# DIE BONDING

This invention relates to die bonding.

The use of dies with die attach films (DAF) transported on a base material carrier tape to provide direct bonding of dies to a die pad is well known in the microelectronics industry. On picking up a singulated die from the carrier tape, an adhesive layer is carried on a lower surface of the die and, after placing the die on a die pad, the adhesive layer is cured by heating to adhere the die to the die pad. A cross-section of such a structure 10 of a wafer 11 mounted on a DAF adhesive layer 12 and carrier base 13 before dicing is shown on Figure 1. The wafer 11 and the DAF 12 are singulated to form a singulated die and DAF 15, as shown in Figure 2, as in dicing a wafer without a DAF, by cutting a channel 14 through the wafer and DAF and leaving a shallow trench 16 in the base film carrier tape 13.

Known dicing of a wafer with a DAF uses a mechanical saw but using higher speed revolution of a dicing saw blade than used to dice a wafer without a DAF, to avoid the adhesive layer adhering to the saw blade. However, such high-speed mechanical cutting tends to cause delamination of the DAF and base film and to create burrs, resulting in yield loss. Burrs created by the mechanical saw can be millimetre long strands of the adhesive layer. These strands may come into contact with an upper surface of the die, either by being carried to the upper surface by the saw blade or in subsequent handling and, in particular, may interfere with a die attach process. In some cases, adhesive is placed on individual die after mechanical saw dicing in order to avoid the problems associated with delamination when using a DAF and creation of burrs. This process is extremely time consuming and inefficient.

It is an object of the present invention at least to ameliorate the aforesaid difficulties in the prior art.

According to a first aspect of the present invention there is provided a method of die bonding comprising the steps of: providing a structure comprising a wafer substrate separated from carrier base means by an adhesive layer; laser machining through the wafer substrate and through the adhesive layer no more than at most to scribe the carrier base means to form a singulated die with an attached singulated

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adhesive layer; curing the structure to release the attached singulated adhesive layer from the carrier base means; picking and placing the die and attached singulated adhesive layer on a die pad; and curing the attached singulated adhesive layer to adhere the die to the die pad.

Advantageously, the step of providing a structure comprises providing an adhesive layer adhered to the carrier base means by a first adhesive and the step of curing the structure comprises curing the first adhesive.

Preferably, the step of laser machining comprises laser machining the wafer substrate using a first laser beam with a first machining profile of selected laser pulse power, laser pulse repetition rate, laser pulse width, laser beam scanning speed and laser wavelength; using a second laser beam with a second such machining profile to machine the adhesive layer and using a third laser beam with a third such machining profile to machine the carrier base means such that a speed of machining is maximised while providing a predetermined quality of singulated dies without substantial delamination of the adhesive layer and the carrier base means or substantial production of burrs.

Conveniently, at least two of the first machining profile, the second machining profile and the third machining profile are a same machining profile.

Advantageously, the step of curing the structure comprises curing with ultraviolet light.

Conveniently, the step of curing the attached singulated adhesive layer comprises heat curing the adhesive layer.

Advantageously, the step of machining the wafer substrate comprises machining a blind via in the wafer substrate or a via through the wafer substrate and a die attach film.

Preferably, the step of laser machining includes a further step, after laser machining, of washing the structure to remove accumulated laser machining debris from the singulated die.

Conveniently, the step of providing a structure comprises providing a structure having a protective film to protect the structure from debris produced during laser

machining and the step of washing the structure comprises removing the protective film and accumulated debris thereon.

Advantageously, the step of providing a structure comprises providing a structure having a wafer substrate less than 800 microns thick.

Preferably, the step of laser machining comprises providing an assist gas environment for laser machining.

Advantageously, the step of providing an assist gas environment comprises providing a gas environment in which photo-dissociation produces active radicals.

Preferably, the step of providing a gas environment reduces deposition of solid machining debris around a laser-machining site.

Conveniently, the carrier base means is one of: a dicing tape, an inflexible tape suitable for thin wafer dicing or backgrinding; and a glass or other transparent solid.

Advantageously, the step of providing a structure comprises providing a structure including a wafer substrate separated facedown from substantially inflexible transparent backgrinding tape means by the adhesive layer and the step of laser machining is performed subsequent to backgrinding the wafer substrate.

Alternatively, the step of picking and placing the die and attached singulated adhesive layer comprises picking and placing the die and attached singulated adhesive layer on another die to form a multistack die package.

According to a second aspect of the present invention, there is provided die bonding apparatus comprising: laser machining means for machining a wafer substrate and an adhesive layer attached to the wafer substrate and for no more than at most scribing underlying carrier base means to form a singulated die with a singulated adhesive layer; first curing means for curing the carrier base means to release the singulated adhesive layer from the carrier base means; pick and place means for picking the singulated die and adhesive layer from the carrier base means and placing the singulated die and adhesive layer on die pad means and second curing means for curing the singulated adhesive layer of the singulated die to adhere the singulated die to the die pad means.

Preferably, the laser machining means comprises: laser source means for providing a pulsed laser beam; laser beam scanning means; and control means for

controlling at least one of laser pulse energy, laser wavelength, laser repetition frequency, laser pulse width, laser beam scanning speed and a number of scans by the pulsed laser beam.

Advantageously, the laser machining means further comprises memory means for storing a machining profile of at least one of laser pulse energy, laser wavelength, laser repetition frequency, laser pulse width, laser beam scanning speed and a number of scans by the pulsed laser beam, for use by the control means.

Preferably, the first curing means comprises ultraviolet curing means.

Advantageously, the second curing means comprises heat curing means.

Conveniently, the die bonding apparatus includes washing means for washing laser machining debris from the singulated die.

Advantageously, the wafer substrate is provided with a protective film to protect the wafer substrate from laser machining debris, and the washing means is arranged to remove the protective film from the singulated die.

Conveniently, the die bonding apparatus is adapted for carrier base means which is one of: a dicing tape, an inflexible tape suitable for thin wafer dicing or backgrinding; and a glass or other transparent solid.

Advantageously, the die bonding apparatus is adapted for machining a structure comprising a wafer substrate separated facedown from substantially inflexible transparent backgrinding tape means by the adhesive layer.

The invention will now be described, by way of example, with reference to the accompanying drawings in which:

Figure 1 is a vertical cross-section of a known wafer, adhesive layer and carrier film structure;

Figure 2 is the vertical cross-section of Figure 1 after dicing;

Figure 3 is a perspective schematic view of laser machining, according to the invention, of the wafer of the structure of Figure 1;

Figure 4 is a perspective schematic view of laser machining, according to the invention, of the adhesive layer of the structure of Figure 1; and

Figure 5 is a perspective schematic view of laser scribing, according to the invention, of the carrier film of the structure of Figure 1.

In the Figures like reference numerals denote like parts.

Referring to the Figures, using a laser beam 31, 32, 33 to dice a structure 10 comprising a wafer 11 with a DAF 12 mounted on a carrier base 13, it is possible to machine through the wafer and the DAF without causing substantially any delamination of the adhesive layer 12 and carrier base 13 or causing substantially any burrs, from, for example, the adhesive layer 12.

The carrier base 13 may be, for example, any known carrier film as used in industry, a substantially inflexible support used in thin film dicing or backgrinding or a glass or other transparent solid. Alternatively, the carrier base may an inflexible transparent backgrinding tape with the wafer mounted facedown on the backgrinding tape for dicing after a backgrinding process.

Referring to Figures 3 to 5, by controlling critical machining parameters of pulse power, pulse repetition rate, pulse width, laser wavelength and laser beam scan speed of a laser beam 31, 32, 33, it is possible to dice the wafer 11 and the DAF 12 while only scribing the carrier base 13 and perform complete singulation without problems of delamination and burr. These critical parameters of the laser beam can be optimised for each layer 11, 12, 13 to use a laser beam 31, 32, 33 with a respective different cutting strategy or machining profile for each of the three layers, to maximise machining speed while obtaining a required quality of machined die.

In this case, each layer 11, 12, 13 is scanned with a predetermined number of one or more scans with predetermined machining parameters dependent on a known thickness and known machinability of material of the layer. Where the thickness and/or material are unknown, a nature of a material being machined and interfaces between layers may be determined by observation of machining characteristics. Alternatively, the parameters may be determined empirically from samples of wafers to be machined.

In order to optimise efficiency of singulation, all machining of the wafer may be performed before all machining of the adhesive layer, which may be performed before all machining of the carrier base or each dice lane may be completely machined in turn, or a combination of such strategies may be used.

Alternatively, where machining quality of the individual layers may be sacrificed for overall processing speed, a single cutting strategy or machining profile is used to cut two or all three layers 11, 12, 13, using an optimised machining profile for a combination of such layers.

A known translation table may be provided to allow access of the laser beam to all parts of the wafer to be machined.

Although the laser machining process has been described as conveniently scribing the carrier base, it will be understood that alternatively laser machining may be halted at an interface of the adhesive layer and carrier base, without significantly, or at all, scribing the carrier base.

The laser machining process of the invention has been found to be suitable for wafers up to 800μm thick.

This laser machining process is suitable not only for dicing wafers but also for machining via structures in wafers with a DAF.

The laser machining process of the invention may optionally be performed, in a known manner, in an active gas environment or in a gas environment where photo-dissociation produces active radicals. Laser machining in a suitable active gas environment changes a chemical nature of debris produced. In particular, under suitable conditions, a chemical reaction between a suitable active gas and the debris while in a molten state results in removal of debris in gaseous form, with consequentially reduced deposition of solid debris around a laser machining site.

Following singulation, the singulated die may be washed to remove debris produced during laser machining, before curing of the DAF. Alternatively, the wafer substrate may be protected from such debris by a protective film and the protective film and accumulated debris may be removed by washing.

Once the structure has been machined, die bonding of a singulated die proceeds substantially as in the prior art. The carrier base 13, or an adhesive, not shown, between the carrier base, tape or film and the adhesive layer, is cured with ultraviolet light to release the singulated die 15 from the carrier tape or film 13. The singulated die 15 is picked from the carrier base, tape or film 13 and placed on a die pad. Alternatively, the die 15 may be picked and placed on another die to form a multi-

stack die package. The adhesive layer on the singulated die 15 is heat cured to adhere the singulated die to the die pad, or another die, for further known processing.

**CLAIMS:**

1. A method of die bonding comprising the steps of: providing a structure (10) comprising a wafer substrate (11) separated from carrier base means (13) by an adhesive layer (12) adhered to the carrier base means by a first adhesive between the carrier base (13) and the adhesive layer (12); laser machining through the wafer substrate, the first adhesive and through the adhesive layer no more than at most to scribe the carrier base means to form a singulated die (15) with an attached singulated adhesive layer (12); curing the structure to release the attached singulated adhesive layer from the carrier base means by curing the first adhesive; picking and placing the die and attached singulated adhesive layer on a die pad; and curing the attached singulated adhesive layer to adhere the die to the die pad.

2. A method as claimed in claim 1, wherein the step of laser machining comprises laser machining the wafer substrate (11) using a first laser beam (31) with a first machining profile of selected laser pulse power, laser pulse repetition rate, laser pulse width, laser beam scanning speed and laser wavelength; using a second laser beam (32) with a second such machining profile to machine the adhesive layer (12) and using a third laser beam (33) with a third such machining profile to machine the carrier base means (14) such that a speed of machining is maximised while providing a predetermined quality of singulated dies without substantial delamination of the adhesive layer and the carrier base means or substantial production of burrs.

3. A method as claimed in claim 2, wherein at least two of the first machining profile, the second machining profile and the third machining profile are a same machining profile.

4. A method as claimed in any of the preceding claims, wherein the step of curing the structure (10) comprises curing with ultraviolet light.

5. A method as claimed in any of the preceding claims, wherein the step of curing the attached singulated adhesive layer (12) comprises heat curing the adhesive layer.

6. A method as claimed in any of the preceding claims, wherein the step of machining the wafer substrate comprises machining a blind via (14) in the wafer substrate (11) or a via through the wafer substrate (11) and the adhesive layer (12).

7. A method as claimed in any of the preceding claims, wherein the step of laser machining includes a further step, after laser machining, of washing the structure to remove accumulated laser machining debris from the singulated die (15).

8. A method as claimed in claim 7, wherein the step of providing a structure comprises providing a structure having a protective film to protect the structure from debris produced during laser machining and the step of washing the structure comprises removing the protective film and accumulated debris thereon.

9. A method as claimed in any of the preceding claims, wherein the step of providing a structure comprises providing a structure having a wafer substrate (11) less than 800 microns thick.

10. A method as claimed in any of the preceding claims, wherein the step of laser machining comprises providing an assist gas environment for laser machining.

11. A method as claimed in claim 10, wherein the step of providing an assist gas environment comprises providing a gas environment in which photo-dissociation produces active radicals.

12. A method as claimed in claims 10 or 11, wherein the step of providing a gas environment reduces deposition of solid machining debris around a laser-machining site.

13. A method as claimed in any of the preceding claims, wherein the carrier base means is one of: a dicing tape, an inflexible tape suitable for thin wafer dicing or backgrinding; and a glass or other transparent solid.

14. A method as claimed in any of the preceding claims, wherein the step of providing a structure comprises providing a structure including a wafer substrate separated facedown from substantially inflexible transparent backgrinding tape means by the adhesive layer and the step of laser machining is performed subsequent to backgrinding the wafer substrate.

15. A method as claimed in any of the preceding claims, wherein the step of picking and placing the die and attached singulated adhesive layer comprises picking and placing the die and attached singulated adhesive layer on another die to form a multistack die package.

16. A die bonding apparatus comprising: laser machining means arranged for machining a wafer substrate (11) and an adhesive layer (12) adhered to the wafer substrate (11) and attached to carrier base means (13) by a first adhesive between the carrier base means (13) and the adhesive layer (12) and for no more than at most scribing underlying carrier base means (13) to form a singulated die with a singulated adhesive layer (15); first curing means arranged for curing the first adhesive to release the singulated adhesive layer (12) from the carrier base means (13); pick and place means arranged for picking the singulated die and adhesive layer (15) from the carrier base means (13) and placing the singulated die and adhesive layer (15) on die pad means and second curing means arranged for curing the singulated adhesive layer (12) of the singulated die to adhere the singulated die to the die pad means.

17. A die bonding apparatus as claimed in claim 16, wherein the laser machining means comprises: laser source means arranged for providing a pulsed laser beam (31, 32, 33); laser beam scanning means; and control means arranged for controlling at least one of laser pulse energy, laser wavelength, laser repetition frequency, laser pulse width, laser beam scanning speed and a number of scans by the pulsed laser beam.

18. A die bonding apparatus as claimed in claim 17, wherein the laser machining means further comprises memory means for storing a machining profile of at least one of laser pulse energy, laser wavelength, laser repetition frequency, laser pulse width, laser beam scanning speed and a number of scans by the pulsed laser beam, for use by the control means.

19. A die bonding apparatus as claimed in any of claims 16 to 18, wherein the first curing means comprises ultraviolet curing means.

20. A die bonding apparatus as claimed in any of claims 16 to 19, wherein the second curing means comprises heat curing means.

21. A die bonding apparatus as claimed in any of claims 16 to 20, including washing means arranged for washing laser machining debris from the singulated die.

22. A die bonding apparatus as claimed in claim 21, wherein the wafer substrate is provided with a protective film to protect the wafer substrate from laser machining debris, and the washing means is arranged to remove the protective film from the singulated die.

23. A die bonding apparatus as claimed in any claims 16 to 22, adapted for carrier base means which is one of: a dicing tape, an inflexible tape suitable for thin wafer dicing or backgrinding; and a glass or other transparent solid.

24. A die bonding apparatus as claimed in any claims 16 to 22, adapted for machining a structure comprising a wafer substrate separated facedown from substantially inflexible transparent backgrinding tape means by the adhesive layer.