy resin are observed around them. Fig. 3, which is an

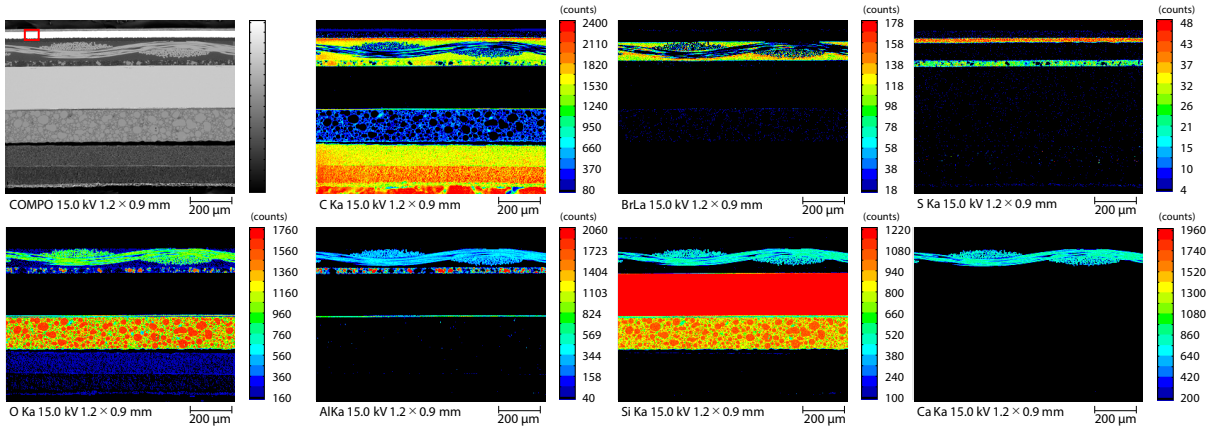

Fig. 2 Mapping Analysis in a Cross-Section of the Contact Type IC Card

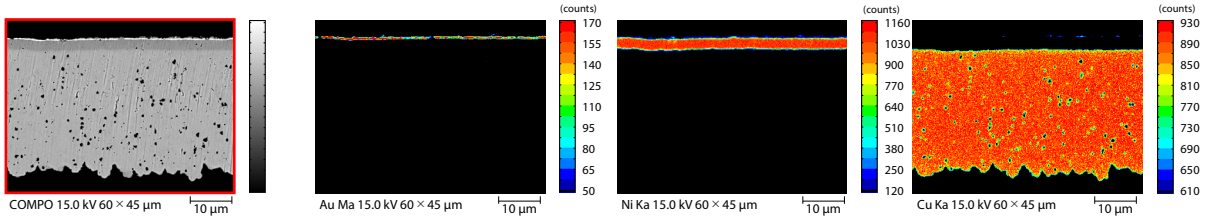

Fig. 3 Mapping Analysis of the Terminal in a Cross-Section of the Contact Type IC Card (Enlarged Image of Fig. 2)

enlarged image of the terminal shows the distribution of gold (Au), nickel (Ni), and copper (Cu) in this order from the surface. It was also confirmed that the copper surface in contact with the epoxy resin had irregularities of several µm.

The IC is located below the previously mentioned FR-4 substrate. The IC chip is manufactured by forming a large number of transistor devices and wiring them together with Al on an ultrahigh purity silicon single crystal substrate that is about 300 µm thick. In general, the IC chip is packaged because it is too small to handle by itself and is prone to damage and corrosion. The encapsulating material for the package is a mixture of resin and spherical silica (SiO_2) particles about 0.1 to 100 µm in diameter, which has a low coefficient of thermal expansion and excellent flow and fill properties. In Fig. 2, Si was observed on a silicon single crystal substrate, and the Al wiring layer can be seen on the substrate surface. Moreover, it was also confirmed that the spherical SiO_2 particles were protecting the Al wires.

■ Elemental Analysis of Wiring Patterns in IC Chips

In an IC chip, Al which has low electric resistance and good processability, is used for the wiring that connects the individual devices (transistors, etc.) electrically. SiO_2, which is an excellent insulator, is used to isolate devices. Between the Al and SiO_2 is a barrier metal that suppresses reactions between the two materials and which improves the reliability of the interconnect.

In the case of Al, titanium nitride (TiN) is mainly used as the barrier metal. Furthermore, as devices are miniaturized, the interconnect become multilayer and are connected vertically by high melting point materials such as tungsten (W). The top layer of the chip is a dense silicon nitride (Si_3N_4) passivation layer, which prevents scratches and impurities from affecting the chip.

Fig. 4 and 5 show wiring patterns of the IC chip. Fig. 4 shows the multilayered Al wires that are connected vertically by W plugs and the Si and O in the insulating layer that surrounds them. In addition, the components of the passivation layer were detected at the surface, and Fig. 5, which is an enlarged image, shows the TiN between the Al and Si that acts as a barrier metal. Moreover, the RGB overlay of Fig. 4 makes it easy to identify each layer, for example, the magenta area shows Si_3N_4, and the orange area shows TiN.

■ Conclusion

The mapping analyses of a cross-section of an IC card and the wiring of the IC chip were conducted by EPMA. The wide-area mapping enabled the structure of the whole card and the distribution of each element to be clarified. In addition, the high magnification mapping allowed visualization of the correspondence between each layer and the elements in the wiring pattern. EPMA is an effective tool for evaluating material reliability and analyzing product failures.

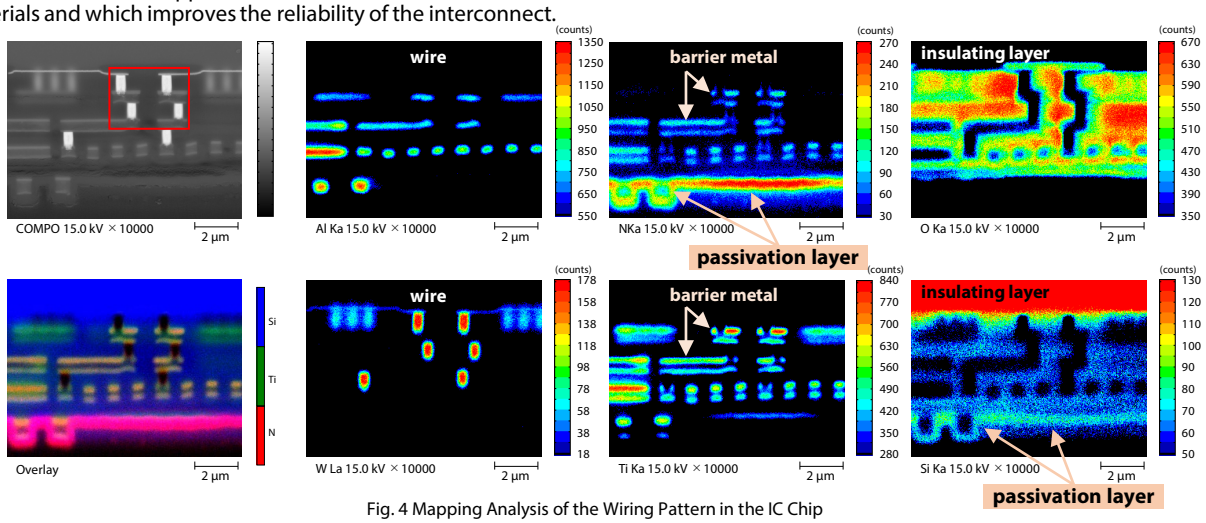

Fig. 4 Mapping Analysis of the Wiring Pattern in the IC Chip

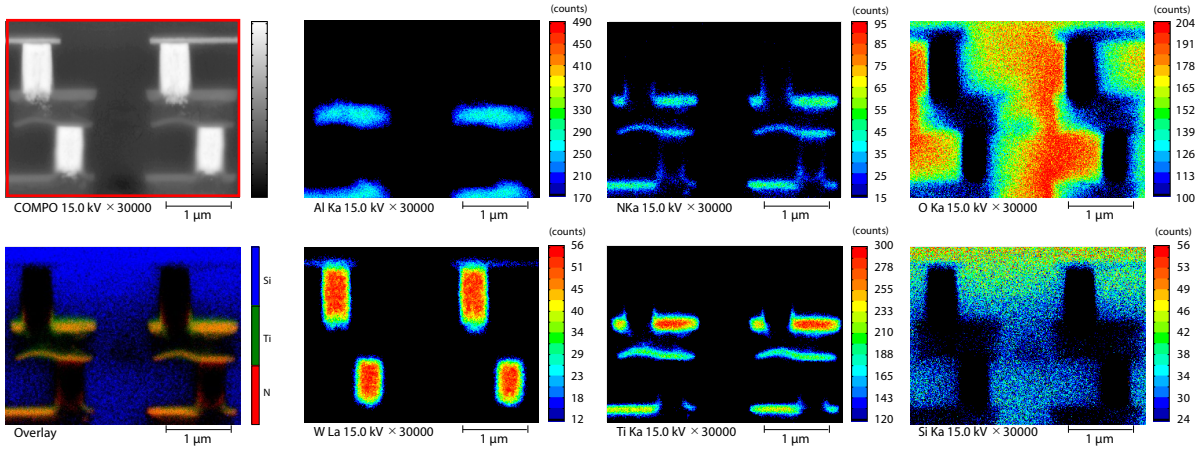

Fig. 5 Mapping Analysis of the Wiring Pattern in the IC Chip (Enlarged Image of Fig. 4)

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