WEAROUT RELIABILITY STUDIES OF BONDING WIRES USED IN NANO ELECTRONIC DEVICE PACKAGING

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by

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LIST OF SYMBOLS

Ag	Silver
Ag-Al	Silver-Aluminium
Ag-Pd-Cu	Silver-Palladium-Copper
Ag-Au-Pd	Silver-Aurum-Palladium
Al	Aluminium
Al^{3+}	Aluminium Ion
$AlBr_3$	Aluminium tri-Bromide
$[Al(Cl)_4]^-$	Aluminium tetra-Chloride Ion
$Al(OH)_3$	Aluminium tri-Hydroxide
$Al(OH)_2Cl$	Aluminium di-Hydroxide Chloride Ion
Au	Aurum or Gold
Au-Al	Aurum-Aluminium
Au_4Al	Aurum Aluminide
$AlCl_3$	Aluminium tri-chloride
Al_2O_3	Aluminium (III) Oxide
Br	Bromine

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Cu	Copper
Cu^+	Copper (I) Ion
Cu_2O	Copper (I) Oxide
Cu-Al	Copper-Aluminium
Cu-Al-Pd	Copper-Aluminium-Palladium
Cu_9Al_4	Copper (IV) Aluminide
CuBr	Copper Bromide
Cu-Pd	Copper-Palladium
Cl^-	Chloride
cm^2/s	centimeter square per seconds
E_{aa}	Apparent activation energy
F	Failure Rate
H_2	Hydrogen
H^+	Hydroxonium Ion
H_2O	Water
HCl	Hydrochloric Acid
Pd	Palladium
PdCu	Palladium Coated Copper

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ppm	Parts per million
pH	Power of Hydrogen
D_o	Diffusion Coefficient
exp	Exponential function
F	Failure Rate
g	gram
gf	gram-force
K	Kelvin
k	Boltzmann Constant
O_2	Oxygen Gas
OH^-	Hydroxide Ion
mg	milligrams
mm	millimeter
m^2/s	meter square per seconds
R	Ryberg gas constant
R_o	Constant
RH	Relative Humidity
t	Thickness
t_{first}	Time of first failure occurrence

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t_{50}	median-time-to failure
$t_{63.2}$	characteristics life
T	Temperature
kHz	kilo Hertz
%	Percentage
ΔT	Delta in Temperature
Δx	Delta in Distance
α	characteristic life
β	weibull slope
η	characteristic life
eV	Electron Volt
°C	Degree Celsius

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LIST OF ABBREVIATIONS

AECG1	Automotive Electronic Council Grade 1
Ag	Silver
BGA	Ball Grid Array
EFO	Electronic Flame Off
EMC	Epoxy Mold Compound
FAB	Free Air Ball
FBGA	Fineline Ball Grid Array
FEM	Finite Element Modeling
HAST	Highly Accelerated Temperature and Humidity Stress Test
HTSL	High Temperature Storage Life
IMC	Intermetallic Compound
IMD	Intermetal Dielectric
IUPAC	International Union of Pure and Applied chemistry
PCT	Pressure Cooker Test
TC	Temperature Cycling

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TSOP	Thin Small-Outline Package
THB	Temperature Humidity Bias
UHAST	Unbiased Highly Accelerated Temperature and Humidity Stress

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Kajian Keboleharapan Hausan Dalam Pelekatan Wayer bagi Pembungkusan Peranti Nano Electronik

ABSTRAK

Wayer kuprum secara tradisional adalah lebih senang mengalami pengaratan selepas kelembapan berbanding dengan wayer emas. Setakat ini, pengetahuan di bidang kajian kebolehrapan adalah terhad terutamanya dalam antara-sambungan paras satu (ikatan bebola). Objektif projek ini bertujuan untuk menguji-kaji keboleharapan hausan, tenaga pengaktifan dan penumbuhan ketebalan bagi liputan antara logam (IMC) bagi wayer emas, wayer kuprum salutan Palladium (Pd) dan wayer kuprum dengan pendopan Pd dalam bidang pembungkusan semikonduktur. Skop penyelidikan meliputi penyelidikan pengaruh jenis wayer atas keboleharapan hausan bagi komponen flash, pencirian tenaga pengaktifan ketara (E_{aa}) bagi liputan antara logam (IMC), HTSL serta formulasi mekanisme kegagalan bagi wayer berlainan. Kebolehrapan hausan bagi pincangan HAST, HAST tanpa pincangan, pengitaran suhu (TC) dan ujian simpanan pada suhu tinggi (HTSL) telah diciri. Sampel-sampel dimasukkan dalam mesin keboleharapan dan diuji sampai kegagalan hausan. Graf Weibull diplotkan bagi ujian-ujian keboleharapan untuk tiga jenis wayer. Masa kegagalan pertama (t_{first}), median masa hingga kegagalan (t_{50}), hayat karasteristik ($t_{63.2}$) serta kecerunan Weibull (β) dicirikan. Kajian seterusnya meliputi pengamalan suhu simpanan pada suhu 150 ºC, 175 ºC dan 200 ºC untuk masa yang berlainan. Tenaga pengaktifan ketara telah ditentukan bagi HTSL dan ketebalan bagi liputan antara logam (IMC) bagi wayer emas, wayer kuprum salutan Palladium (Pd) dan wayer kuprum dengan pendopan Pd. Ketuhar Dispatch digunakan di dalam ujian HTSL. Keputusan analisis menunjukkan kecerunan weibull (β) bagi wayer pelekatan berlainan adalah melebihi 1.0 dan merupakan data untuk hausan dalam keboleharapan. Wayer kuprum dopan dengan palladium mempamerkan masa sehingga kegagalan dan kitar sehingga kegagalan yang lebih tinggi dalam pincangan HAST, HAST tanpa pincangan dan pengitaran suhu (TC) berbanding wayer emas dan wayar kuprum diplat dengan palladium. Ini membuktikan wayer kuprum didop dengan palladium mempunyai potensi dan keboleharapan hausan lebih tinggi berbanding wayer emas dan wayer kuprum diplat dengan palladium. Wayer kuprum asal dibuktikan dengan keboleharapan hausan yang paling rendah. Pertumbuhan ketebalan bagi liputan antara logam (IMC) telah ditentukan bagi pelekatan wayar yang berlainan. Tenaga pengaktifan ketara (E_{aa}) bagi wayer emas adalah dalam lingkungan 0.92 eV ~ 1.10 eV manakala 0.72 eV ~ 0.83 eV bagi wayer kuprum diplat dengan palladium dalam ujian HTSL. Bagi kajian ketebalan IMC, tenaga pengaktifan ketara (E_{aa}) bagi CuAl adalah 1.08 eV dan 1.04 eV masing-masing dengan EMC A dan EMC B manakala tenaga pengaktifan ketara (E_{aa}) bagi AuAl adalah 1.04 eV dan 0.98 eV masing-masing dengan EMC A dan EMC B. Kekuatan heretan dan cukuran wayar telah dianalis dan mempunyai variasi lebih kecil bagi wayer kuprum dopan dengan palladium berbanding wayer emas dan wayer kuprum diplat dengan

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palladium. Kesimpulannya, bebola emas juga dikenalpasti dengan penumbuhan liputan antara logam (IMC) yang lebih cepat berbanding dengan penumbuhan liputan antara logam (IMC) yang lambat di dalam wayer kuprum.

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Wearout Reliability Studies of Bonding Wires Used in Nano Electronic Device Packaging

ABSTRACT

Conventional bare Cu bonding wires, in general, are more susceptible to moisture corrosion compared to gold (Au) and Cu wires. There is very limited knowledge based reliability studies which have been carried out on 1st level interconnect (ball bond in this matter) on nano device semiconductor packages. The objective of this project is to evaluate the wearout reliability, apparent activation energy and Intermetallic compound (IMC) thickness growth of Au, Pd-coated Cu wire and Pd-doped Cu wire used in semiconductor packaging. Methodology of this work include investigation on the effects of bonding wires on wearout reliability of flash component, characterization of the apparent activation energy of IMC and HTSL test and formulation of the failure mechanisms in different wires. Wearout reliability of biased Highly Accelerated Temperature and Humidity Stress (HAST), unbiased HAST (UHAST), Temperature Cycling (TC) and High Temperature Storage Life (HTSL) have been characterized. Samples are loaded into each reliability chambers and stressed until wearout open failure. Weibull plot is plotted for each reliability stresses and for three wire types. First failure (t_{first}), median-time-to-failure (t_{50}) and characteristic life ($t_{63.2}$) and weibull slope (β) are calculated accordingly. Next study includes applying thermal storage conditions at 150 °C, 175 °C and 200 °C at various intervals time. The apparent activation energy (E_{aa}) has been investigated for HTSL and IMC thickness growth of Au, Pd-coated Cu wire and Pd-doped Cu wire. Dispatch oven is used in HTSL test. Results indicated that the obtained weibull slope (β) of three wire types are greater than 1.0 and belong to wearout reliability data point. Pd-doped copper wire exhibits larger time-to-failure and cycles-to-failure in HAST, UHAST and TC tests. This proves Palladium (Pd)-doped copper wire has a greater potential and higher reliability margin compared to Au and Pd-coated copper wires. Bare Cu wire is not observed with lowest wearout reliability performance. Intermetallic compound (IMC) diffusion kinetics has been established among the different bonding wires. E_{aa} obtained of Au ball bonds are ranging from 0.92 ~ 1.10 eV and 0.72 ~ 0.83 eV for Pd-coated Cu ball bonds in HTSL test. For IMC thickness growth study, E_{aa} obtained for CuAl IMC are 1.08 eV and 1.04 eV respectively with EMC A and EMC B. E_{aa} obtained are 1.04 eV and 0.98 eV respectively on EMC A and EMC B on AuAl IMC. Wire pull and ball bond shear strengths have been analyzed and we found smaller variation in Pd-doped copper wire compared to Au and Pd-doped copper wire. In conclusion, Au bonds were identified to have faster IMC formation, compared to slower intermetallic compound thickness growth compared to Pd-coated Cu wire and Pd-doped Cu wire.

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