EFFECT OF ELECTROLESS NICKEL-BORON (EN-B) SURFACE FINISH ON SOLDERABILITY OF SAC305 AND SOLDER JOINT STRENGTH

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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
^oC	degree celcius
MPa	Megapascal
θ	angle
↑	produced as a gas
k	Growth rate constant
μm	micrometer
T_p	Peak temperature
$T_{s\ max}$	Maximum solidus temperature
$T_{s\ min}$	Minimum solidus temperature
T_c	Classification temperature
T_L	Liquidus temperature
t	time
t_L	Liquidus time
^oC	degree celcius
MPa	Megapascal

LIST OF ABBREVIATIONS

Ag	Silver
ASTM	American Society for Testing and Materials
Au	Gold
B	Boron
Bi	Bismuth
BGA	Ball Grid Array
Cu	Copper
Cr	Chromium
EDX	Energy Dispersive X-ray Spectroscopy
EN	Electroless Nickel
ENEP	Electroless Nickel Electroless Palladium
ENEPIG	Electroless Nickel Electroless Palladium Immersion Gold
ENIG	Electroless Nickel Immersion Gold
FESEM	Field Emission Scanning Electron Microscope (
Ge	Germanium
IMC	Intermetallic compound
ImAg	Immersion Silver
ImSn	Immersion Tin
IPC	Association Connecting Electronics Industries
JEDEC	Joint Electron Device Engineering Council
$NaBH_4$	Sodium Borohydride
NaCl	Natrium Chloride

Ni	Nickel
Pb	Lead
PCB	Printed circuit board
Pd	Palladium
PDA	Personal digital assistant
SAC	Sn-Ag-Cu
SEM	Scanning Electron Microscopy
Si	Silicon
Sn	Tin
Ti	Thalium
TSM	Top surface morphology
XRD	X-ray diffraction
Zn	Zink

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ABSTRAK

Perkembangan pesat dalam teknologi merupakan satu cabaran besar dalam industri elektronik untuk bergerak seiring dengan keperluan industri bagi menyediakan teknologi pintar yang kos efektif dan dalam masa yang sama, berkualiti. Kualiti pembungkusan elektronik berkait terus dengan sambungan pateri yang merupakan kebimbangan utama. Dalam kajian ini, percubaan telah dibuat untuk mengkaji kebolehan *electroless nickel boron* sebagai lapisan pada papan litar bercetak dengan mengkaji kebolehpateriannya, menyelidik jenis sebatian antara logam terhasil dan pertumbuhan selepas proses pematerian *reflow* dan juga proses penuaan sekaligus mengenalpasti kesan kadar penyejukan dan suhu penuaan (125°C and 150°C) terhadap pembentukan sebatian dan kekuatan ricih sambungan pateri. *Electroless nickel boron* telah dilapis atas kuprum melalui teknik *electroless.* Beberapa kepekatan borohydride natrium telah digunakan iaitu 0.4, 0.6, 0.8, 1.0 dan 1.2 g/L bagi mengenalpasti kesan kandungan Boron terhadap ciri-ciri lapisan *electroless nickel boron.* Morfologi permukaan lapisan *electroless nickel boron* telah dianalisis menggunakan mikroskop imbasan elektron. Struktur fasa lapisan *electroless nickel boron* pula dianalisis menggunakan pembelauan sinar-x dan pengukuran kekasaran permukaan telah dijalankan menggunakan perisian *3D Roughness Reconstruction.* Selepas itu, pematerian *reflow* dijalankan menggunakan Sn-3.0Ag-0.5Cu aloi pateri untuk membentuk sambungan pateri sebelum melalui proses penyejukan yang mana dua jenis media penyejukan digunakan iaitu udara (kadar penyejukan perlahan) dan air (kadar penyejukan cepat). Kebolehpaterian permukaan seterusnya dikaji dengan mengukur sudut sentuhan diantara Sn-3.0Ag-0.5Cu aloi pateri dengan lapisan *electroless nickel boron.* Kemudian, satu set sampel melalui proses penuaan selama 250, 500, 1000 dan 2000 jam untuk 125°C dan satu lagi set sampel untuk 150°C sebelum ujian kekuatan ricih untuk mengkaji kekuatan sambungan pateri. Ketebalan sebatian antara logam dan rekahan permukaan hasil daripada ujian ricih dianalisis menggunakan mikroskop optik, mikroskop imbasan elektron manakala pelepasan mikroskop imbasan elektron yang dilengkapi dengan spektroskopi serakan tenaga sinar-x digunakan untuk mengenalpasti elemen pada sebatian antara logam. Berdasarkan keputusan kajian, kepekatan yang sesuai digunakan untuk papan litar bercetak ialah 0.6 g/L berdasarkan kebolehannya untuk menyediakan permukaan kebolehpaterian dengan 42.5° sudut sentuhan. Selepas proses *reflow*, diperhatikan bahawa sebatian antara logam mengandungi Ni_3Sn_4 dan $(Ni, Cu)_3Sn_4$ untuk kedua penyejukan udara dan air. Bagaimanapun, apabila sambungan pateri melalui suhu penuaan (1000 jam), sebatian antara logam bertukar kepada hanya $(Ni, Cu)_3Sn_4$ untuk kedua penyejukan. Bagi kadar penyejukan pula, dikenalpasti bahawa kadar penyejukan perlahan (15.7 ˚C/min) menghasilkan sebatian antara logam yang lebih tebal untuk keadaan *as reflow* dan penuaan berbanding kadar penyejukan cepat (110.5˚C/min) tanpa menghiraukan suhu penuaan yang digunakan. Bagaimanapun, 125°C menyediakan sebatian antara logam yang lebih nipis berbanding 150°C berdasarkan kepada tenaga pengaktifannya yang tinggi. Selain itu, kekuatan sambungan pateri didapati untuk berkurang apabila ketebalan sebatian antara logam bertambah dan 125°C menunjukkan sambungan yang lebih kuat berbanding 150°C suhu penuaan. Bagaimanapun, pengaruh ketebalan sangat sedikit berbanding dengan pembentukan *underfill* dan serpihan daripada sebatian antara logam yang kelihatan lebih banyak mempengaruhi kekuatan ricih sambungan pateri. Bagaimanpun, lapisan *electroless nickel boron* menunjukkan kebolehan yang menjanjikan sebagai alternatif lapisan kepada papan litar bercetak di dalam industry elektronik.

ABSTRACT

Rapid developments in technology have been a great challenge for the electronics industry to keep up with the industrial requirement to provide cost-effective smart devices while, at the same time, maintaining their quality. The quality of electronic packaging is directly related to the solder joints, which turn out to be the main concern in the electronics industry. In the current study, an attempt was made to study the ability of electroless nickel boron as printed circuit board's surface finish by study the solderability, investigate the type of intermetallic compound formation and growth after reflow soldering and isothermal aging as well as determine the effect of cooling rate and isothermal aging temperature (125°C and 150°C) on the intermetallic compound formation and solder joint's strength. Electroless nickel boron was deposited on a copper substrate through electroless plating method. Several sodium borohydrade concentration were used, 0.4, 0.6, 0.8, 1.0 and 1.2 g/L. in order to investigate the effect of Boron content on the electroless nickel boron. The morphology of the electroless nickel boron surface finish was analysed by using scanning electron microscopy. The phase structure analysis of the surface finish also analysed using x-ray diffraction and surface roughness measurement was carried out using 3D Roughness Reconstruction software. Then, reflow soldering was conducted using Sn-3.0Ag-0.5Cu solder alloy to form the solder joint prior to cooling process which two different cooling medium was used which is air (for slow cooling rate) and water (for fast cooling rate). The solderability of the surface finishes then evaluated by measuring the contact angle between the Sn-3.0Ag-0.5Cu solder alloy and the electroless nickel boron surface finish. After that, a set of samples were underwent isothermal aging for 250, 500, 1000 and 2000 hours for 125°C and another set for 150°C prior to lap shear test to study the strength of the solder joint. Thickness of the intermetallic compound and surface fractured of the shear test were analysed by using Optical microscope, Scanning Electron Microscopy while Field Emission Scanning Electron Microscope that equipped with energy dispersive x-ray spectroscopy system was used to identify the element on the intermetallic compound. From the results, it was observed that the suitable $NaBH_4$ concentration to be used on printed circuit board to deposit an electroless nickel boron surface layer is 0.6 g/L $NaBH_4$ based on its ability to provide most solderable surface with 42.5° contact angle. After reflow process, it was observed that intermetallic compound consist of of Ni_3Sn_4 and $(Ni, Cu)_3Sn_4$ for both air and water cooling. However, as the joint thermally aged (1000 hours), the intermetallic compound changes to only $(Ni, Cu)_3Sn_4$ for both cooling. In term of cooling rate, it was found that slow cooling rate (15.7 ˚C/min) produced higher intermetallic compound thickness for both as reflow and aging compared to fast cooling rate (110.5˚C/min) regardless the aging temperature used. However, 125°C provided thinner intermetallic compound compare to 150°C due to its higher activation energy. Besides, the strength of the solder joint was found to decrease as intermetallic compound thickness increased owing to the cooling rate and 125°C shows stronger joint than 150°C aging temperature. However, the influent is minimal compared to the formation of underfill and spalling behaviour of the intermetallic compound that seems to affect the solder joint strength significantly instead. Nevertheless, electroless nickel boron surface finish shows promising ability to be an alternative in regards to the surface finish on printed circuit board in electronic industry

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