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COMPOSITE FILM AND LEAD FRAME WITH COMPOSITE FILM ATTACHED

BACKGROUND OF THE INVENTION



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1. Field of the invention

The present invention relates to a composite film for use in semiconductor packaging of LOC (Lead on Chip), COL (Chip on Lead), and composite lead frames with heat sinks attached, and a lead frame to which the composite film is attached.

2. Description of the Prior Art

For bonding chips to lead frames to establish LOC or COL structures or for bonding inner leads to heat dissipators to form composite lead frames with heat sinks attached, a composite film in which a base film is coated with an adhesive is used.

On the whole, for application to a lead frame, a composite film is punched out and the bonding elements thus obtained are pressed against required parts of the lead frames. Upon punching high normal stress and shear stress appear in forms of elongation and compression on the composite film, so that burrs or flashes are generated as powders and threads at the edge of the composite film punched. These burrs or flashes cause a decrease in the yield and

productivity of the lead frames with composite films attached, as well as having fatal influence on the reliability of the semiconductor package chips.

U. S. Pat. Nos. 5,593,774 and 5,998,020 disclose improvements in which the composite films employ a base film having such an edge tearing resistance defined within a certain range as to suppress the occurrence of burrs and flashes at the edge of the composite films upon punching.

Actually, when punching composite films over lead frames, burrs and flashes are generated in significant quantities on the adhesives as well as the base films. Therefore, as suggested in the prior art, mere limitation of the edge tearing resistance of the base film is not of practical use.

SUMMARY OF THE INVENTION

Leading to the present invention, the intensive and thorough research into the occurrence of burrs and flashes upon punching composite films, conducted by the present inventors, resulted in the finding that the concentrated stress (modulus of elasticity x modulus of strain) generated upon punching is exerted onto the interface between the base film and adhesive layer of a composite film, giving different strains to the components of the composite film, respectively,

and a modification of the elastic moduli of the composite film and the base film, in conjunction with the interfacial adhesion strength between the base film and the adhesive, can effectively suppress the occurrence of burrs and splashes at the edge of the composite films upon punching.

Therefore, it is an object of the present invention to provide a composite film for semiconductor packaging, which has such an excellent punching capability that no burrs/flashs are formed at the punched edges.

It is another object of the present invention to provide a lead frame with composite film attached to required portions of the lead frame, with which highly reliable semiconductor packages can be produced at high yield and productivity.

In one aspect of the present invention, there is provided a composite film, comprising a base film coated with an adhesive, in which the elastic moduli of the composite film and the base film and the interfacial adhesion strength between the base film and the adhesive satisfy the following formulas 1 and 2:

$$R = E/E_B \quad 0.5 \leq R \leq 1.0 \quad [1]$$

$$F_{AD} \geq 150/R + 300 \quad [2]$$

is low, higher similarity in elastic modulus between the base film and the composite film causes the occurrence of burrs and splashes to a lesser extent. This is because there is generated a larger difference in strain modulus between the base film and the composite film upon punching as the gap between their elastic moduli is greater. In other words, the larger the difference in elastic modulus between the base film and the composite film is, the larger the difference between the strains exerted on the films is and the higher the frequency of the interfacial delamination is.

In order to reduce the concentrated stress upon punching, there have been made various instrumental adjustments including the adjustment of a clearance of a punching tool. However, the present invention is based on the finding that the occurrence of the burrs and splashes is closely related to the interfacial adhesion strength between the base film and the adhesive, and to the elastic moduli of the base film and the composite film.

A composite film for use in semiconductor packaging according to the present invention has a structure in which an adhesive is laminated on a base film, characterized in that the elastic moduli of the composite film and the base film and the interfacial adhesion strength between the base film and the adhesive satisfy the following formulas 1 and 2:

$$R = E/E_B \quad 0.5 \leq R \leq 1.0 \quad [1]$$

$$F_{AD} \geq 150/R + 300 \quad [2]$$

wherein E and E_B , expressed by the unit GPa (10^9N/m^2), are elastic moduli of the composite film and the base film, respectively, and F_{AD} , expressed by the unit gf/10 mm, is an interfacial adhesion strength between the base film and the adhesive.

The composite film of the present invention has a base film with an adhesive on both sides. Typically, the composite film is prepared by coating an adhesive on both sides of a base film and drying it. An adhesive may be applied to one side of a base film, dried and then applied to the other side of the base. Alternatively, an adhesive may be coated on both sides of a base film simultaneously or in order and then dried. Also, different adhesives may be applied to both sides of a base film.

Suitable for use in the base film of the present invention is a heat-resistant, engineering plastic, examples of which include polyimide, polyamide, polysulfone, polyphenylene sulfide, and polyarylate, polyethersulfone. The thickness of the base film is preferably on the order of 10-150 μm and more preferably on the order of 20-100 μm .

Since the composite film is used in a semiconductor packaging process which is typically conducted at as high as

or higher than 300 °C, the base film is required to be high in glass transition temperature and have low coefficients of thermal expansion. Preferred is a base film that has a glass transition temperature of 250 °C or higher and a coefficient of thermal expansion of 30 ppm/°C or less as measured according to ASTM D-691-91.

To achieve a high adhesion strength between the base film and the adhesives, the base film may be subjected to various surface treatments, which are exemplified by chemical treatment such as alkali treatment and silane coupling agent treatment, and physical treatment such as sand blasting, plasma treatment and corona treatment. Also, it is possible to use, in combination, two or more treatments which are the most suitable for the adhesives and base film used. Of various surface treatments, plasma treatment and sand blasting are the most effective in terms of the improvement in adhesion strength.

Another technique for increasing the adhesion strength between the base film and the adhesives is coextrusion. An adhesive material with a glass transition temperature of 150-300 °C is coextruded, along with the base film, to a thickness of 0.1-5 µm on one side or both sides of the base film. Preferably, the glass transition temperature of each of the adhesive layers thus formed is at least 30 °C lower than that of the base film. More preferable is a thinner

coextrusion thickness.

Increasing the adhesion strength between the base film and the adhesives may resort to the intercalation of a primer coating between the base film and the adhesives. In this regard, a primer with a glass transition temperature of 200 °C or less is coated to a thickness of 1 μm or less and preferably to a thickness of 0.2 μm or less on both sides of the base film, in advance of the application of the adhesives. The glass transition temperature of the primer is preferably 50 °C lower than that of the base film.

In addition, the drying temperature after the application of the adhesives and/or the solvent used may affect the adhesion strength.

Suitable in the present invention is an adhesive, based on a heat-resistant, thermoplastic resin, with a glass transition temperature of 135-250 °C. Preferably, the thermoplastic resin is a polyimide or polyamide with a weight average molecular weight of 15,000 to 100,000. The term "polyimide" as used herein means not only polyimide, but also any other resin containing imide bonds, such as polyamideimide, polyesterimide or polyetherimide.

If the glass transition temperature of the heat-resistant adhesive is lower than 135 °C, inner leads may be moved during a wire bonding process. On the other hand, higher than 250 °C of the glass transition temperature of the

heat-resistant adhesive requires too high a temperature for bonding leads or chips and too long a bonding time. When a thermoplastic adhesive with a weight average molecular weight less than 15,000 is employed, the punch may be significantly contaminated with the adhesive. On the other hand, a thermoplastic adhesive with a weight average molecular weight greater than 100,000 suffers the problem of being too viscous upon coating.

To adjust the elastic modulus of the adhesive, organic or inorganic particles may be used. In the case of using inorganic particles, a coupling agent may be also added to increase the bonding force between the inorganic particles and the heat-resistant adhesive. Examples of useful coupling agents include; silane-based agents such as vinyltrimethoxysilane, vinyltriethoxysilane and γ -methacryloxy-propyltrimethoxysilane; and coupling agents such as titanates, aluminum chelates and zircoaluminates.

An adhesive varnish is prepared by dissolving a thermoplastic resin in an organic solvent. Also, the adhesive varnish may be of a precursor structure which can be converted into a heat-resistant adhesive by a heat treatment after coating. For instance, polyamic acid is converted into a polyimide by a suitable heat treatment.

A small amount of a surfactant may be helpful in increasing the adhesive's coatability, thereby making the

surface of the coating more smooth. Also, addition of a surfactant may make a contribution to the wetting property of the adhesive to the base film, resulting in an improvement in the adhesion strength between the adhesive and the base film.

For use in applying the adhesive varnish to the base film, a coater is used, examples of which include, but are not limited to, a comma type, a reverse type, and a die type, with preference for a die type coater in an aspect of preventing the occurrence of external impurities and bubbles.

As a drying means for drying the polyimide varnish after coating the adhesive varnish onto one side or both sides of the base film, there is used a roll carrier in which a roll is moved with the coated film loaded. In the case of coating the adhesive varnish onto both sides of the base film, the drying means takes a floating carrier manner in which the film is carried without contact with a roll. A process comprising coating an adhesive on both sides of a base film simultaneously or sequentially and then drying it is favorable for productivity and workability, but requires a floating carrier. A close examination of various factors including initial drying temperature, wind direction, etc., must be made in order to define an optimal drying process.

Removal of the solvent of the adhesive varnish from the coated film requires gradual drying at 50-250 °C over 3-20 min. Rapid heating is highly apt to cause the generation of

bubbles in the adhesive layers, resulting in defectives upon bonding to lead frames and thus poor reliability of the semiconductor packages obtained. Thus, in order to form a coating layer free of bubbles, the drying temperature is preferably increased as slowly as possible until 90 % of the solvent of the adhesive coated on the base film is removed.

A preferable thickness of the adhesive layer formed on each side of the base film falls within the range of 5-50 μm . If the adhesive layer is less than 5 μm in thickness, leads may show low adhesion strength upon bonding to the lead frames.

In another aspect, the present invention pertains to a lead frame to which the composite film is attached.

The composite film of the present invention is punched out and attached to a lead frame. The lead frame may have any structure. In a typical structure, a lead frame has a composite film attached to a predetermined portion thereof, with inner and outer lead portions being connected to a semiconductor chip and connected to external circuits, respectively. A lead frame with composite film attached may be obtained by punching the composite film onto a lead frame body. Excellent reliability is found in semiconductor packages produced by taking advantage of the lead frames with composite film of the present invention attached.

To effectively bond the composite film to lead frames, for example, the composite film is placed over a lead frame body, with one adhesive layer facing the lead frame, and punched into strips which are continuously pressed against predetermined portions of the lead frame body at a pressure of 0.1 to 10 MPa for 0.1 to 5 seconds. The forms of the punched-out composite film strips vary with the forms of chips, the locations of chips on lead frames or the designs of lead frames. At the time of punching, the lead frame body is generally heated to 200 to 500 °C.

It was experimentally found that when being punched out, the composite film satisfying the formulas 1 and 2 did not generate burrs and flashes which would, if formed around the punched strips, adhere to bonding areas of lead frames to interfere with wire bonding.

Having generally described this invention, a further understanding can be obtained by reference to certain specific examples which are provided herein for purposes of illustration only and are not intended to be limiting unless otherwise specified.

To measure physical properties of composite films in the following examples and comparative examples, JIS K 7121 was adopted for glass transition temperature, ASTM D 882 for elastic modulus at 25 °C, and a 180 °C peeling experiment for interfacial adhesion strength (measured temperature: 25 °C,

peel speed 50 mm/min).

EXAMPLE 1

After being treated with plasma, each side of a polyimide film 0.75 μm thick, having a glass transition temperature of 300 $^{\circ}\text{C}$ or higher, a coefficient of thermal expansion of 12 ppm/ $^{\circ}\text{C}$, and an edge tearing strength of 77 kgf/20 mm, was coated with a polyimide adhesive (weight average molecular weight 50.000, $M_w/M_n=2.1$) having a glass transition temperature of 205 $^{\circ}\text{C}$, at a thickness of 15.0 μm , and dried, to produce a composite film 105 μm thick in total, which was measured to have an elastic modulus ratio of 0.80 compared to the base film and an interfacial adhesion strength of 620 gf/10 mm. The composite film was placed over a nickel alloy 42 lead frame heated to 380 $^{\circ}\text{C}$, and was then punched with the aid of a puncher to give strips which were then continuously pressed against the lead frame for 0.6 sec at a pressure of 10 MPa, to produce a lead frame with a composite film attached. Neither burrs nor flashes were generated at the edges of the punched composite film, as observed under a microscope.

COMPARATIVE EXAMPLE 1

A composite film was produced in the same manner as in Example 1, with the modification that a polyimide film 0.75 μm thick, having a glass transition temperature of 300 $^{\circ}\text{C}$ or higher, a coefficient of thermal expansion of 12 ppm/ $^{\circ}\text{C}$, and an edge tearing strength of 77 kgf/20 mm, was not treated with plasma. The composite film was measured to have an elastic modulus ratio of 0.8 compared to the base film, and an interfacial adhesion strength of 420 gf/10 mm. Also, the composite film was attached to a lead frame as in Example 1. Burrs and flashes were observed by microscopic examination of the edges of the punched composite film.

EXAMPLE 2

Immediately after a polyimide film 50 μm thick, having a glass transition temperature of 300 $^{\circ}\text{C}$ or higher, a coefficient of thermal expansion of 12 ppm/ $^{\circ}\text{C}$ and an edge tearing strength of 44 kgf/20 mm was subjected to corona treatment, a polyimide adhesive (weight average molecular weight 50,000, $M_w/M_n=2.1$) having a glass transition temperature of 157 $^{\circ}\text{C}$ was coated to a thickness of 15.0 μm on each side of the polyimide film, and dried to produce a composite film 80 μm thick in total, which was measured to have an elastic modulus ratio of 0.75 compared to the base film and an interfacial adhesion strength of 535 gf/10 mm.

The composite film was placed over a nickel alloy 42 lead frame heated to 380 °C, and was then punched with the aid of a puncher to give strips which were then continuously pressed against the lead frame for 0.6 sec at a pressure of 10 MPa, to produce a lead frame with a composite film attached. Neither burrs nor flashes were found at the edges of the punched composite film, as observed under a microscope.

COMPARATIVE EXAMPLE 2

On each side of a polyimide film 50 μm thick having a glass transition temperature of 300 °C or higher, a coefficient of thermal expansion of 12 ppm/°C and an edge tearing strength of 47 kgf/20 mm, a polyimide adhesive (weight average molecular weight 50,000, $M_w/M_n=2.1$) with a glass transition temperature of 205 °C was coated to a thickness of 15.0 μm , and dried to produce a composite film 80 μm thick in total, which was measured to have an elastic modulus ratio of 0.77 compared to the base film and an interfacial adhesion strength of 450 gf/10 mm. The composite film was placed over a nickel alloy 42 lead frame heated to 380 °C, and was then punched with the aid of a puncher to give strips which were then continuously pressed against the lead frame for 0.6 sec at a pressure of 10 MPa, to produce a lead frame with a composite film attached. Burrs and flashes

were found at the edges of the punched composite film, as observed under a microscope.

EXAMPLE 3

On each side of a polyimide film 50 μm thick having a glass transition temperature of 300 $^{\circ}\text{C}$ or higher, a coefficient of thermal expansion of 10 ppm/ $^{\circ}\text{C}$ and an edge tearing strength of 40 kgf/20 mm, a polyimide adhesive (weight average molecular weight 35,000, $M_w/M_n=2.1$) with a glass transition temperature of 155 $^{\circ}\text{C}$ was coated to a thickness of 25.0 μm , and dried to produce a composite film 100 μm thick in total, which was measured to have an elastic modulus ratio of 0.57 compared to the base film and an interfacial adhesion strength of 610 gf/10 mm. The composite film was placed over a nickel alloy 42 lead frame heated to 320 $^{\circ}\text{C}$, and was then punched with the aid of a puncher to give strips which were then continuously pressed against the lead frame for 0.6 sec at a pressure of 10 MPa, to produce a lead frame with a composite film attached. Neither burrs nor flashes were found at the edges of the punched composite film, as observed under a microscope.

COMPARATIVE EXAMPLE 3

On each side of a polyimide film 50 μm thick having a glass transition temperature of 300 $^{\circ}\text{C}$ or higher, a coefficient of thermal expansion of 10 ppm/ $^{\circ}\text{C}$ and an edge tearing strength of 55 kgf/20 mm, a polyimide adhesive (weight average molecular weight 35,000, $M_w/M_n=2.1$) with a glass transition temperature of 155 $^{\circ}\text{C}$ was coated to a thickness of 25.0 μm , and dried to produce a composite film 100 μm thick in total, which was measured to have an elastic modulus ratio of 0.45 compared to the base film and an interfacial adhesion strength of 650 gf/10 mm. The composite film was placed over a nickel alloy 42 lead frame heated to 400 $^{\circ}\text{C}$, and was then punched with the aid of a puncher to give strips which were then continuously pressed against the lead frame for 0.6 sec at a pressure of 10 MPa, to produce a lead frame with a composite film attached. A microscopic examination showed that burrs and flashes were not generated at the edges of the punched composite film.

COMPARATIVE EXAMPLE 4

On each side of a polyimide film 50 μm thick having a glass transition temperature of 300 $^{\circ}\text{C}$ or higher, a coefficient of thermal expansion of 10 ppm/ $^{\circ}\text{C}$ and an edge tearing strength of 40 kgf/20 mm, a polyimide adhesive (weight average molecular weight 50,000, $M_w/M_n=2.1$) with a

glass transition temperature of 155 °C was coated to a thickness of 25.0 μm , and dried to produce a composite film 100 μm thick in total, which was measured to have an elastic modulus ratio of 0.57 compared to the base film and an interfacial adhesion strength of 510 gf/10 mm. The composite film was placed over a nickel alloy 42 lead frame heated to 320 °C, and was then punched with the aid of a puncher to give strips which were then continuously pressed against the lead frame for 0.6 sec at a pressure of 10 MPa, to produce a lead frame with a composite film attached. A microscopic examination showed that burrs and flashes were generated at the edges of the punched composite film.

EXAMPLE 4

On each side of a polyimide film 25 μm thick having a glass transition temperature of 300 °C or higher, a coefficient of thermal expansion of 10 ppm/°C or less and an edge tearing strength of 15 kgf/20 mm, a polyimide adhesive (weight average molecular weight 35,000, $M_w/M_n=2.5$) with a glass transition temperature of 155 °C was coated to a thickness of 15.0 μm , and dried to produce a composite film 55 μm thick in total, which was measured to have an elastic modulus ratio of 0.55 compared to the base film and an interfacial adhesion strength of 625 gf/10 mm. The composite

film was placed over a nickel alloy 42 lead frame heated to 300 °C, and was then punched with the aid of a puncher to give strips which were then continuously pressed against the lead frame for 0.6 sec at a pressure of 10 MPa, to produce a lead frame with a composite film attached. Neither burrs nor flashes were found at the edges of the punched composite film, as observed under a microscope.

COMPARATIVE EXAMPLE 5

Each side of a polyimide film 50 μm thick, having a glass transition temperature of 300 °C or higher, a coefficient of thermal expansion of 10 ppm/°C or less and an edge tearing strength of 47 kgf/20 mm, was coated with a polyimide adhesive (weight average molecular weight 50,000, $M_w/M_n=2.1$), having a glass transition temperature of 205 °C, at a thickness of 15.0 μm , and dried to produce a composite film 55 μm thick in total, which was measured to have an elastic modulus ratio of 0.52 compared to the base film and an interfacial adhesion strength of 500 gf/10 mm. The composite film was placed over a nickel alloy 42 lead frame heated to 380 °C, and was then punched with the aid of a puncher to give strips which were then continuously pressed against the lead frame for 0.6 sec at a pressure of 10 MPa, to produce a lead frame with a composite film attached.

Burrs and flashes were found at the edges of the punched composite film, as observed under a microscope.

EXAMPLE 5

Each side of a polyimide film 25 μm thick, having a glass transition temperature of 300 $^{\circ}\text{C}$ or higher, a coefficient of thermal expansion of 10 ppm/ $^{\circ}\text{C}$ or less and an edge tearing strength of 27 kgf/20 mm, was coated with a polyimide adhesive (weight average molecular weight 35,000, $M_w/M_n=2.5$) having a glass transition temperature of 125 $^{\circ}\text{C}$ at a thickness of 0.1 μm , then with a polyimide adhesive (weight average molecular weight 35,000, $M_w/M_n=2.5$) at a thickness of 15 μm , and then dried to produce a composite film 55.2 μm thick in total, which was measured to have an elastic modulus ratio of 0.52 compared to the base film and an interfacial adhesion strength of 700 gf/10 mm. The composite film was placed over a nickel alloy 42 lead frame heated to 300 $^{\circ}\text{C}$, and was then punched with the aid of a puncher to give strips which were then continuously pressed against the lead frame for 0.6 sec at a pressure of 10 MPa, to produce a lead frame with a composite film attached. Neither burrs nor flashes were observed by microscopic examination of the edges of the punched composite film.

The physical properties of composite films prepared in

the above examples and comparative examples are summarized in Table 1, below.

TABLE 1

Exmp. No.	R (Ec/Eb)	F _{AD} (gf/10mm)	Burr/Splash	Delamination
1	0.80	620	None	None
C.1	0.80	420	Generated	Generated
2	0.75	535	None	None
C.2	0.70	450	Generated	None
3	0.57	610	None	None
C.3	0.45	650	Generated	None
C.4	0.57	510	Generated	None
4	0.55	625	None	None
C.5	0.52	500	Generated	Generated
5	0.52	700	None	None

As apparent from the data of Table 1, the composite film of the present invention is excellent in terms of punching capability such that not only are no burrs and flashes formed at the punched edges, but also delamination does not occur. Therefore, by using lead frames with the composite film attached, there can be produced semiconductor packages of high reliability.

The present invention has been described in an illustrative manner, and it is to be understood that the terminology used is intended to be in the nature of description rather than of limitation. Many modifications

and variations of the present invention are possible in light of the above teachings. Therefore, it is to be understood that within the scope of the appended claims, the invention may be practiced otherwise than as specifically described.

CLAIMS

1. A composite film, comprising a base film coated with an adhesive, in which the elastic moduli of the composite film and the base film and the interfacial adhesion strength between the base film and the adhesive satisfy the following formulas 1 and 2:

$$R = E/E_B \quad 0.5 \leq R \leq 1.0 \quad [1]$$

$$F_{AD} \geq 150/R + 300 \quad [2]$$

wherein E and E_B , expressed by the unit GPa (10^9N/m^2), are elastic moduli of the composite film and the base film, respectively, and F_{AD} , expressed by the unit gf/10 mm, is an interfacial adhesion strength between the base film and the adhesive.

2. The composite film as set forth in claim 1, wherein the base film has a glass transition temperature of 250 °C or higher and a coefficient of thermal expansion of 30 ppm/°C or less.

3. The composite film as set forth in claim 1, wherein the adhesive ranges from 135 to 250 °C in glass transition temperature and from 15,000 to 100,000 in weight average

molecular weight.

4. The composite film as set forth in claim 1, wherein the adhesive is coated to a thickness of 5-50 μm on one side or both sides of the base film.

5. The composite film as set forth in claim 1, wherein the base film is made of a polymer selected from the group consisting of polyimide, polyamide, polysulfone, polyphenylene sulfide, polyetheretherketone, polyarylate, and combinations thereof.

6. The composite film as set forth in claim 1, wherein the base film is made of polyimide or polyamide.

7. A lead frame with a composite film attached, said composite film comprising a base film coated with an adhesive, in which the elastic moduli of the composite film and the base film and the interfacial adhesion strength between the base film and the adhesive satisfy the following formulas 1 and 2:

$$R = E/E_B \quad 0.5 \leq R \leq 1.0 \quad [1]$$

$$F_{AD} \geq 150/R + 300 \quad [2]$$

wherein E and E_B , expressed by the unit GPa (10^9N/m^2), are elastic moduli of the composite film and the base film, respectively, and F_{AD} , expressed by the unit gf/10 mm, is an interfacial adhesion strength between the base film and the adhesive.