SPECIFICATION

METHOD FOR ATTACHING AND DETACHING WAFERS DURING INTEGRATED CIRCUIT MANUFACTURING

TECHNICAL FIELD

[0001] The present application relates to integrated circuit manufacturing in general, and, in particular, to a method for attaching and detaching wafers during integrated circuit manufacturing.

BACKGROUND

[0002] During integrated circuit manufacturing, a thinning step is often performed on each semiconductor wafer having integrated circuits in order to reduce the thickness of the semiconductor wafer. The semiconductor wafer is typically bonded to a rigid carrier prior to the thinning process. Existing approaches for attaching a semiconductor wafer to a carrier involve the usage of an adhesive placed directly between the semiconductor wafer and the carrier. After back-grinding and all the required backside processing have been completed on the semiconductor wafer, the thinned semiconductor wafer is then detached from the carrier so that it can progress to its next intended destination.

[0003] The present disclosure provides an improved method for attaching and detaching substrates during integrated circuit manufacturing.

SUMMARY OF THE INVENTION

[0004] In accordance with one embodiment, a reusable carrier is initially formed by depositing a layer of partially transparent light-absorbing material (LAM) on a transparent carrier. An ultraviolet (UV) curable adhesive is deposited on a wafer. The wafer is then placed on the reusable carrier with the partially transparent LAM layer in contact with the UV-curable adhesive to form a carrier stack. Next, a UV light is directed through the transparent carrier and the partially transparent LAM layer in order to cure the UV-curable adhesive. After the wafer has been processed, a light pulse is sent from a flashlamp through the transparent carrier to detach the wafer from the transparent carrier.

[0005] All features and advantages of the present invention will become apparent in the following detailed written description.

BRIEF DESCRIPTION OF THE DRAWINGS

[0006] The invention itself, as well as a preferred mode of use, further objects, and advantages thereof, will best be understood by reference to the following detailed description of an illustrative embodiment when read in conjunction with the accompanying drawings, wherein:

[0007] Figure **1** is a flow diagram of a method for forming a reusable carrier, according to one embodiment;

[0008] Figure **1A** is a diagram of a reusable carrier made by the method depicted in Figure **1**;

[0009] Figure **2** is a flow diagram of a method for attaching and detaching a wafer from a carrier, according to one embodiment;

[0010] Figure **2A** is a diagram of a carrier stack made by the method depicted in Figure **2**;

[0011] Figure **2B** shows the reusable carrier being released from the wafer from Figure **2A**;

[0012] Figure **3** is a block diagram of an apparatus for attaching and detaching a wafer from a carrier, according to one embodiment; and

[0013] Figure **4** illustrates a vacuum table holding down a carrier stack, according to one embodiment.

DETAILED DESCRIPTION OF A PREFERRED EMBODIMENT

[0014] Before any attaching (bonding) and detaching (debonding) of wafers can be performed, a reusable carrier needs to be made for such a purpose. Referring now to the drawings, and in particular to Figure **1**, there is depicted a flow diagram of a method for forming a reusable carrier, according to one embodiment. Starting at block **100**, a layer **170** of partially transparent light-absorbing material (LAM) is deposited on a transparent carrier **180**, as shown in block **110**. Transparent carrier **180** is preferably rigid and is thermally stable beyond 400 °C. In addition, transparent carrier **180** is preferably transparent to most (*e.g.*, greater than 50%) of the light emitted by a flashlamp that is a broadband emission from 200 nm to 1,100 nm. Transparent carrier **180** can be round or in the form of a rectangular panel, etc. Transparent carrier **180** can be made of glass. Examples of glass include Eagle XG glass made by Corning, Inc. or D263 glass made by Schott Glass, Inc. Transparent carrier **180** may also made of quartz or a ceramic material such as an oxide, nitride, or carbide, or a high-temperature polymer.

[0015] LAM layer **170** can be deposited on transparent carrier **180** via a variety of additive techniques, including thermal evaporation, sputtering, CVD, PECVD, ALD, or other vacuum techniques. It may also be deposited with wet processing techniques such as spin coating, printing, etc. Transparent carrier **180** and LAM layer **170** together formed a reusable carrier **190**, as shown in Figure **1A**. LAM layer **170** is approximately 1 to 2,000 nm thick and can transmit 0.1% to 20% of light within a wavelength range of 150 nm to 1,500 nm, which includes ultra-violet (UV) light. LAM layer **170** may include metals (such as tungsten, titanium, molybdenum, niobium, etc.), metal alloys (such as titanium-tungsten), ceramics (such as oxides, nitrides, and carbides) polymers and other materials including carbon (such as amorphous carbon, diamondlike carbon, graphene, etc.). LAM layer **170** is preferably made of a high-temperature material that is stable at a temperature beyond 400 °C. In addition, LAM layer **170** has a coefficient of thermal expansion (CTE) within 9×10^{-6} $°C^{-1}$ of the material of transparent carrier **180**. Importantly, LAM layer **170** is partially transparent to light, including UV light, but is capable of absorbing some of the light emitted by a flashlamp. LAM layer **170** can transmit 0.1% to 20% of light within a wavelength range of 150 to 500 nm.

[0016] After reusable carrier **190** has been made, reusable carrier **190** can be utilized to attach to a wafer with an adhesive disposed between them in order to process the wafer.

After the wafer processing has been completed, reusable carrier **190** is detached from the wafer. Reusable carrier **190** can then be cleaned and be utilized again for another wafer.

[0017] With reference now to Figure **2**, there is depicted a method for attaching reusable carrier **190** to a wafer and for detaching reusable carrier **190** from the wafer, according to one embodiment. Like reusable carrier **190**, the wafer can be round or in the form of a rectangular panel, etc. The wafer may be a semiconductor, such as silicon or gallium arsenide. The wafer may also be glass, quartz, ceramic, polymer, or a composite structure.

[0018] Starting at block **200**, a layer **270** of UV-curable adhesive is disposed on a wafer **280**, as shown in block **210**. Next, wafer **280** is placed on reusable carrier **190**, as depicted in block **220**, such that UV-curable adhesive layer **270** comes into contact with LAM layer **170** in order to form a carrier stack, as shown in Figure **2A**. Alternatively, UV-curable adhesive can be disposed on LAM layer **170** of reusable carrier **190** and wafer **280** can then be placed on the UV-curable adhesive in order to form a carrier stack. UV-curable adhesive **270** may be deposited on wafer **280** using a variety of techniques. This includes directly depositing in liquid form onto reusable carrier **190** or wafer **280** using spin coating, casting, etc. After coating UV-curable adhesive layer **270**, a drying step may also follow to remove excess solvent prior to placing reusable carrier **190** and wafer **280** adjacent to each other. UV-curable adhesive layer **270** may also be a multilayer UV-curable adhesive layer. This may be cast separately in the form of a self-supporting film before being applied directly to either reusable carrier **190** or wafer **280** and prior to placing them adjacent to each other. In that case, UV-curable adhesive layer **270** may be composed of two layers of UV-curable adhesive with an additional polymeric layer disposed between them to maintain dimensional stability of the self-supporting adhesive film. In the case of a multilayer UV-curable adhesive, it is required that each layer, including the central polymeric layer, is at least partially transparent to the curing light. This is because the UV-curing is performed from one side of a carrier stack. So in order to cure all the layers, each layer must be at least partially transparent to the UV-curing source.

[0019] In order to cure UV-curable adhesive layer **270**, UV light from a UV source is directed from the side of transparent carrier **180** through LAM layer **170**, as shown in block **230**. The UV light can be light between 150 nm and 500 nm. The source of UV light can be

a light-emitting diode, a mercury arc lamp, an excimer lamp, a flashlamp, etc. At this point, reusable carrier **190** is adhered to wafer **280**, as depicted in Figure **2A**.

[0020] After wafer **280** has been secured to reusable carrier **190**, the back-side of wafer **280** can be processed, as depicted in block **240**. The processing may include wafer thinning, redistribution layer (RDL) buildup, deep reactive ion etching (DRIE), photolithography, sputtering, via formation, plating, device building, etc.

[0021] After all the wafer processing has been completed on wafer **280**, wafer **280** is now ready to be detached (debonded) from reusable carrier **190** (which includes transparent carrier **180** and LAM layer **170**). As such, a light pulse is sent from a flashlamp **300** from the side of transparent carrier **180** to heat up LAM layer **170** in order to detach wafer **280** from reusable carrier **190**, as shown in block **250**.

[0022] As shown in Figure **2B**, reusable carrier **190** (which includes transparent carrier **180** and LAM layer **170**) is detached from wafer **280**. Reusable carrier **190** is then cleaned and is ready to be reused again. In other words, transparent carrier **180** along with LAM layer **170** are reusable.

[0023] Referring now to Figure **3**, there is depicted a block diagram of an apparatus for performing detachment of a wafer from a carrier, according to one embodiment. As shown, an apparatus **300** includes a flashlamp control unit **301** and detaching unit **302**. Flashlamp control unit **301** includes a capacitor-bank-charging power supply **310**, a capacitor bank **320**, an insulated gate barrier transistor (IGBT)-based switching device **330**, a position sensor **340**, a photodiode **360**, a bolometer **370**, an integrator **380**, and a computer **390**. Computer **390** includes a processor and various storage devices that are well-known to those skilled in the art. The capacitors in capacitor bank **320** are, for example, electrolytic capacitors. The capacitors in capacitor bank **320** may also be pulse discharge capacitors. Capacitor bank **320** may alternatively be switched with a silicon-controlled rectifier (SCR) switching device.

[0024] Capacitor bank **320** can be charged by capacitor-bank-charging power supply **310**. Current from capacitor bank **320** is then discharged into flashlamp **350** via IGBT-based switching device **330** while IGBT-based switching device **330** is being switched on-and-off by

position sensor **340** during the discharge. Position sensor **340** controls the gating of IGBT-based switching device **330** that, in turn, controls the switching of the discharge. The on-and-off switching of IGBT-based switching device **330** is intended to modulate the current flow from capacitor bank **320** to flashlamp(s) **350**, which in turn switches flashlamp(s) **350** on-and-off. In other words, the switching of light pulses emitted by flashlamp(s) **350** is dictated by position sensor **340**.

[0025] If the area of flashlamp illumination is smaller than the size of carrier stack, multiple exposures of light pulse are needed to debond the entire wafer. In that case, the flashlamp head may be indexed relative to the carrier stack to illuminate a portion of the carrier stack until the entire carrier stack has been exposed. The conveyance may be in two dimensions (*e.g.*, x-y) to cover the entire bonded wafer stack and the illuminations may be somewhat overlapped. For example, in the case when the flashlamp illumination area is approximately 75 mm × 150 mm, 18-23 pulses of light may be needed to debond a 300 mm diameter wafer, but only 2 pulses of light may be needed to debond a 100 mm wafer.

[0026] Detaching unit **302** includes a wafer feeding robot **352**, a vacuum table **354**, and a vacuum gripper **356**.

[0027] Prior to detaching, a dicing tape **410** may be attached to bonded wafer stack with film frame **420** to form a bonded wafer assembly, as shown in Figure **4**. Wafer feeding robot **352** conveys the bonded wafer assembly to vacuum table **354**. A vacuum is then applied on dicing tape **410** from vacuum table **354**. Then, a light pulse from flashlamp **350** is utilized to illuminate the bonded wafer assembly from the side of transparent carrier **180** in order to detach processed wafer **280** from transparent carrier **180**.

[0028] At the separation station, vacuum gripper **356** separates reusable carrier **190** from the bonded wafer assembly, while wafer **280** mounted on dicing tape **410** is being held down by vacuum table **354**. Both reusable carrier **190** and wafer **280** on dicing tape **410** are conveyed to a cleaning station to remove any residual adhesive. Residual adhesive may be removed with a wet process via solvent or a dry process with plasma and/or may be peeled off mechanically.

[0029] At this point, wafer **280** is so fragile that the vacuum being applied to wafer **280** should be distributed across wafer **280** so as not to break it during removal. This may be accomplished with multiple suction cups **430** distributed across the surface of wafer **280**, as depicted in Figure **4**. Alternatively, the vacuum may be applied by a distributed vacuum, such as a vacuum table with perforated holes. Vacuum table **354** may have a polymer on its surface so that wafer **280** is not damaged during handling. As an alternative to a vacuum table and a vacuum gripper, an electrostatic chuck and electrostatic gripper may be used instead.

[0030] As has been described, the present invention provides a method for bonding and debonding wafers during integrated circuit manufacturing. One novelty of the present invention is that the LAM layer is reusable. Another novelty of the present invention is that a UV-curable material can be cured through the LAM layer. One advantage of the present invention is that the partial transparency of the LAM layer allows the ability to carefully align the reusable carrier and the wafer relative to each other.

[0031] While the invention has been particularly shown and described with reference to a preferred embodiment, it will be understood by those skilled in the art that various changes in form and detail may be made therein without departing from the spirit and scope of the invention.

CLAIMS

What is claimed is:

1. A method for attaching and detaching wafers, said method comprising:

forming a reusable carrier by depositing a layer of partially transparent light-absorbing material (LAM) on a transparent carrier;

disposing a UV light-curable adhesive on a wafer;

placing said wafer on said reusable carrier with said partially transparent LAM layer in contact with said UV light-curable adhesive to form a carrier stack;

directing a UV light through said transparent carrier and said partially transparent LAM layer in order to cure said UV light-curable adhesive;

processing said wafer;

sending a light pulse through said transparent carrier to facilitate separation of said wafer from said transparent carrier.

2. The method of Claim 1, wherein said transparent carrier is quartz, glass, ceramic, or polymer.

3. The method of Claim 1, wherein said partially transparent LAM layer includes metal, metal alloy, ceramic carbon, or polymer.

4. The method of Claim 3, wherein said ceramic includes oxides, nitrides, or carbides.

5. The method of Claim 1, wherein said wafer is made of semiconductor, glass, or polymer.

6. The method of Claim 1, wherein said forming a reusable carrier further includes depositing said LAM layer on said transparent carrier via a vacuum deposition or a wet deposition process.

7. The method of Claim 1, wherein said sending a light pulse further includes sending a light pulse from a flashlamp through said transparent carrier.

8. The method of Claim 1, wherein said method further includes cleaning said reusable carrier and said partially transparent LAM on said transparent carrier for future use.

9. A method for attaching and detaching wafers, said method comprising:

forming a reusable carrier by depositing a layer of partially transparent light-absorbing material (LAM) on a transparent carrier;

disposing a light-curable adhesive on said partially transparent LAM layer on said transparent carrier;

placing a wafer on said light-curable adhesive to form a carrier stack;

directing a light through said transparent carrier and said partially transparent LAM layer in order to cure said light-curable adhesive;

processing said wafer;

sending a plurality of light pulses through said transparent carrier to detach said wafer from said transparent carrier.

10. The method of Claim 9, wherein said transparent carrier is quartz, glass, ceramic, or polymer.

11. The method of Claim 9, wherein said partially transparent LAM layer includes metal, ceramic, carbon, or polymer.

12. The method of Claim 9, wherein said wafer is made of semiconductor, glass, or polymer.

13. The method of Claim 9, wherein said light-curable adhesive is a UV light-curable adhesive, and said directing further includes directing a UV light through said transparent carrier.

14. The method of Claim 9, wherein said forming a reusable carrier further includes depositing said LAM layer on said transparent carrier via a vacuum deposition or a wet deposition process.

15. The method of Claim 9, wherein said sending a light pulse further includes sending a light pulse from a flashlamp through said transparent carrier.

16. The method of Claim 9, wherein said method further includes cleaning said reusable carrier and said partially transparent LAM on said transparent carrier for future use.

17. A reusable carrier comprising:

a transparent carrier; and

a layer of partially transparent light-absorbing material (LAM) deposited on said transparent carrier, wherein said partially transparent LAM layer transmits 0.1% to 20% of light within a wavelength range of 150 to 500 nm, wherein said transparent carrier and said partially transparent LAM are cleanable for future usage.

18. The reusable carrier of Claim 17, wherein said transparent carrier is quartz, glass or polymer.

19. The reusable carrier of Claim 17, wherein said partially transparent LAM layer includes metal, ceramic, carbon or polymer.

20. The method of Claim 17, wherein said partially transparent LAM layer is stable at a temperature beyond 400 °C and has a coefficient of thermal expansion that is within 9×10^{-6} $°C^{-1}$ of said transparent carrier.