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(54) Title: THIN BOND LINE SEMICONDUCTOR PACKAGES

(57) Abstract: A semiconductor assembly comprises a plurality of semiconductor dies that are stacked one on top of the other and bonded to each other using a two-part adhesive system, in which one part of the adhesive system is applied to the top side of one die and the second part of the adhesive system is applied to the back side of another die, in which the two parts of the adhesive system are reactive with each other, and in which the two parts of the adhesive system when contacted together initiate a reaction and partial curing between the two parts of the adhesive system.

THIN BOND LINE SEMICONDUCTOR PACKAGES

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application claims the benefit of United States Provisional Patent Application No. 61/170803 filed April 20, 2009, the contents of which is incorporated herein by reference.

BACKGROUND

[0002] This invention is directed to thin bond line semiconductor packages and methods for making such packages.

[0003] Miniaturization and slimming of electrical and electronic equipment leads to a need for smaller semiconductor packages and thinner semiconductor chips or dies. Smaller packages are obtained through the stacking of semiconductor dies, and particularly through the stacking of ever yet thinner semiconductor dies. Thinner dies, however, are more fragile than their thicker counterparts, and exhibit a greater number of fractures and cracks during thermal excursions or mechanical handling. Moreover, as the size of integrated circuits shrinks and the density of inputs/outputs increases, cross-talk between interconnections occurs and causes malfunction in the circuit. This can be corrected by the use of low dielectric constant ("low-K") materials to insulate the interconnects from their surroundings. Low-K interlayer dielectrics (particularly those below about 2.5) are generally weaker and more brittle than conventional dielectric materials and this fragility can also lead to fractures and cracks during thermal excursions or mechanical handling. To date there is a limit to techniques for achieving thinner electrical and electronic devices, which creates a need within the semiconductor industry to seek other avenues to reach miniaturization.

[0004] One such way is the reduction of the adhesive bond line between dies in a die stacking arrangement, which allows for the stacking of an increased number of dies in a given amount of vertical height. (At present, the die attach adhesive bond line is about 25 micron.)

[0005] Stacked die packaging has caused a shift to film adhesives and away from liquid die attach paste adhesives for die attach. The advantages of a film adhesive over a paste adhesive, when building a stack of multiple dies, are the elimination of separate attach cure steps for each of the individually placed dies, and sufficient mechanical strength and tack to hold six, eight or

more dies together in a stack prior to die attach cure, and, in some cases, sufficient strength to allow completion of wire bonding on the entire stack before die attach cure.

[0006] Processes for pyramid and shingle or staircase stacks use this advantage with the film adhesives by stacking all the dies first, then wire bonding all at one time at the same station. Attempting this process with a dispensable liquid or paste adhesive is not practical because of the potential for die shifting and misalignment of the die stack when the adhesive is not cured independently for each die as it is stacked.

[0007] Despite these advantages, film die attach adhesives are more expensive than liquid paste counterparts, they are difficult to obtain in a thickness of less than 0.005 microns, and they can cause placement voids if not handled properly.

[0008] It would be desirable to have a process by which a die attach adhesive bond line of less than 0.005 microns may be created without the expense and voiding issues of die attach adhesive films, but with sufficient strength to allow multiple die stacking and wire bonding on the entire stack before die attach cure.

SUMMARY OF THE INVENTION

[0009] This invention relates to a fast-setting two-part adhesive system that uses a minimal amount of adhesive to adhere semiconductors and their substrates. There is a reduction in bond line thickness when the minimal amount of adhesive is used, which then contributes to miniaturization. A semiconductor can be either a chip or a package; a package comprises at least one chip and one substrate. A substrate can be another chip or any rigid or flexible frame or carrier for a chip or for a package, such as, an interposer or a circuit board.

[00010] In one embodiment, the adhesive system comprises a first part, A, which is a low viscosity, self-leveling liquid that activates a cure mechanism on contact with the second part, B, with little or no heating; and a second part B, which is capable of being B-staged. Capable of being B-staged means that the adhesive can be heated or irradiated to a partial cure or to evaporate any solvent present, typically to the point that the adhesive after B-staging has no or low tack.

[00011] In other embodiments, the invention is a method for preparing an assembly of a semiconductor and a substrate, and in particular a semiconductor die stack prepared from a plurality of semiconductor dies.

[00012] In a further embodiment, the method comprises the steps of (1) providing (a) an adhesive system comprising a first part, A, which is a low viscosity, self-leveling liquid that activates a cure mechanism on contact with the second part, B, with little or no heating; and a second part B, which is capable of being B-staged, and (b) at least one semiconductor and one substrate; (2) dispensing part A on the top side of a substrate; (3) coating part B on the back side of a semiconductor and B-staging part B; (4) contacting the back side of the semiconductor with the B-staged part B to the part A adhesive on the top side of the substrate and spreading the part A adhesive to a combined adhesive layer with a thickness of $\leq$ 50 microns (preferably $\leq$ 5 microns); (5) allowing the part A and part B adhesives to react at room temperature, thereby partially curing; (6) repeating steps 2 through 5 as many times as needed to compose the assembly; and (7) subsequently, completing the curing of the part A and part B adhesives with heat.

[00013] In another embodiment, the method comprises (1) providing (a) an adhesive system comprising a first part, A, which is a low viscosity, self-leveling liquid that activates a cure mechanism on contact with the second part, B, with little or no heating; and a second part B, which is capable of being B-staged, and (b) at least one substrate and one semiconductor; (2) dispensing part A onto the top side of the substrate; (3) dispensing part B onto the part A adhesive on the top side of the substrate; (4) contacting the back side of the semiconductor with the top side of the substrate and spreading the part A and part B adhesives to a layer with a thickness of $\leq$ 50 microns (preferably $\leq$ 5 microns); (5) allowing the part A and part B adhesives to react at room temperature, thereby partially curing; (6) repeating steps 2 through 5 as many times as needed to compose the assembly; and (7) subsequently, completing the curing of the part A and part B adhesives with heat.

DETAILED DESCRIPTION OF THE INVENTION

[00014] The liquid part A is dispensed on the top of the substrate that is to come into contact with the back side of a semiconductor. Part A is typically dispensed in a pattern, such as, a dot, cross, X, snowflake, and the like). Part A has a thixotropic index in the range of 1 to 6 so that,

when later subjected to shear imposed by contact with a semiconductor having part B dispensed on it, it will flow and level over any topography on the substrate surface.

[00015] In one embodiment, part B is dispensed onto the back side of a semiconductor wafer using spraying, printing, spin coating or any other known method of coating. After coating, part B is B-staged by a method appropriate to the chemistry. The dispense is done to accomplish a level of approximately ≤ 50 microns, preferably ≤ 5 microns, thickness after B-staging. After B-staging, the wafer is diced into individual semiconductor dies. The B-staged part B on the back side of each of the semiconductor dies is then contacted to the part A adhesive on the substrate with sufficient pressure to cause capillary flow of the part A and ensure full coverage of part A over that part of the substrate desired. Because part A levels out on the substrate, void formations are prevented when the flat semiconductor die is placed on it using standard die attachment conditions of temperature (120 – 150°C), force (0.5 to 4.0 N), and time (1 to 1000 msecs).

[00016] In a further embodiment, part A is dispensed onto a substrate and part B is dispensed onto part A. In this embodiment, part B is not B-staged. The dispense volumes of A and B are calculated to achieve a cured thickness ≤ 50 microns (preferably ≤ 5 microns) . The back side of the semiconductor is then contacted to the combination of the part A and part B adhesive. Under standard placement conditions (120 – 150°C, 0.5 to 4.0 N, and 1 to 1000 msecs), there is sufficient pressure and time for parts A and B to mix.

[00017] In both embodiments, parts A and B after coming into contact begin curing and develop sufficient strength to withstand additional processing, such as, die stacking and subsequent wire bonding. Full cure is achieved during other heating steps, such as, at wire bond or molding.

[00018] The dispensing of the adhesive parts A and B can be effected by spraying, atomizing, blade coating, syringe dispensing, printing, jet printing, spin-coating, and laminating. In any of these application techniques, a thin, substantially uniform layer is applied to the semiconductor and/or substrate.

[00019] In another embodiment, this invention is a semiconductor assembly comprising a plurality of semiconductor dies that are stacked one on top of the other and bonded to each other using a two-part adhesive system, in which one part of the adhesive system was applied to the

top side of one die and the second part of the adhesive system was applied to the back side of another die, in which the two parts of the adhesive system are reactive with each other, and in which the two parts of the adhesive system were contacted together, thereby initiating a reaction and partial curing between the two parts of the adhesive system.

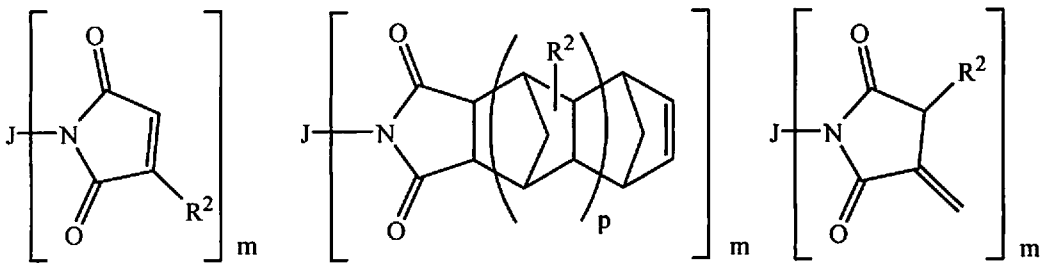
[00020] The two part adhesive is designed so that neither part will cure without contact with the other part, but will begin to cure immediately upon contact. Suitable chemistry pairs for two part systems are those that react with each other, for example, a curable compound with an activator or initiator for the curing. Examples are acrylate and peroxide; epoxy and amine; bismaleimide and peroxides or amines; cyanoacrylates and water (or primers/accelerators made of organic or inorganic bases).

[00021] The adhesive parts A and B are applied in thickness to yield a bond that after cure has a thickness in the range of 0.001 to 0.050 mm. In one embodiment, the cured bond thickness will be in the range of 0.001 to 0.005 mm.

[00022] The relative sizes of the semiconductor and substrate can be the same or different, and the alignment of the semiconductor chip and substrate can be similar or offset provided it allows bonding. The surface area of the semiconductor chip and substrate will be in the range of 1 mm^2 to 625 mm^2, and in one embodiment will be in the range of 30 mm^2 to 80 mm^2.

[00023] The adhesive system may be based on one or more of the following chemistries and a curing initiator for that chemistry. The chemistries include epoxy, episulfide, (meth)acrylate, cyanoacrylate, maleimide, nadimide, itaconimide, and isocyanate.

[00024] Suitable maleimide, nadimide or itaconimide compounds include, respectively, structures I, II, and III:



I II III

in which m is 1-15; p is 0-15; each R^2 independently is hydrogen or lower alkyl; J is a monovalent or a polyvalent organic moiety having sufficient length and branching to render the maleimide, nadimide and/or itaconimide compound a liquid. In one embodiment J is an organosiloxane or a hydrocarbyl, optionally containing heteroatoms (such as, oxygen, nitrogen, and sulfur). In some embodiments, p is zero (organic radical enclosed in parentheses is not present) and m is 1 to 6; in another embodiment, p is zero and m is 1 to 3. In those cases in which the J moiety contains heteroatoms or groups containing heteroatoms, the heteroatoms or groups are selected from the group consisting of -O-, -S-, -NR-, -O-C(O)-, -O-C(O)-O-, -O-C(O)-NR-, -NR-C(O)-, -NR-C(O)-O-, -NR-C(O)-NR-, -S-C(O)-, -S-C(O)-O-, -S-C(O)-NR-, -S(O)-, $-S(O)_2-$, $-O-S(O)_2-$, $-O-S(O)_2-O-$, $-O-S(O)_2-NR-$, -O-S(O)-, -O-S(O)-O-, -O-S(O)-NR-, -O-NR-C(O)-, -O-NR-C(O)-O-, -O-NR-C(O)-NR-, -NR-O-C(O)-, -NR-O-C(O)-O-, -NR-O-C(O)-NR-, -O-NR-C(S)-, -O-NR-C(S)-O-, -O-NR-C(S)-NR-, -NR-O-C(S)-, -NR-O-C(S)-O-, -NR-O-C(S)-NR-, -O-C(S)-, -O-C(S)-O-, -O-C(S)-NR-, -NR-C(S)-, -NR-C(S)-O-, -NR-C(S)-NR-, $-S-S(O)_2-$, $-S-S(O)_2-O-$, $-S-S(O)_2-NR-$, -NR-O-S(O)-, -NR-O-S(O)-O-, -NR-O-S(O)-NR-, $-NR-O-S(O)_2-$, $-NR-O-S(O)_2-O-$, $-NR-O-S(O)_2-NR-$, -O-NR-S(O)-, -O-NR-S(O)-O-, -O-NR-S(O)-NR-, $-O-NR-S(O)_2-O-$, $-O-NR-S(O)_2-NR-$, $-O-NR-S(O)_2-$, $-O-P(O)R_2-$, $-S-P(O)R_2-$, $-NR-P(O)R_2-$, where each R is independently hydrogen, alkyl or substituted alkyl.

[00025] A semiconductor package so formed includes a semiconductor chip bonded to a substrate by a two-step adhesive system as described in this specification.

CLAIMS

1. An adhesive system comprising:

a first part, A, that is a low viscosity, self-leveling liquid that activates a cure mechanism on contact with the second part, B, with little or no heating; and

a second part B, that is capable of being B-staged.

2. The adhesive system of claim 1 in which

part A adhesive is selected from the group consisting of peroxide; amine; water; and primers/accelerators made of organic or inorganic bases; and

part B adhesive is selected from the group consisting of epoxy, episulfide, (meth)acrylate, cyanoacrylate, maleimide, nadimide, itaconimide, and isocyanate,

provided that part A part B can react together.

3. A method for preparing an assembly of a semiconductor and a substrate comprising the steps of:

(1) providing (a) an adhesive system comprising a first part, A, that is a low viscosity, self-leveling liquid that activates a cure mechanism on contact with the second part, B, with little or no heating; and a second part B, that is capable of being B-staged, and (b) at least one semiconductor and one substrate;

(2) dispensing part A on the top side of a substrate;

(3) coating part B on the back side of a semiconductor die and B-staging part B;

(4) contacting the back side of the die with the B-staged part B to the part A adhesive on the top side of the substrate and spreading the part A adhesive resulting in a total adhesive layer with a thickness of $\leq$ 50 microns (preferably $\leq$ 5 microns);

(5) allowing the part A and part B adhesives to react at room temperature, thereby partially curing;

(6) repeating steps 2 through 5 as many times as needed to compose the assembly; and

(7) subsequently, completing the curing of the part A and part B adhesives with heat and/or irradiation.

4. A method for preparing an assembly of a semiconductor and a substrate comprising the steps of:

(1) providing (a) an adhesive system comprising a first part, A, that is a low viscosity, self-leveling liquid that activates a cure mechanism on contact with the second part, B, with little or no heating; and a second part B, that is capable of being B-staged, and (b) at least one substrate and one semiconductor die;

(2) dispensing part A onto the top side of the substrate;

(3) dispensing part B onto the part A adhesive on the top side of the substrate;

(4) contacting the back side of the semiconductor die with the top side of the substrate and spreading the part A and part B adhesives resulting in a total adhesive layer with a thickness of $\leq$ 50 microns (preferably $\leq$ 5 microns);

(5) allowing the part A and part B adhesives to react at room temperature, thereby partially curing;

(6) repeating steps 2 through 5 as many times as needed to compose the assembly; and

(7) subsequently, completing the curing of the part A and part B adhesives with heat and/or irradiation.

5. A semiconductor assembly comprising a plurality of semiconductor dies that are stacked one on top of the other and bonded to each other using a two-part adhesive system, in which one part of the adhesive system was applied to the top side of one die and the second part of the adhesive system was applied to the back side of another die, in which the two parts of the adhesive system are reactive with each other, and in which the two parts of the adhesive system were contacted together, thereby initiating a reaction and partial curing between the two parts of the adhesive system.

6. The semiconductor assembly according to claim 6 in which the stack of semiconductor dies is adhered to a substrate using the two-part adhesive system.