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COMPARATIVE STUDY ON THE ELECTRICAL AND MECHANICAL CHARACTERISTICS OF Ni-30WT%Co AND Cu-2WT%Be ALLOY FOR DEVELOPMENT OF SEMICONDUCTOR TEST PROBE PIN

Ultra-precision testing is a very important procedure to secure the reliability of the products as well as for the technology development in the areas of semiconductor and display. Accordingly, companies manufacturing equipment for testing of semiconductor and display have been continuously executing researches for the improvement of the performances of test sockets used in test equipment.

Through this study, characteristics of the materials in accordance with the mechanical and electrical properties of Ni-30wt%Co alloy and newly developed Cu-2wt%Be alloy were analyzed in order to select the probe pin material of the socket, which is a key component used in the semiconductor testing equipment. In addition, finite element interpretation was executed by using Ansys Workbench 14.0 to comparatively analyze the finite element interpretation results and experimental results. Experiment was executed for the mechanical properties including tensile strength, elasticity modulus, specific heat, thermal expansion coefficient and Contact Force, for electrical properties, experiment on surface resistance, specific resistance and electrical conductivity was executed to measure the properties. It was confirmed that the results of finite element interpretation and experiment displayed similar trend and it is deemed that the Contact Force value was superior for Be-Co alloy.

Through this study, it was confirmed that the newly developed Be-Co alloy is more appropriate as probe pin material used as the core component of test socket used in the semiconductor testing equipment than the existing Ni-Co alloy.

Keywords: Probe Pin, Be-Cu Alloy, Ni-Co Alloy, Test socket, Mechanical Properties, Electrical Properties

1. Introduction

With the rapid increase in the quantities of semiconductors used due to the advancement of digital industry, equipment capable of determining whether the semiconductor elements can be used or not have become an important factor [1]. Semiconductor process can be divided largely into circuit design and preliminary process for processing of wafer as well as the post processing for assembling and testing stages that manufactures wafer into final product [2]. Probe pin is the component used during the testing stage among the semiconductor processes. MEMS Probe Pin used in the semiconductor tester is a component assembled into the Test Socket to play the role of applying the waveforms generated by the Tester without distortion of the waveform [3-5].

Probe Pin, which is a part of testing equipment, executes the role of applying voltage and current to the external electrodes [6]. Here, reproducibility of semiconductor elements is evaluated through the deviation values of voltage and current, which varies according to the electrical and mechanical characteristics of the probe pin [7-8].

LIGA test socket with improvement of various current problems including difficulties in design due to limitation on the pitch between the Pins, high cost and complicated structure was developed. LIGA test socket can cope with minute pitch of 0.25 mm and enables easy design and manufacturing. However, there are difficulties in improving the reliability of Probe Pin assembled into the LIGA test socket due to the problem of low allowable current due to high specific resistance.

Through this study, mechanical and electrical properties of Ni-30wt%Co alloy and newly developed Cu-2wt%Be alloy as well as the characteristics of materials according to the Contact Force were analyzed for the improvement of the performances of Probe Pin material, which is the core component of test socket used in the semiconductor testing equipment. In addition, finite element interpretation through Ansys Workbench 14.0 was executed to comparatively analyze the interpretation result values and the experimental result values obtained through actual experiment in order to determine to what extent the newly developed Co-2wt%Be alloy Probe Pin has been improved in comparison to the existing Ni-30wt%Co alloy Probe Pin.

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2. Experimental method

This study is aimed at comparing the mechanical and electrical properties of Ni-30wt%Co alloy manufactured through electroforming and Cu-2wt%Be alloy imported from Japan.

Since it is not possible for elevate current any further with the currently used alloy, Ni-30wt%Co alloy, the existing Contact Force must be satisfied if the electrical characteristics are satisfied. Therefore, Cu-2wt%Be, which is a type of Cu alloys with outstanding electrical conductivity, was selected.

In this study, finite element interpretation was executed on the basis of the mechanical properties of each alloy. Contact Force and Directional Deformation was confirmed by using Ansys Workbench 14.0 as the interpretation program in order to execute comparative analysis with the actual phenomenon.

Measurement of tensile strength and elasticity modulus of Ni-30wt%Co alloy and Cu-2wt%Be alloy was executed under the ASTM E8/E8M specifications by using the Ag-x 50kn equipment in the format of fixed bottom and jig movement of the top portion.

Thermal expansion coefficient was measured by using thermal mechanical analyzer (TMA 402 F1) in the temperature range of 80~120°C, which is a high temperature sector among the range of application of probe pin. Experiment was executed by increasing the temperature at the interval of 1°C.

Specific heat was measured by using DSC204 F1 Phoenix, which is a Differential Scanning Calorimeter with fluctuating temperature, in the temperature range of 25 ~ 100°C with the interval of approximately 20°C between the measurements. Specific heat was measured at each point by holding for 5 minutes.

Electrical properties including specific resistance, surface resistance and electrical conductivity were measured by using executing experiment with metal specific resistance electrical conductivity measurement equipment of DASOLENG, and by executing the experiment through setting of stabilization time of 1 minute for each measurement.

When executing structural interpretation, the material properties were set on the basis of those obtained from the experiment for execution of interpretation. The properties of Ni-30wt%Co alloy and Cu-2wt%Be alloy are illustrated in Table 1. In addition, both alloys were designed in the exactly same manner, and number of mashes and conditions of interpretation were set to be the same for execution of finite element interpretation.

TABLE 1

Experimental Properties Used in Finite Element Analysis

	Ni-30wt%Co	Cu-2wt%Be
Density [Kg m^3]	8899	8248.6
Poisson's ratio [-]	0.31	0.3
Young's modulus [Gpa]	183.12	95.83
Tensile strength [Mpa]	447.33	243.14

For the conditions of interpretation, the bottom surface of the bottom section was set with Fixed Support while the upper surface of the head section was set under the displacement conditions to allow vertical movement conditions in the range of 0 ~ 150 um, while the lateral surfaces of the head section and bottom section were set as Frictionless support for execution of interpretation.

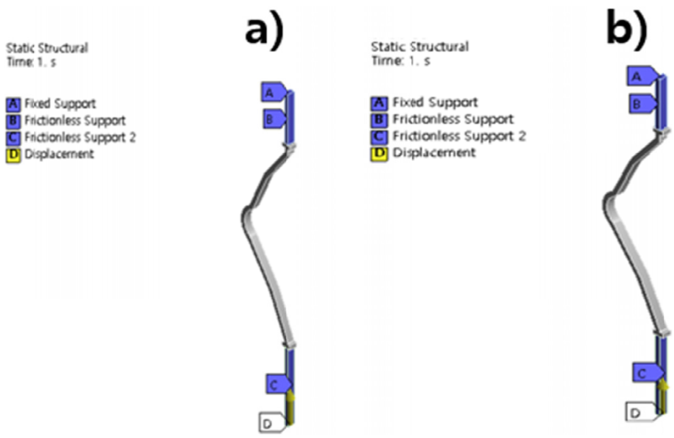

Fig. 1. Structural analysis constraint and boundary conditions. a) Ni-30wt%Co Alloy, b) Cu-2wt%Be Alloy

Contact Force experiment for the actual PIN was executed by manufacturing probe pin with each alloy and assembling the probe pin into the Test Socket. Force acting on the probe pin was measured by using 1 KN load cell.

Allowable current of Probe Pin was measured by using direct current supply device. The allowable current value is the value of Contact Force that is maintained within 15% of the original value when current is applied over prescribed period of time while being pressed with the maximum value of Over Drive, 150 um.

Allowable current was increased by the interval of 0.2A and experiment was executed with the hold time of 1 minute.

3. Results and considerations

In this study, results of the analysis of tensile strength and elasticity modulus of Ni-30wtCo and Cu-2wt%Be alloys, which were executed to examine the mechanical characteristics of probe pin as the core component of test socket, are illustrated in Figure 2. As the result of analysis, the tensile strengths of Ni-30wt%Co alloy and Cu-2wt%Be alloy are 453.21 [Mpa] and 243.14 [Mpa], respectively, while the elasticity modulus of Ni-30wt%Co alloy and Cu-2wt%Be alloy are 231.15 [Gpa] and 95.83 [Gpa], respectively. Accordingly, it is deemed that greater values of the elasticity modulus and tensile strength of Ni-30wt%Co alloy were obtained since Ni metal promotes the stability of FCC Austenite.

Structural interpretation results include Directional Deformation and Force Reaction under the maximum displacement condition of 150 um. The maximum Directional Deformations of Ni-30wt%Co alloy and Cu-2wt%Be alloy are 0.13105 [mm] and 0.13112 [mm], respectively. In addition, the maximum Total

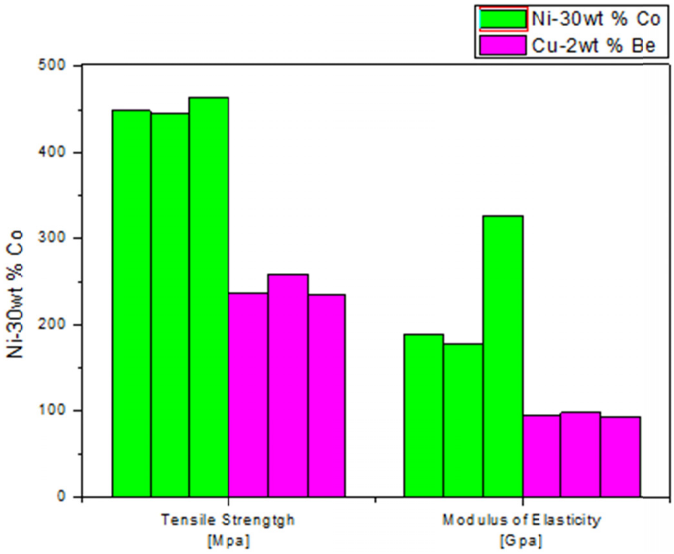

Fig. 2. Results of Tensile Strength and Elastic Modulus of Ni-30wt%Co Alloy and Cu-2wt% Be Alloy

Force Reactions of Ni-30wt%Co alloy and Cu-2wt%Be alloy are 0.18909 [N] and 0.18909 [N], respectively.

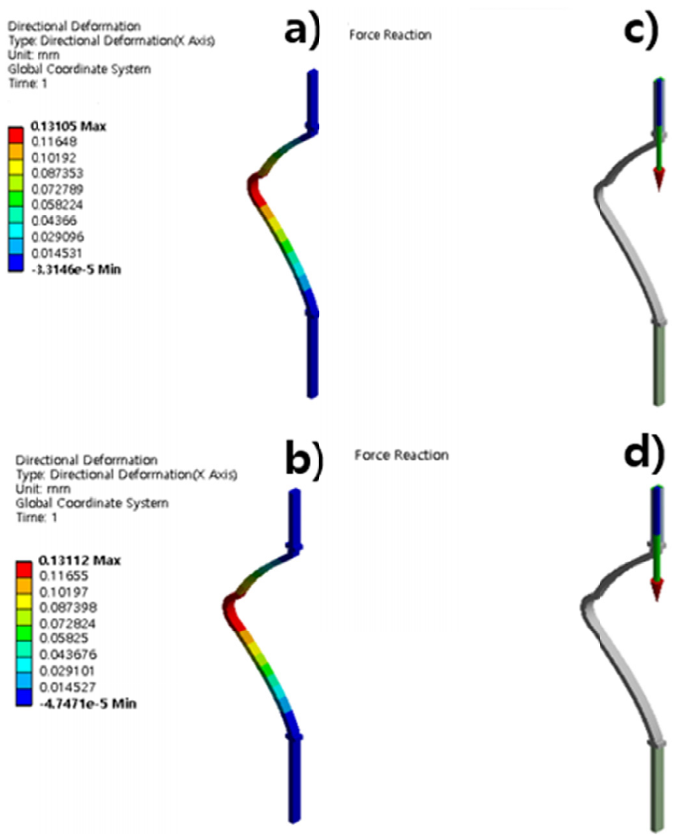

Fig. 3. Directional Deformation and Force Reaction: (a) Ni-30wt%Co Directional Deformation, (b) Ni-30wt%Co Force Reaction, (c) Cu-2wt%Be Directional Deformation, (d) Cu-2wt%Be Force Reaction

In addition, since not only the strength or elasticity but also the thermal expansion coefficient and specific heat are important factors that determine the performances of the core component of the test socket, Probe Pin, since it is used not only in high but also in low temperature domains, thermal expansion coefficient and specific heat were analyzed and illustrated in Figure 4. The thermal expansion coefficients of Ni-30wt%Co alloy and Cu-2wt%Be alloy are 14.00 × 10^{-6}/°C and 1.0618 × 10^{-5}/°C, respectively. The smaller value of thermal expansion coefficient of Cu-2wt%Be alloy in comparison to that of Ni-30wt%Co alloy was deduced.

The specific heats of Ni-30wt%Co alloy at the temperatures of 25, 40, 50, 70, 90 and 100°C are 0.443, 0.448, 0.452, 0.46, 0.464 and 0.466 [J/g*°C], respectively, while those of Cu-2wt%Be alloy at the temperatures of 25, 40, 50, 70, 90 and 100°C are 0.410, 0.414, 0.416, 0.419, 0.421 and 0.423 [J/g*°C], respectively. Similarly, small value of specific heat was deduced for Ni-30wt%Co alloy.

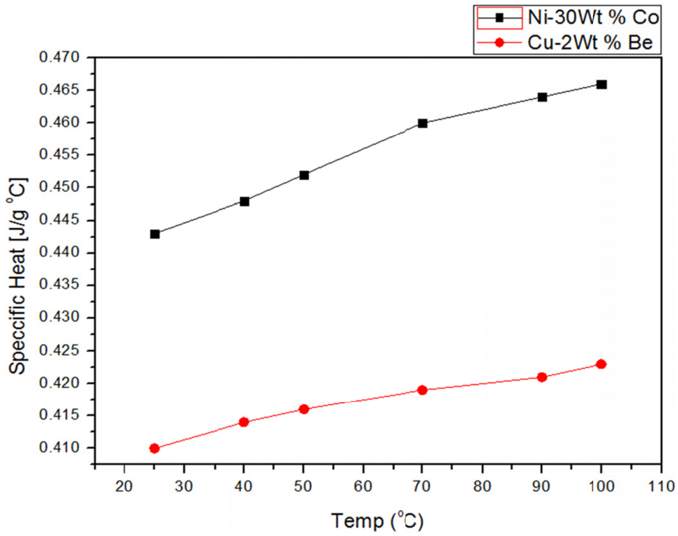

Fig. 4. Results of specific heat analysis of Ni-30wt% Co alloy and Cu-2wt% Be alloy

Results of analysis of surface resistance, specific resistance and electrical conductivity, which are electrical characteristics, are illustrated in Figure 5. Ni-30wt%Co alloy had surface resistance of 241.9 [μΩ], specific resistance of 39.336 [μΩ·cm] and electrical conductivity of 25.412 [kS/cm], while Cu-2wt%Be alloy had surface resistance of 114.1 [μΩ], specific resistance of 13.264 [μΩ·cm] and electrical conductivity of 75.356 [kS/cm]. It is deemed that Cu-2wt%Be alloy has outstanding electrical characteristic since it has high Cu contents, which is a metal with the 2^{nd} highest electrical conductivity among all metals.

Results of analysis of Contact Force and allowable current by manufacturing the core component of test socket, Probe pin, are illustrated in Figure 6. The results of Contact Forces for Ni-30wt%Co alloy and Cu-2wt%Be alloy are 9.66 [g force] and 7.74 [g force], respectively.

Allowable currents for Ni-30wt%Co alloy and Cu-2wt%Be alloy were 0.4 [A] and 1.28 [A], respectively. It is deemed that allowable current of Cu-2wt%Be alloy is higher due to its more outstanding electrical characteristics.

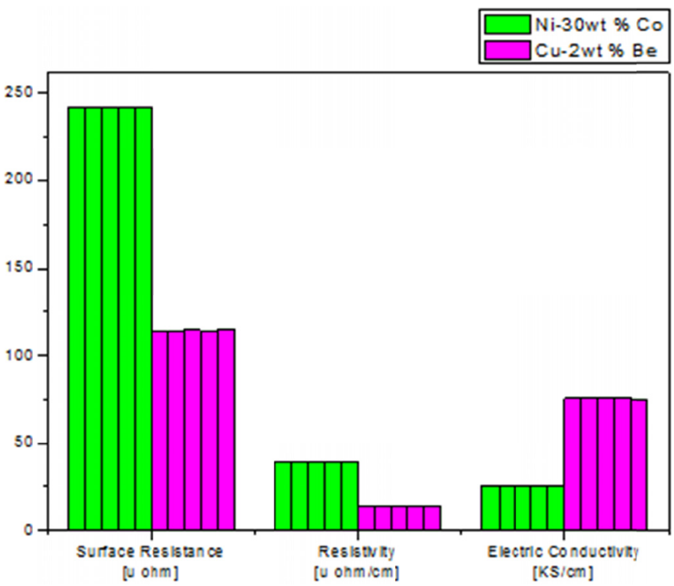

Fig. 5. Surface resistivity, specific resistance and electrical conductivity of Ni-30wt% Co alloy and Cu-2wt% Be alloy

In addition, although Contact Force value changed and Pin was discolored or plasticization deformation occurred on its own for the Ni-30wt%Co alloy even at low current during the analysis, Cu-2wt%Be alloy did not display deformation even when current in excess of 1 A was applied.

4. Conclusion

In this study, the following conclusions were derived through the results of experiment on the mechanical and electrical properties of Ni-30wt%Co alloy and Cu-2wt%Be alloy.

1. Thermal expansion coefficient of Ni-30wt%Co alloy and Cu-2wt%Be alloy were 14.00×10^{-6}/°C and 1.0618×10^{-5}/°C, respectively. Since Cu-2wt%Be alloy has lower value than Ni-30wt%Co alloy, it is deemed that Probe Pin manufactured with Cu-2wt%Be alloy will undergo less deformation in high temperature domain.
2. The specific heats in the high temperature domain for Cu-2wt%Be alloy and Ni-30wt%Co alloy are 0.421[J/g*°C] and 0.466[J/g*°C], respectively, with Cu-2wt%Be alloy having slightly lower value. However, the difference is only minor and it is deemed that there would be no problem in using it in manufacturing of semiconductor Probe Pin.
3. In comparison to Ni-30wt%Co alloy, Cu-2wt%Be alloy has surface resistance value that is lower by 127.8 [μΩ], specific resistance value that is lower by 26.072 [μΩ·cm] and electrical conductivity value that is larger by 49.944 [kS/cm], thereby producing outstanding results of current characteristics. The outstanding electrical characteristics are deemed to be the results of higher contents of Cu, which is a metal with the 2nd highest electrical conductivity, in Cu-2wt%Be alloy. Therefore, it is deemed that the conveyance of signal and reliability will improve if Probe Pin is manufactured with Cu-2wt%Be alloy.
4. Although there was difference of 10 [g force] in the data obtained from finite element interpretation and data obtained from actual experiment, it was confirmed that they displayed similar trend. In addition, The Contact Force measured through experiment is 7.74 [g force] with Cu-2wt%Be alloy displaying more outstanding characteristics.

The difference between the resultant value deduced by setting the physical property data prepared at the time of finite element interpretation as the experimental data and the resultant values deduced through actual experiment is deemed to be the results of the error that occurs at the time of manufacturing of Pin rather than the error due to the external influences at the time of physical properties and measurement test.

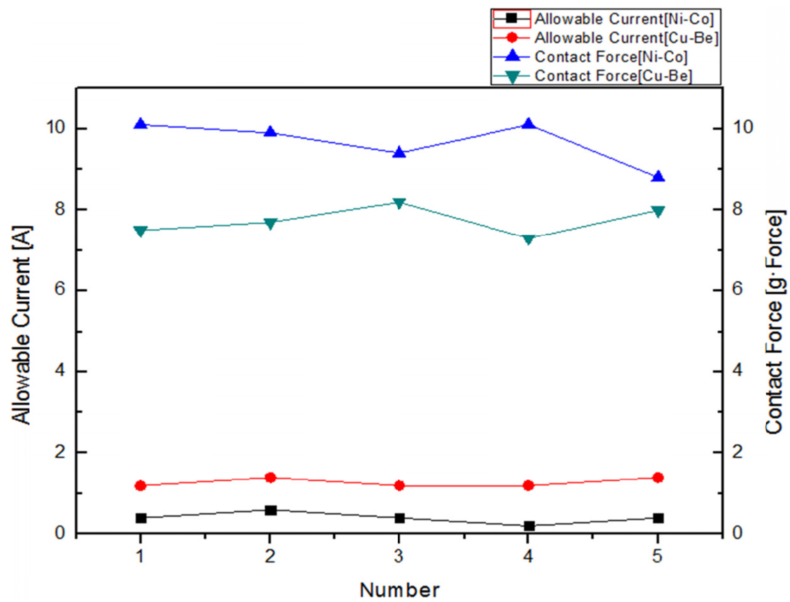

Fig. 6. Contact Force and Allowable Current of Ni-30wt% Co Alloy and Cu-2wt% Be Alloy

Since Cu-2wt%Be alloy has lower thermal expansion coefficient and specific heat, it can be used at both high and low temperature domains, making it a material capable of producing outstanding effects. In addition, it is deemed to be more appropriate for use in semiconductor Probe Pin due to its more outstanding Contact Force and electrical characteristics in comparison to those of Ni-30wt%Co alloy.

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