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Evaluation of Bond Pad Structures by using Harsh Wire Bonding

Arun Kumar

Department of Electronics and Communication Engineering, Sureya College of Engineering, Trichy, India

E-mail: arun_kumar05@gmail.com

Abstract

IC bond pad structures having Al metallization and SiO_2 insulator are historically designed with full plates in underlying metallization layers, connected by vias. Additionally, pads having bond over active electronic equipment (BOAC) that square measure way more sensitive to pad cracks, square measure possible gift within the same IC. Cracks within the pad insulator weaken the bond dependableness and will cause electrical outpouring or shorts to electronic equipment beneath the pad. Cracks square measure additional possible to occur throughout metallic element wire bond thanks to higher bonding stress as compared to Au alloy wire bonding. Experimental knowledge from bonding with 1mil Au or metallic element wires reveals dramatic variations in pad hardiness against cracking, relying upon the underlying metal structures and patterns. A "harsh" Au wire bond formula is additionally developed to supply the strain effects of metallic element wire bond in experiments while not having to upgrade older bonding instrumentation for metallic element wire. Cratering check once wire bond is employed to judge pad cracking. Ball shear checking followed by a cratering test any reveals pad cracking tendencies. Style principles for exaggerated pad hardiness to cracking square measure developed supported the information. Dependableness knowledge verifies the effectiveness of the planning principles. Correct style of interconnects at a lower place the pad will greatly increase pad hardiness to cracking, permitting way more margin in bonding stress, sanctionative the choice of Au or metallic element wire bond on an equivalent IC while not pad cracking.

Keywords: *Harsh wire bonding, SiO_2, instrumentation, metallic element, IC*

INTRODUCTION

Gold (Au) wire bonding typically has little or no method margin as a result of the pad structure is fragile. Wire bonder recipes area unit typically supposed to avoid problems with the pad structure, like an excessive amount of pad metal (Al) displacement, bond lifting, material cracking, divots within the material, and cratering of the Si. To boot for circuit-under-pad (CUP) or bond-over-active-circuitry (BOAC) styles, deformation of Al within the interconnects below the "pad window" or delicate shifts within the conductor electrical behavior ought to be avoided [1, 2]. Deformation and cracking area unit found along on ancient pad structures that have tough an excessive amount of stress. However, deformation within the Al of CUP pads is damaging although there are not any cracks, attributable to native increase in impedance and degraded electromigration dependableness.

Traditional pad structures do not seem to be sufficiently sturdy to tolerate a switch to the upper mechanical stress required for in copper (Cu) wire bond while not considerably increasing pad Al thickness or creating alternative process changes that add price or need unacceptable style or producing tradeoffs. In conductor bonding on sensitive BOAC pads may be a huge challenge. Bond pads we will take into account have a Si substrate and a couple of or a lot of layers of Al-based metallization. Metallization includes skinny titanium-nitride (TiN) barrier layers on top of and below the Al (actually conductor–doped Al with 0.5% Cu) conductor film [3]. The bond pad metal is that the exposed Al of the skinny "metal top" (MT) layer among the pad window, wherever the wire bond makes contact. The pad window is enclosed by the passivation films covering the die surface. In these experiments the pad structure of interest includes all of the options coarctate by the drawn pad window, which means everything physically among or below the pad window gap right down to the Si substrate. These are the structures expected to receive highest stress throughout bonding on the pad Al.

The traditional bond pad structure has sheets of metal all told metal layers across the complete pad window. Tungsten (W) plug vias within the stuff layers between the metal levels electrically connect all of the degree to the pad. Mechanical stress from each wafer probe and wire bond will cause pad harm, with wire bond expected to exacerbate a weakness or crack already gift from searching. This can be a significant dependability concern, however, would not be thought-about here; most of those experiments use unprobed pads to avoid any pre-damage [4]. This project explores the bond pad structure's hardiness to cracking through the employment of harsh ball bonding exploitation Au wire, supposed to simulate the upper mechanical stress which can really occur throughout a metallic element wire bond method. "Harsh" Au ball wire bond recipes were developed to advisedly cause nearly 100 percent of ancient pads to crack, as discovered within the usual "cratering test" (etching to get rid of the bond ball and pad Al, then magnifier examines for damage). Au wire diameter is 1mil, and pad dimensions area unit usually 75um x 75um, with pad Al thickness of 1um or less for many tests, and up to 3um for one check. a couple of styles were additionally secured with AuPd and metallic element wires to verify that the Au wire "harsh" bonding is sufficiently similar.

A sample of a minimum of three die were analyzed for every pad structure and bonding condition, every die usually having thirty to forty pads warranted. Warranted pads were sample tested for bond pull strength and wire ball shear, and every one pads were inspected when cratering print. Extra knowledge was obtained on smaller sample sizes by etching away the barrier to induce a transparent read of harm to underlying options, or scaning microscope (SEM), polished cross section SEM (XSEM), or cross section by centered particle beam (FIB). TiN barrier and high nonconductor films bending on high of an unshapely underlying metal layer are detectable by a "ripple effect" seen optically in magnifier examination, having a look the same as ripples on a pool. Ripple impact is well discovered (but in poor detail) at low magnifications. We tend to were ready to regulate lighting and sample tilt sufficiently to look at ripple at higher magnifications on commonplace microscopes, although the photos do not reveal the maximum amount detail. Ripple is best discovered employing a differential interference distinction (DIC) magnifier. Wire pull strength check (PST) and ball shear check (BST) knowledge is gathered on smaller sample sizes [5].

Harsh bonding recipes for Au ball bond made the specified results by increasing the inaudible power and reducing the stage temperature. The griddlecake formed bond usually becomes additional planate, sometimes with larger diameter than targeted for production. we tend to assume that the lower pad temperature causes less of the inaudible energy to be absorbed at the bonding interface or dissipated across the pad Al, inflicting additional of the energy to transfer into the highest SiO_2 and into the underlying Al of MT (-1). Later within the experimentation, a second capillary vogue was tried, forming an additional bell formed bond that gave the impression to cause even additional cracking in harsh recipes because of the multiplied down force and inaudible energy coupling at the ball's periphery [6].

Traditional pads square measure extremely broken within the harsh bonding conditions, showing sturdy ripple and heavy cracking. Bonding stress includes the dynamic downward force of the ball combined with inaudible vibration, with the very best stress focused beneath the ball contact approach our harsh recipes. Additional care had to be taken within the sample preparation and cratering print sequence, therefore, on not pull apart the pads by laterally stressing the wires, and not etching away all the underlying pad metal Al through the cracks inflicting the highest SiO_2 to interrupt off before cratering examine.

Standard Au wire bonding generally caused 100% to five hundredth cracking to the weakest ancient pads (pad structures with prime vias and full sheets of metal all told interconnect layers below the pad window). While not prime vias below the pad window, third to twenty cracked pads is typical in these experiments. There was no cracking response for normal bonding in any experimental pad style. The ripple impact is often ascertained on secure ancient pads, cracked or not, prime vias or not, optimized or harsh bonding-indicating that bonding systematically deforms MT (-1) Al into native “valleys” and “hills”.

Every experimental pad structure showed less cracking, reduced or nonexistent ripple impact, and no barrier lifting or SiO2 divots as compared to ancient pads. No crack was found that was not in the course of robust ripple impact in this location. Pads having greatly reduced MT (-1) pattern density improved considerably, with third to thirteen cracking overall.

Full Metal Sheets

Pad structures containing a full metal sheet across the pad window in any underlying layer showed ripple impact, decreasing in magnitude because the impactive high material thickness increased: MT (-1) full sheet pads cracked the maximum amount because the ancient pads despite the pattern in metals below MT (-1) with sturdy ripple effect ascertained, MT (-2) full sheet (with speckled or absent MT (-1) within the pad window had but 100 percent of the pads cracked and reduced ripple impact, MT (-3) full sheet (with speckled or absent MT (-1) and MT (-2) layers within the pad window had but a hundred and twenty fifth of the pads cracked and weak ripple impact ascertained.

Other Relevant Tests

PST and BST knowledge for each customary and harsh Au wire bonding indicate that pads sturdy to cracking perform also or higher than ancient pads in comparative tests. Civil time followed by cratering take a look at is not sometimes done, as a result of it is best-known that ancient pads are too fragile. For the experimental pads, civil time followed by cratering take a look at showed no cracking or craters. BST followed by cratering is not sometimes done as a result of ancient pads is fragile. In these experiments, ninety nine of one hundred twenty ancient pads were cracked when customary bonding followed by ball shear then cratering test; whereas, no experimental pads out of 697 showed cracks, divots, or craters.

DISCUSSION

Cracking and ripple result along facilitate show, however, the applying of high stress to a bond pad structure containing brittle SiO_2 non conductor blur a ductile Al film ends up in cracking. This is often caused by the non conductor bending in agreement to the Al valleys and hills (We ignore the skinny TiN films for simplicity).

The presence of high vias additional weakens the SiO_2, making the weakest pad structure of any that were tested. It becomes clear that such cracks are also prevented if the SiO_2 does not bend considerably. This could be accomplished by limiting the dimension of SiO_2 higher than MT (-1) within the region of high bonding stress, and eliminating the employment of full sheets of metal in underlying levels of the pad structure. Increasing pad Al thickness is also wont to greatly cut back cracking, however, this is often not an entire answer for harsh bonding.

Non-BOAC pads will be designed for improved hardiness to cracking, exchange ancient pads, and facilitating a switch to Cu wire bond while not the need of thick MT. Cu wire bond exchange Au not solely reduces value, however, lower electric resistance and stiffer wire behavior throughout packaging are vital benefits. Also, Cu's abundant lower rate of intermetallic formation at the bond interface will result in improved dependability as compared to Au wire bond at higher operative temperature.

One may also follow the easy principles of reduced metal pattern density and restricted metal dimension between areas, slots, or holes. This can facilitate successful style of free-form CUP electronic equipment all told interconnect layers below the pad window to provide a sturdy pad structure, and permits the thought of Cu wire bond on BOAC pads while not the necessity for thick MT. Additional positive results were later obtained victimisation actual AuPd wire bond (more bonding stress during this direction than for Au) and Cu wire bond (even additional bonding stress).

PST and BST testing was done to check 240 "robust" pads to sixty ancient pads ball guaranteed with 1mil AuPd wire. All samples passed, with no applied mathematics distinction in values discovered. civil time and BST testing was conjointly done to check 360 "robust" pads to sixty ancient pads ball guaranteed with 1mil copper wire. All samples passed, with no applied mathematics distinction in values discovered. As usual, ancient pads showed cracking.

CONCLUSION

Harsh bonding experiments on varied pad structures, analyzed by cratering take a look at, aid in our understanding of the pad cracking mechanism and the way to forestall cracks. Ancient pad styles having full sheets of metal underneath the pad window, and particularly those with prime vias, area unit the weakest in terms of pad cracking from bonding tests. The importance of underlying Al-based metal structures, their pattern density, and limiting the metal dimension between areas, slots or holes is shown. These principles will simply be utilized in each booming pad style and booming BOAC pad style. “Robust” pad styles area unit incontestible to be proof against cracking and different harm from harsh bonding. Ripple impact exists for all cracks found, and is gift, whenever, there is a sufficiently wide metal feature within the pad structure. Ripple impact is not discovered in sturdy pads. Sample BOAC pad styles, having electronic equipment altogether interconnect levels below the pad window and Si devices below, were dependability tested, demonstrating no pad cracking, and positive results overall for each Au and copper wire bond on skinny pad Al.

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