EFFECT OF NICKEL DOPING INTO SOLDER ALLOY AND ITS STRENGTH BETWEEN SnCu-Ni/IMMERSION GOLD JOINT

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MASTER OF ENGINEERING (MECHANICAL)

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SUPERVISOR'S DECLARATION

We hereby declare that we have checked this thesis and in our opinion, this thesis is adequate in terms of scope and quality for the award of the degree of Master of Engineering (Mechanical).

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STUDENT'S DECLARATION

I hereby declare that the work in this thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at Universiti Malaysia Pahang or any other institutions.

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LIST OF SYMBOLS

wt.%	Weight Percentage
˚C	Degree Celsius
MPa	Mega pascal
θ	Angle
µm	Micro meter
t	Time

LIST OF ABBREVIATIONS

Ag	Silver
ASTM	American Society for Testing and Materials
Au	Aurum/Gold
Co	Cobalt
Cu	Copper
EDX	Electron Dispersive X-ray
ENIG	Electroless Nickel Immersion Gold
Fe	Ferum
IMC	Intermetallic Compound
ImAg	Immersion Silver
ImAu	Immersion Gold
ImSn	Immersion Tin
NaCl	Natrium Chloride
Ni	Nickel
Pb	Lead
PCB	Printed Circuit Board
Pd	Palladium
SAC	Sn-Ag-Cu
Sn	Tin

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ABSTRAK

Sambungan cip mengalih, juga terkenal sebagai sambungan (C4) cip kejatuhan terkawal telah digunakan dengan meluas dalam industri semikonduktor. Pateri bertindak sebagai satu bahan penyambung antara cip dengan substrat dalam cip mengalih, bagi menyediakan kesinambungan elektrik dan mekanikal dalam sambungan. Oleh kerana pemilihan bahan pateri penting dalam prestasi sambungan pateri, salah satu strategi untuk meningkatkan kebolehpercayaan penyambungan adalah untuk menambah tambahan unsur aloi untuk pateri. Lantaran itu, kesan nikel sebagai tambahan dalam aloi pateri SnCu and SnAgCu telah disiasat dalam kajian ini. Walaupun aloi SnCu and SnAgCu dianggap sebagai pilihan baik dalam memajukan aloi pateri bebas plumbum, ia menunjukkan satu keretakan antara muka rapuh bertambah berbanding dengan pateri SnPb di bawah pembebanan hentaman. Maka, menambah unsur seperti nikel kepada komposisi aloi menjadi salah satu isu menarik dalam kajian-kajian pateri bebas plumbum, kerana ia akan terus meningkatkan sifat mekanik pancalogam dan kebolehpercayaan sambungan pateri. Tambahan pula, tambahan nikel untuk pateri aloi dalam kajian ini juga bertindak sebagai satu gantian salutan nikel yang biasa digunakan sebagai satu lapisan pemisah antara pateri dan Cu substrat. Objektif kajian ini adalah untuk memeriksa kesan pelbagai peratusan nikel di pembentukan sebatian antara logam dan pertumbuhan, serta kekuatan sambungan pateri. Untuk membangunkan aloi pateri (Sn-0.7Cu) SnCu-xNi, pateri komersial dan serbuk nikel telah diletakkan dalam mangkuk pijar sebelum ia cair dalam relau di bawah suhu 425˚C kepada 450˚C selama 40 minit. Prosedur sama digunakan untuk membangunkan aloi pateri SnAgCu-xNi, tetapi dengan tambahan 3.0 peratus berat serbuk perak kepada komposisi aloi. Peratusan berat nikel yang digunakan dalam kajian ini ialah 0.05, 0.10, 0.20 dan 0.25wt.%. Komposisi kedua-dua jenis aloi pateri kemudian disahkan menggunakan analisis sinar-x sebar tenaga. Daripada analisis, dua fasa eutektik telah dikesan dalam aloi pateri yang merupakan timah dan Cu_6Sn_5. Peratusan berat nikel dalam aloi pateri juga dicatatkan sebagaimana jumlah yang telah diperkenalkan sebelum proses melebur. Proses *reflow* kemudian dijalankan antara setiap jenis pateri dan substrat bersadur emas pada suhu 250˚C selama 25 minit. Beberapa spesimen kemudian diletakkan untuk melalui proses penuaan isoterma dalam ketuhar penuaan pada suhu 150˚C untuk 250, 500, 1000 dan 2000 jam masing-masing. Mikrostruktur sambungan pateri untuk sebagai keadaan *reflow* dan selepas penuaan diperhatikan menggunakan kedua-dua mikroskop elektron pengimbasan mikroskop optik dan pancaran medan. Terdapat dua jenis antara logam membentuk semasa *reflow* dan proses penuaan, iaitu Cu_3Sn and Cu_6Sn_5. Ketebalan antara logam untuk semua sambungan meningkat dengan waktu penuaan, terutamanya disebabkan pertumbuhan Cu_3Sn and Cu_6Sn_5. Berdasarkan ketebalan diukur, sambungan dengan 0.05 dan 0.25 peratusan berat Ni memberi ketebalan antara logam diingini berbanding dengan sambungan-sambungan lain. Selain itu , kadar pertumbuhan sebatian antara logam atas waktu penuaan dikira menggunakan hubungan Arrhenius. Pusingan ujian ricih juga dijalankan mengikut standard ASTM D1002. Keputusan-keputusan ujian ricih pusingan menunjukkan peratusan tambahan Ni dalam aloi pateri (0.05 dan 0.25 peratusan berat) meningkatkan kekuatan pusingan ujian ricih sambungan pateri. Oleh itu, berdasarkan keputusan dan perbincangan kajian ini, nilai peratusan berat Ni 0.05 dan 0.25 dicadangkan untuk ditambah dalam aloi pateri.

ABSTRACT

Flip chip assembly, which is well known as controlled collapse chip connection (C4) has been widely used in semiconductor industry. Solder acts as a joining material in flip chip to interconnect chip with substrate, in order to provide electrical and mechanical continuity in assemblies. Since selection of solder material is important in solder joint performance, one of the strategies to improve joint's reliability is to add additional alloying elements to solder. Therefore, the effect of nickel doping or addition in SnCu and SnAgCu solder alloy was investigated in this study. Although SnCu and SnAgCu alloy are considered as promising alternative in developing lead free solder alloy, it showed an increased brittle interfacial fracture compared to SnPb solder under impact loading. Thus, adding element such as nickel to the alloy composition become one of the interesting issues in lead free solder studies, as it will further enhance the mechanical properties of the alloys and the reliability of solder joints. Furthermore, addition of nickel to solder alloy in this study also acts as a replacement of nickel coating that is commonly used as a barrier layer between solder and Cu substrate. The objective of this study is to examine the effect of various nickel percentage on intermetallic compound formation and growth, as well as solder joint strength. To develop SnCu-*x*Ni solder alloy, commercial solder (Sn-0.7Cu) and nickel powder were placed in crucible before it is melted in furnace under temperature 425˚C to 450˚C for 40 minutes. The same procedure was used to develop SnAgCu-*x*Ni solder alloy, but with the addition of 3.0 weight percent of silver powder to alloy composition. Nickel weight percentages that were used in this study are 0.05, 0.10, 0.20 and 0.25. The composition of both types of solder alloy was then confirmed using energy dispersive x-ray analysis. From analysis, two eutectic phases were detected in solder alloy which is tin and intermetallic Cu_6Sn_5. The weight percentages of nickel in solder alloy were also similar to the amount that had been introduced before melting process. Reflow process was then conducted between each type of solder and substrate coated with immersion gold at 250˚C for 25 minutes. Some specimens were then put to go through isothermal aging process in aging oven at temperature 150˚C for 250, 500, 1000 and 2000 hours respectively. Microstructures of solder joint for as reflow condition and after aging were observed using both optical microscope and field emission scanning electron microscopy. There are two types of intermetallic formed during reflow and aging processes, which are Cu_3Sn and Cu_6Sn_5. Thickness of intermetallic for all joints increases with aging time, mainly due to Cu_3Sn and Cu_6Sn_5 growth. Based on thickness measured, joints with 0.05 and 0.25 weight percentage gave desired intermetallic thickness compared to other joints. Besides that, growth rate of intermetallic compounds over aging time was calculated using Arrhenius relationship. Lap shear test is also performed according to standard ASTM D1002. The lap shear test results indicated that percentage of Ni addition in solder alloy (0.05 and 0.25 weight percentage) does affect the solder joint shear strength. Apparently, based on the result and discussion of this study, the weight percentage values of 0.05 and 0.25 were recommended to be doped in solder alloy.

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