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Article / Book Information

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Title(English)	Study on Control of Chemical Durability and Electrical Properties of Ag Thick-Film Conductors Containing Borosilicate or Tellurite Glass Frits
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論 文 要 旨

THESIS SUMMARY

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要旨（英文 800 語程度）
Thesis Summary（approx.800 English Words ）

Glass frits in conductor pastes promote the sintering of metal powders during the firing process and binding of the metal film to the substrate. Recently, material design with Sustainable Development Goals is becoming important, and further function control of thick-film conductors is required. The purpose of this study is to investigate the effect of glass frit composition on the chemical durability and electrical properties of Ag thick-film conductors, and build new underlying technology for Ag thick-film conductors by controlling the interfacial glass layer between the thick-film conductor and substrate. This thesis consists of 6 Chapters.

Chapter 1 – General Introduction. In this Chapter, the general background of thick-film conductors including the history, electrical properties, chemical durability, circuit formation process, substrates, glass frits in thick-film conductors, and market was presented.

Chapter 2 – Analytical Instruments and Methods. In this Chapter, the analytical instruments and methods for the characterization of the glass frits and thick films were described. The glass frits were characterized by a thermogravimeter-differential thermal analyzer, laser scattering particle distribution analyzer, X-ray diffraction (XRD) instrument, dry-process pycnometer, and ball-up viscometer. The thick films were characterized by a XRD instrument, scanning electron microscope (SEM) equipped with an energy-dispersive X-ray spectroscopy, and scanning transmission electron microscope (STEM). In addition, the methods of the acid durability test, contact resistivity measurement, and solder leach resistance test for the thick films were explained.

Chapter 3 – Glass Frit Preparation for Ag Thick-Film Conductors and Characterization. In this Chapter, the thermal behavior, particle size distribution, crystalline structure, density, and melt viscosity of the prepared glass frits were characterized.

Chapter 4 – Effect of Micro-Crystallization of Alkali and Alkaline-Earth Borosilicate (AEB) Glass on Acid Durability of Ag Thick-Film Conductor. Pb-free electronic materials are environmentally required but that makes a problem of acid durability of electroplated Ag thick-film conductors in acidic solutions. In this Chapter, it was observed that the micro-crystallization of the AEB glass was promoted by the addition of MgO powder to the glass pastes on the Al_2O_3 substrates during the firing process at 850°C. Improved acid durability was observed for the micro-crystalized glass thick films on the basis of the weight loss characterization and SEM images after immersion in a 1 M H_2SO_4. The STEM images showed the existence of micro-crystals in the AEB glass layer of the Ag thick-film conductor with the addition of MgO powder. This observation suggests that the micro-crystallization, promoted by the addition of MgO powder to the glass pastes, occurred in the Ag thick-film conductor. The Ag thick-film conductor with the addition of MgO powder exhibited small corrosion behavior of the glass layer, small deterioration of peel adhesion in the acidic solutions, and slow change of the failure mode in comparison to the Ag thick-film conductor without the addition of MgO powder. These results suggest that the improved acid durability of the Ag thick-film conductor is correlated with the micro-crystallization of the AEB glass induced by the addition of MgO powder to the thick-film pastes during the firing process at 850°C. On the other hand, the addition of MgO powder to the Ag thick-film conductor slightly increased the bulk resistivity.

Chapter 5 – Reduction in Contact Resistivity of Ag Thick-Film Conductor on SiN_x-Coated Si Wafer Using Lead Tellurite (PT) Glass Frit. It is still difficult to remove Pb in Ag thick-film conductors for photovoltaic cells, while further lowering of the contact resistivity on SiN_x-coated Si wafers is required for Ag thick-film conductors to improve the photo-conversion efficiency and increase the renewable source of energy. In this Chapter, at the interface between the Ag thick-film conductor and Si wafer after the firing process at 750°C, cross-sectional SEM images showed the thin glass layer in the Ag thick-film conductor containing the PT glass frit. Compared with the lead borosilicate (PS) glass frit, the glass transition temperature and melt viscosity of the PT glass frit were lower. In addition, the wettability of the PT glass on the Si wafer at 750°C was superior to that of the PS glass. The results suggest that these properties of the PT glass frit enabled to form such thin glass layer in the Ag thick-film conductor. The reactivity of the silicon nitride with the PT glass frit was higher than that with the PS glass frit. The contact resistivity of the Ag thick-film conductor containing the PT glass frit on the Si wafer was

less than one-tenth of the value for the Ag thick-film conductor containing the PS glass frit at 750°C in the transfer length method. The high reactivity of the SiN_x layer with the PT glass frit and the formation of the thin glass layer finally enabled it to achieve better conductive contacts. The resistance increased as increasing the dipping time in the solder, and the solder leach was accelerated for the Ag thick-film conductors at high temperature. On the other hand, the solder leach resistance of the Ag thick-film conductor containing the PT glass frit was nearly equal to that containing the PS glass frit.

Chapter 6 – General Conclusion. Conclusions drawn from Chapter 3, 4, and 5 were presented in this Chapter.

(843 words)