

DESCRIPTION

TAPE FOR GLASS PROCESSING

TECHNICAL FIELD

[0001] The present invention relates to an expandable tape for glass processing, which can be utilized for fixing glass in a dicing step of dividing glass into chip-like elements, which can also be utilized in a die bonding step or a mounting step, where adhesion is applied between one chip and another chip or between a chip and a substrate after dicing, and which can also be utilized in a step of dividing an adhesive layer along the chips by expansion.

BACKGROUND ART

[0002] In cameras and sensors that are mounted in smart phones and the like, glasses having various distinctive optical characteristics are mounted. These glasses are generally produced by vacuum depositing various materials on glass that serves as a matrix, or the like. Subsequently, a tape for glass processing having tackiness and elasticity is attached to these glasses, and then a dicing step of dividing glass into chip units, an expanding step of expanding the tape for glass processing, a pickup step of picking up the divided chips, and a die bonding step of adhering the picked-up chips at specific sites, are

carried out.

[0003] In the above-described glass dicing step, cutting by means of a blade has been hitherto predominantly implemented; however, chippage, which is called chipping, and the like have caused problems due to the effect of thickness reduction of the glass itself and vapor deposition, and thereby, there has been a problem that the product yield is decreased.

[0004] In order to solve such problems, in recent years, a so-called stealth dicing method, by which glass can be cut in a non-contact manner using a laser processing apparatus, has been suggested as a method for cutting glass. For example, Patent Document 1 discloses, as a stealth dicing method, a method for cutting a semiconductor substrate, the method including a step of adjusting focused light into the interior of a semiconductor substrate, on which a sheet has been laminated by means of an adhesive layer (die-bond resin layer) interposed therebetween, irradiating the semiconductor substrate with laser light, thereby forming regions modified by multiphoton absorption in the interior of the semiconductor substrate, and using these modified regions as intended cutting parts; and a step of cutting the semiconductor substrate and the adhesive layer along the intended cutting parts by expanding the sheet.

[0005] Furthermore, as another method for cutting a wafer using a laser processing apparatus, for example, there is

suggested in Patent Document 2 a method of splitting a wafer, the method including a step of mounting an adhesive layer (adhesive film) for die bonding on the back surface of a wafer; a step of laminating a stretchable protective temporary adhesive tape on the adhesive layer side of the wafer, to which the adhesive layer has been laminated; a step of irradiating the wafer having the protective temporary adhesive tape laminated thereto, with laser light through the front surface along streets, and thereby splitting the wafer into individual chips; a step of expanding the protective temporary adhesive tape to apply tensile force to the adhesive layer and breaking the adhesive layer for each of the chips; and a step of detaching the chips with the broken adhesive layer laminated thereto, from the protective temporary adhesive tape.

[0006] According to these methods for cutting a wafer as described in Patent Document 1 and Patent Document 2, since a wafer is cut in a non-contact manner by means of irradiation with laser light and expansion of a tape, the physical burden on the wafer is small, and the wafer can be cut without generating cutting debris of the wafer, as in the case of performing blade dicing of the current mainstream. Furthermore, since the adhesive layer is divided by expanding the adhesive layer, there is no chance of generating cutting debris of the adhesive layer. For this reason, attention has been paid to these methods as an excellent technology that can replace blade dicing.

[0007] The splitting technology described these above-mentioned documents is mainly directed to wafers; however, the splitting technology can also be applied to glass by replacing the laser engine of the apparatus with a laser engine for glass.

[0008] However, in the methods of dividing an adhesive layer by expanding the adhesive layer through expansion as described in Patent Documents 1 and 2, in the case of using a conventional tape for semiconductor processing, there is a problem that along with an increase in the quantity of expansion, the portion thrust up by an expansion ring is stretched, and after expansion is undone, the relevant portion becomes slackened so that the distance between chips (hereinafter, "kerf width") cannot be maintained.

[0009] Thus, methods in which the adhesive layer is divided by expansion, after the expansion is undone, the slackened portions of the tape for semiconductor processing are caused to shrink by heating the slackened portions, and thereby the kerf width is maintained, have been proposed (for example, Patent Documents 3 and 4).

CITATION LIST

PATENT DOCUMENT

[0010] Patent Document 1: JP 2003-338467 A

Patent Document 2: JP 2004-273895 A

Patent Document 3: WO 2016/152957 A

Patent Document 4: JP 2015-211081 A

SUMMARY OF THE INVENTION

PROBLEM TO BE SOLVED BY THE INVENTION

[0011] However, regarding a method of causing the slack of a tape for semiconductor processing induced by expansion to shrink by heating, generally, a method of causing a pair of hot air nozzles to orbit around the ring-shaped portion that has been thrust up by an expansion ring and has slackened, thereby exposing the slackened portion to hot air, and causing the portion to shrink by heating, has been used.

[0012] In the tape for semiconductor processing described in the above-described Patent Document 3, when the tape is heated for 10 seconds at 100°C, the thermal shrinkage in both the longitudinal direction and the width direction of the tape is from 0% to 20%. However, when the tape is heated by causing hot air nozzles to orbit around, the temperature in the vicinity of the surface of the tape for glass processing increases slowly, and therefore, there is a problem that some time is taken in order to eliminate slack at all sites of the ring shape. Furthermore, there is a problem that the maintainability for the kerf width is not sufficient; during the process of picking up chips, adjoining chips are likely to be simultaneously picked up; and when the tape for semiconductor processing is diverted

for the splitting of glass, the product yield of the glass processing process is deteriorated.

[0013] Furthermore, the tape for semiconductor processing described in the above-described Patent Document 4 has a shrinkage ratio of 0.1% or greater at 130°C to 160°C (see Claim 1 of Patent Document 4), and the temperature inducing shrinkage is high. Therefore, in the case of achieving heat-shrinking using hot air, a high temperature and a long heating time are needed, and there is a risk that hot air may exert influence even on the adhesive layer in the vicinity of the outer periphery of the wafer, and the split adhesive layer may be fused and fusion-bonded again. Furthermore, there is a problem that the maintainability for the kerf width is not sufficient, and when the tape is diverted for the splitting of glass, during the process of picking up chips, adjoining chips are likely to be simultaneously picked up so that the product yield of the glass processing process is deteriorated.

[0014] Thus, it is an object of the invention to provide a tape for glass processing, which can be caused to heat-shrink sufficiently in a short period of time and can maintain a sufficient kerf width to the extent that simultaneous pick-up of adjoining chips can be suppressed.

MEANS FOR SOLVING PROBLEM

[0015] In order to solve the above-described problems, the

tape for glass processing according to the invention has a temporary adhesive tape having a substrate film and a temporary adhesive layer formed on at least one surface side of the substrate film, wherein regarding the temporary adhesive tape, the sum of the sum total of derivative values of the thermal deformation rate in the MD direction per 1°C between 40°C and 80°C as measured at the time of raising temperature by means of a thermomechanical characteristics testing machine, and the sum total of derivative values of the thermal deformation rate in the TD direction per 1°C between 40°C and 80°C as measured at the time of raising temperature by means of a thermomechanical characteristics testing machine, is a negative value.

[0016] Furthermore, in order to solve the above-described problems, the tape for glass processing according to the invention has a temporary adhesive tape having a substrate film and a temporary adhesive layer formed on at least one surface side of the substrate film, wherein the substrate film is formed of an ionomer resin or a mixed resin composition of polypropylene and a styrene-butadiene copolymer, and regarding the temporary adhesive tape, the sum of the sum total of derivative values of the thermal deformation rate in the MD direction per 1°C between 40°C and 80°C as measured at the time of raising temperature by means of a thermomechanical characteristics testing machine, and the sum total of

derivative values of the thermal deformation rate in the TD direction per 1°C between 40°C and 80°C as measured at the time of raising temperature by means of a thermomechanical characteristics testing machine, is a negative value.

MEANS FOR SOLVING PROBLEM

[0017] Furthermore, it is preferable that the tape for glass processing is used for full-cut blade dicing, full-cut laser dicing, or laser-induced stealth dicing.

[0018] Furthermore, it is preferable that the tape for glass processing has an adhesive layer laminated on the temporary adhesive layer side, and the adhesive layer has a light transmittance of 90% or higher to light having a wavelength of 550 nm.

EFFECT OF THE INVENTION

[0019] When the tape for glass processing according to the invention is used, the tape can be caused to sufficiently heat-shrink in a short period of time, and a sufficient kerf width can be maintained to the extent that simultaneous pick-up of adjoining chips can be suppressed.

BRIEF DESCRIPTION OF DRAWINGS

[0020] Fig. 1 is a cross-sectional view schematically illustrating the structure of a tape for glass processing according to an embodiment of the invention;

Fig. 2 is a cross-sectional view for describing a step of laminating glass and a ring frame to the tape for glass processing according to the embodiment of the invention;

Fig. 3 is a cross-sectional view illustrating a state in which a modified region is formed on glass by laser processing;

Fig. 4(a) is a cross-sectional view illustrating a state in which the tape for glass processing according to the embodiment of the invention is mounted on an expanding apparatus; Fig. 4(b) is a cross-sectional view illustrating an operation of dividing glass into chips by expanding the tape for glass processing; and Fig. 4(c) is a cross-sectional view illustrating the tape for glass processing, an adhesive layer, and chips after expansion;

Fig. 5 is a cross-sectional view for describing a heat-shrinking step;

Fig. 6 is an explanatory diagram illustrating the site of measurement of the kerf width for an evaluation in Examples and Comparative Examples; and

Fig. 7 is an example of the measurement results for the thermal deformation rate.

MODE(S) FOR CARRYING OUT THE INVENTION

[0021] Embodiments of the invention will be described in detail below.

[0022] Fig. 1 is a cross-sectional view illustrating a tape

for glass processing 10 according to an embodiment of the invention. The tape for glass processing 10 of the invention is such that when glass is divided into chips by expansion, a transparent adhesive layer 13 is divided along with the chips. This tape for glass processing 10 has a temporary adhesive tape 15 composed of a substrate film 11 and a temporary adhesive layer 12 provided on the substrate film 11; and a transparent adhesive layer 13 provided on the temporary adhesive layer 12, and the back surface of glass is laminated onto the transparent adhesive layer 13. The respective layers may be cut in advance into a predetermined shape (precut) in accordance with the process or apparatus used. Furthermore, the tape for glass processing 10 of the invention may be in the form in which the tape has been cut out for each sheet of glass, or may be in the form in which a long sheet formed by a plurality of pieces of the tape that has been cut out for each sheet of glass, is wound into a roll shape. In the following description, the configurations of the various layers will be described.

[0023] <Substrate film>

When the substrate film 11 has uniform and isotropic expansibility, it is preferable from the viewpoint that glass can be cut uniformly in all directions during the expansion step, and the material for the substrate film 11 is not particularly limited. Generally, crosslinked resins have high restoring force against pulling as compared to non-crosslinked resins and

have high shrinkage stress when heat is applied to the resins in an elongated state after the expansion step. Therefore, crosslinked resins are excellent from the viewpoint of eliminating the slack produced in the tape after the expansion step through heat-shrinking, and applying tension to the tape to thereby stably maintain the distances (kerf widths) between individual chips. Among the crosslinked resins, thermoplastic crosslinked resins are more preferably used. On the other hand, non-crosslinked resins have low restoring force against pulling as compared to crosslinked resins. Therefore, after the expansion step in a low temperature region such as a range of -15°C to 0°C , when the tape is once relaxed and returned to normal temperature and then is directed to a pick-up step and a mounting step, the tape is not likely to shrink. Therefore, the tape is excellent from the viewpoint that the adhesive layers adhered to the chips can be prevented from contacting with each other. Among the non-crosslinked resins, olefin-based non-crosslinked resins are more preferably used.

[0024] An example of such a thermoplastic crosslinked resin is an ionomer resin obtained by crosslinking, for example, an ethylene-(meth)acrylic acid binary copolymer or a ternary copolymer containing ethylene-(meth)acrylic acid-(meth)acrylic acid alkyl ester as main polymer constituent components, with a metal ion. These are appropriate for the expansion step in terms of uniform expansibility and are

particularly suitable from the viewpoint that the restoring force strongly works during heating due to the crosslinking. The metal ion that is to be included in the ionomer resin is not particularly limited, and examples thereof include zinc and sodium. Zinc ion is less leachable and is preferable from the viewpoint of low contaminability. In the (meth)acrylic acid alkyl ester of the ternary copolymer, an alkyl group having 1 to 4 carbon atoms is preferable from the viewpoint of having a high elastic modulus and being capable of propagating strong force to glass. Examples of such a (meth)acrylic acid alkyl ester include methyl methacrylate, ethyl methacrylate, propyl methacrylate, butyl methacrylate, methyl acrylate, ethyl acrylate, propyl acrylate, and butyl acrylate.

[0025] Furthermore, regarding the above-mentioned thermoplastic crosslinked resin, in addition to the ionomer resins, a product obtained by crosslinking a resin selected from a low-density polyethylene having a specific gravity of 0.910 or more and less than 0.930, an ultralow-density polyethylene having a specific gravity of less than 0.910, and other ethylene-vinyl acetate copolymers, by irradiating the resin with energy rays such as an electron beam, is also suitable. Since such a thermoplastic crosslinked resin has crosslinked sites and non-crosslinked sites co-existing within the resin, the thermoplastic crosslinked resin has certain uniform expansibility. Furthermore, since restoring force strongly

works during heating, a thermoplastic crosslinked resin is also suitable for eliminating the slack of the tape caused by the expansion step. Also, because thermoplastic crosslinked resins hardly contain chlorine in the composition of the molecular chain, even if tapes that have become unnecessary after use are incinerated, the thermoplastic crosslinked resins do not generate chlorinated aromatic hydrocarbons such as dioxin and analogues thereof, and therefore, the resins impose less burden on the environment. By appropriately regulating the amount of the energy rays to be irradiated on the polyethylene or the ethylene-vinyl acetate copolymer, a resin having sufficient uniform expansibility can be obtained.

[0026] Furthermore, an example of the non-crosslinked resin may be a mixed resin composition of, for example, polypropylene and a styrene-butadiene copolymer.

[0027] Regarding polypropylene, for example, a homopolymer of propylene, or a block type or random type propylene-ethylene copolymer can be used. A random type propylene-ethylene copolymer has low rigidity and is preferable. When the percentage content of an ethylene constituent unit in the propylene-ethylene copolymer is 0.1% by weight or more, the propylene-ethylene copolymer is excellent from the viewpoint that the rigidity of a resulting tape and the compatibility between the resins in the mixed resin composition are high. When the rigidity of the tape is appropriate, the cuttability

of glass is enhanced, and in a case in which the resins have high compatibility, the amount of discharge upon extrusion is easily stabilized. The percentage content is more preferably 1% by weight or more. Furthermore, when the percentage content of an ethylene constituent unit in the propylene-ethylene copolymer is 7% by weight or less, it is excellent from the viewpoint that polypropylene is stabilized and is easily polymerized. The percentage content is more preferably 5% by weight or less.

[0028] Regarding the styrene-butadiene copolymer, a hydrogenated styrene-butadiene copolymer may be used. When a styrene-butadiene copolymer is hydrogenated, the styrene-butadiene copolymer has satisfactory compatibility with propylene, and the embrittlement and discoloration caused by oxidative deterioration attributed to the double bonds in butadiene can be prevented. Furthermore, when the percentage content of a styrene constituent unit in the styrene-butadiene copolymer is 5% by weight or more, it is preferable from the viewpoint that the styrene-butadiene copolymer is stabilized and is easily polymerized. Furthermore, when the percentage content is 40% by weight or less, the styrene-butadiene copolymer is flexible and is excellent in view of expansibility. The percentage content is more preferably 25% by weight or less, and even more preferably 15% by weight or less. Regarding the styrene-butadiene copolymer, a block type copolymer and a

random type copolymer can all be used. A random type copolymer is preferable because the styrene phase is uniformly dispersed, excessive increase in rigidity can be suppressed, and expansibility is enhanced.

[0029] When the percentage content of polypropylene in the mixed resin composition is 30% by weight or more, it is excellent from the viewpoint that the thickness unevenness of the substrate film can be suppressed. When the thickness is uniform, expansibility is likely to become isotropic. Furthermore, the occurrence that the stress relaxation properties of the substrate film become excessively strong, the distance between chips become smaller over time, and the adhesive layers come into contact with one another and are fused again, can be easily prevented. The percentage content is more preferably 50% by weight or more. Furthermore, when the percentage content of polypropylene is 90% by weight or less, the rigidity of the substrate film can be easily adjusted as appropriate. If the rigidity of the substrate film becomes too high, the force required to expand the substrate film becomes larger. Accordingly, the load of the apparatus increases, and there are occasions in which an expansion sufficient for the splitting of the glass and the adhesive layer 13 cannot be achieved. Therefore, it is important to appropriately adjust the rigidity. The lower limit of the percentage content of the styrene-butadiene copolymer in the mixed resin composition is

preferably 10% by weight or more, and it is easy to adjust the rigidity of the substrate film to a level appropriate for the apparatus. When the upper limit is 70% by weight or less, it is excellent from the viewpoint that the thickness unevenness can be suppressed, and the upper limit is more preferably 50% by weight or less.

[0030] Meanwhile, in the example illustrated in Fig. 1, the substrate film 11 is a single layer; however, the invention is not limited to this, and the substrate film may have a multilayer structure obtained by laminating two or more kinds of resins, or two or more layers of a single kind of resin may be laminated. Regarding the two or more kinds of resins, it is preferable that the resins are coherently crosslinkable or non-crosslinkable, from the viewpoint that the characteristics of the respective resins are exhibited in an augmented manner. When a combination of crosslinkable resins and non-crosslinkable resins are laminated, it is preferable from the viewpoint that the defects of the respective resins are made up for one another. The thickness of the substrate film 11 is not particularly specified; however, it is desirable that the substrate film is easily stretchable and has a strength that is barely sufficient to remain unbroken during the expansion step for the tape for glass processing 10. For example, the thickness may be about 50 μm to 300 μm , and the thickness is more preferably 70 μm to 200 μm .

[0031] Regarding the method for producing a substrate film 11 having a plurality of layers, an extrusion method, a lamination method and the like, which are conventionally known, can be used. In the case of using a lamination method, a transparent adhesive may be interposed between the layers.

[0032] <Temporary adhesive layer>

The temporary adhesive layer 12 can be formed by applying a temporary adhesive composition on the substrate film 11. The temporary adhesive layer 12 that constitutes the tape for glass processing 10 of the invention may be a temporary adhesive layer which does not cause detachment from the adhesive layer 13 at the time of dicing, has retainability to the extent that defects such as chip flying do not occur, and has a characteristic making the detachment from the adhesive layer 13 easier at the time of pick-up.

[0033] In regard to the tape for glass processing 10 of the invention, the composition of the temporary adhesive composition that constitutes the temporary adhesive layer 12 is not particularly limited. However, in order to enhance the pick-up performance after dicing, an energy ray-curable temporary adhesive composition is preferable, and a material which can be easily detached from the adhesive layer 13 after curing is preferable. According to one embodiment, a temporary adhesive composition including a polymer (A) that includes 60 mol% or more of a (meth)acrylate having an alkyl chain having

6 to 12 carbon atoms and has an energy ray-curable carbon-carbon double bond having an iodine value of 5 to 30 as a base resin, may be mentioned as an example. Here, the energy rays refer to light rays such as ultraviolet radiation, or ionizing radiation such as an electron beam.

[0034] In regard to such a polymer (A), when the amount of introduction of the energy ray-curable carbon-carbon double bonds is 5 or more as the iodine value, it is excellent from the viewpoint that the effect of reducing the temporary adhesive force after being irradiated with energy rays is increased. The iodine value is more preferably 10 or more. Furthermore, when the amount of introduction as an iodine value is 30 or less, it is excellent from the viewpoint that the retentive power for chips exhibited until the pick-up of the chips after irradiation with energy rays is high, and it is easy to widen the gaps between the chips at the time of expansion immediately before the pick-up step. When the gaps between the chips can be sufficiently widened before the pick-up step, it is preferable because image recognition of each chip at the time of pick-up is made easy, or it is easy to pick up the chips. Furthermore, when the amount of introduction of the carbon-carbon double bonds is from 5 to 30 as the iodine value, it is preferable because the polymer (A) is stable, and production thereof is facilitated.

[0035] Furthermore, when the polymer (A) has a glass

transition temperature of -70°C or higher, it is excellent from the viewpoint of heat resistance against the heat associated with irradiation with energy rays, and the glass transition temperature is more preferably -66°C or higher. Furthermore, when the glass transition temperature is 15°C or lower, various films are formed in a surface state, and it is excellent from the viewpoint of the effect of preventing chip flying after dicing in a glass having a surface level difference. The glass transition temperature is more preferably 0°C or lower, and even more preferably -28°C or lower.

[0036] The polymer (A) may be a polymer produced by any method; however, for example, a polymer obtained by mixing an acrylic copolymer and a compound having an energy ray-curable carbon-carbon double bond, or a polymer obtained by reacting an acrylic copolymer having a functional group or a methacrylic copolymer (A1) having a functional group, with a compound (A2) having a functional group that can react with the foregoing functional group and having an energy ray-curable carbon-carbon double bond, is used.

[0037] Among these, an example of the methacrylic copolymer (A1) having a functional group is a polymer obtainable by copolymerizing a monomer (A1-1) having a carbon-carbon double bond, such as an acrylic acid alkyl ester or a methacrylic acid alkyl ester, and a monomer (A1-2) having a carbon-carbon double bond and having a functional group. Examples of the

monomer (A1-1) include hexyl acrylate, n-octyl acrylate, isooctyl acrylate, 2-ethylhexyl acrylate, dodecyl acrylate, decyl acrylate, and lauryl acrylate, all of which have an alkyl chain having 6 to 12 carbon atoms; pentyl acrylate, n-butyl acrylate, isobutyl acrylate, ethyl acrylate, and methyl acrylate, all of which are monomers having an alkyl chain having 5 or fewer carbon atoms; and methacrylates similar to those.

[0038] Meanwhile, with regard to the monomer (A1-1), a component having an alkyl chain having 6 or more carbon atoms is excellent in view of the pick-up properties, since the peeling force between the temporary adhesive layer and the adhesive layer can be made small. Furthermore, a component having an alkyl chain having 12 or fewer carbon atoms has a low elastic modulus at room temperature and is excellent in view of the adhesive force at the interface between the temporary adhesive layer and the adhesive layer. When the adhesive force at the interface between the temporary adhesive layer and the adhesive layer is high, it is preferable because at the time of expanding the tape and cutting glass, the interfacial slippage between the temporary adhesive layer and the adhesive layer can be suppressed, and cuttability is enhanced.

[0039] Furthermore, as a monomer having an alkyl chain with a larger number of carbon atoms is used as the monomer (A1-1), the glass transition temperature is lowered. Therefore, a temporary adhesive composition having a desired glass

transition temperature can be prepared by appropriately selecting the monomer (A1-1). Furthermore, for the purpose of enhancing various performances such as compatibility in addition to the glass transition temperature, it is also possible to incorporate a low molecular weight compound having a carbon-carbon double bond, such as vinyl acetate, styrene or acrylonitrile. In that case, these low molecular weight compounds are incorporated in an amount in the range of 5% by mass or less with respect to the total mass of the monomer (A1-1).

[0040] On the other hand, examples of the functional group carried by the monomer (A1-2) include a carboxyl group, a hydroxyl group, an amino group, a cyclic acid anhydride group, an epoxy group, and an isocyanate group. Specific examples of the monomer (A1-2) include acrylic acid, methacrylic acid, cinnamic acid, itaconic acid, fumaric acid, phthalic acid, 2-hydroxyalkyl acrylates, 2-hydroxyalkyl methacrylates, glycol monoacrylates, glycol monomethacrylates, N-methylol acrylamide, N-methylol methacrylamide, allyl alcohol, N-alkylaminoethyl acrylates, N-alkylaminoethyl methacrylates, acrylamides, methacrylamides, maleic anhydride, itaconic anhydride, fumaric anhydride, phthalic anhydride, glycidyl acrylate, glycidyl methacrylate, and allyl glycidyl ether.

[0041] Furthermore, regarding the functional group used for the compound (A2), in a case in which the functional group carried by the compound (A1) is a carboxyl group or a cyclic

acid anhydride group, the functional group of the compound (A2) may be a hydroxyl group, an epoxy group, an isocyanate group, or the like; in a case in which the functional group is a hydroxyl group, the functional group may be a cyclic acid anhydride group, an isocyanate group, or the like; in a case in which the functional group is an amino group, the functional group may be an epoxy group, an isocyanate group, or the like; and in a case in which the functional group is an epoxy group, the functional group may be a carboxyl group, a cyclic acid anhydride group, an amino group, or the like. Specific examples thereof include the same groups as those mentioned as the specific examples for the monomer (A1-2). Furthermore, as the compound (A2), a compound in which a portion of the isocyanate groups of a polyisocyanate compound has been urethanized using hydroxyl groups or carboxyl groups and a monomer having an energy ray-curable carbon-carbon double bond, can also be used.

[0042] Meanwhile, in regard to the reaction between the compound (A1) and the compound (A2), a product having desired characteristics with regard to characteristics such as the acid value or the hydroxyl group value can be produced by leaving unreacted functional groups. When OH groups are left unreacted such that the hydroxyl group value of the polymer (A) is adjusted to 5 to 100, the temporary adhesive force after irradiation with energy rays is reduced, and thereby the risk of pick-up failure can be further reduced. Furthermore, when COOH groups are left

unreacted such that the acid value of the polymer (A) is adjusted to 0.5 to 30, an effect of improving the state after restoration of the temporary adhesive layer after the tape for glass processing of the invention has been expanded, is obtained, which is preferable. When the hydroxyl group value of the polymer (A) is 5 or greater, it is excellent from the viewpoint of the effect of reducing the temporary adhesive force after irradiation with energy rays, and when the hydroxyl group value is 100 or less, it is excellent from the viewpoint of the fluidity of the temporary adhesive after irradiation with energy rays. Furthermore, when the acid value is 0.5 or greater, it is excellent from the viewpoint of the tape restorability, and when the acid value is 30 or less, it is excellent from the viewpoint of the fluidity of the temporary adhesive.

[0043] In regard to the synthesis of the polymer (A) described above, as the organic solvent in the case of performing the reaction by solution polymerization, a ketone-based solvent, an ester-based solvent, an alcohol-based solvent, or an aromatic solvent can be used. However, among these, a solvent which is generally a good solvent for acrylic polymers and has a boiling point of 60°C to 120°C, such as toluene, ethyl acetate, isopropyl alcohol, benzene methyl cellosolve, ethyl cellosolve, acetone, or methyl ethyl ketone, is preferred. Regarding the polymerization initiator, an azobis-based radical generator such as α,α' -azobisisobutyronitrile, or an

organic peroxide-based radical generator such as benzoyl peroxide is usually used. At this time, a catalyst and a polymerization inhibitor can be used in combination as necessary, and by regulating the polymerization temperature and the polymerization time, a polymer (A) having a desired molecular weight can be obtained. Furthermore, in connection with regulating the molecular weight, it is preferable to use mercaptan or a carbon tetrachloride-based solvent. Meanwhile, this reaction is not intended to be limited to solution polymerization, and other methods such as bulk polymerization and suspension polymerization may also be used.

[0044] The polymer (A) can be obtained in this manner as described above; however, according to the invention, when the molecular weight of the polymer (A) is adjusted to 300,000 or more, it is excellent from the viewpoint of increasing the cohesive force. High cohesive force leads to an effect of suppressing slippage at the interface between the temporary adhesive layer and the adhesive layer at the time of expansion, and since the propagation of tensile force to the adhesive layer is easily achieved, it is preferable from the viewpoint that the splittability of the adhesive layer is enhanced. When the molecular weight of the polymer (A) is adjusted to 2,000,000 or less, it is excellent from the viewpoint of suppressing gelation at the time of synthesis and at the time of coating. Meanwhile, the molecular weight according to the invention

means the mass average molecular weight calculated relative to polystyrene standards.

[0045] Furthermore, with regard to the tape for glass processing 10 of the invention, the resin composition that constitutes the temporary adhesive layer 12 may further include a compound (B) that acts as a crosslinking agent, in addition to the polymer (A). Examples thereof include a polyisocyanate, a melamine-formaldehyde resin, and an epoxy resin, and these can be used singly or in combination of two or more kinds thereof. This compound (B) reacts with the polymer (A) or the substrate film, and the compound (B) can enhance, through the resulting crosslinked structure, the cohesive force of the temporary adhesive containing the polymers (A) and (B) as main components, after the application of the temporary adhesive composition.

[0046] There are no particular limitations on the polyisocyanate, and examples thereof include aromatic isocyanates such as 4,4'-diphenylmethane diisocyanate, tolylene diisocyanate, xylylene diisocyanate, 4,4'-diphenyl ether diisocyanate, and 4,4'-[2,2-bis(4-phenoxyphenyl)propane] diisocyanate; hexamethylene diisocyanate, 2,2,4-trimethylhexamethylene diisocyanate, isophorone diisocyanate, 4,4'-dicyclohexylmethane diisocyanate, 2,4'-dicyclohexylmethane diisocyanate, lysine diisocyanate, and lysine triisocyanate. Specifically, CORONATE L

(manufactured by Nippon Polyurethane Industry Co., Ltd., trade name) and the like can be used. Regarding the melamine-formaldehyde resin, specifically, NIKALAC MX-45 (manufactured by Sanwa Chemical Co., Ltd., trade name), MELAN (manufactured by Hitachi Chemical Co., Ltd., trade name), and the like can be used. Regarding the epoxy resin, TETRAD-X (manufactured by Mitsubishi Chemical Corp., trade name) and the like can be used. According to the invention, it is particularly preferable to use a polyisocyanate.

[0047] A temporary adhesive layer in which the amount of addition of the compound (B) has been adjusted to 0.1 parts by mass or more with respect to 100 parts by mass of the polymer (A), is excellent in view of the cohesive force. The amount of addition of the compound (B) is more preferably 0.5 parts by mass or more. Furthermore, a temporary adhesive layer in which the amount of addition of the compound (B) has been adjusted to 10 parts by mass or less, is excellent in view of suppressing rapid gelation at the time of coating, and thus satisfactory workability for the incorporation, application or the like of the temporary adhesive is obtained. The amount of addition is more preferably 5 parts by mass or less.

[0048] Furthermore, according to the invention, the temporary adhesive layer 12 may also include a photopolymerization initiator (C). The photopolymerization initiator (C) included in the temporary adhesive layer 12 is

not particularly limited, and any conventionally known photopolymerization initiator can be used. Examples thereof include benzophenones such as benzophenone, 4,4'-dimethylaminobenzophenone, 4,4'-diethylaminobenzophenone, and 4,4'-dichlorobenzophenone; acetophenones such as acetophenone and diethoxyacetophenone; anthraquinones such as 2-ethylanthraquinone and t-butylanthraquinone; 2-chlorothioxanthone, benzoin ethyl ether, benzoin isopropyl ether, benzil, a 2,4,5-triaryl imidazole dimer (lophine dimer), and an acridine-based compound, and these can be used singly or in combination of two or more kinds thereof. Regarding the amount of addition of the photopolymerization initiator (C), it is preferable to incorporate the photopolymerization initiator (C) in an amount of 0.1 parts by mass or more, and more preferably 0.5 parts by mass or more, with respect to 100 parts by mass of the polymer (A). Furthermore, the upper limit of the amount of addition is preferably 10 parts by mass or less, and more preferably 5 parts by mass or less.

[0049] In addition, in the energy ray-curable temporary adhesive used for the invention, a tackifier, a temporary adhesiveness modifier, a surfactant and the like, or other modifiers can be incorporated as necessary. Furthermore, an inorganic compound filler may also be added thereto as appropriate.

[0050] The temporary adhesive layer 12 can be formed by utilizing a conventional method for forming a temporary adhesive layer. The temporary adhesive layer 12 can be formed on a substrate film 11 by, for example, a method of forming a temporary adhesive layer by applying the temporary adhesive composition described above on a predetermined surface of the substrate film 11, or a method of applying the temporary adhesive composition on a separator (for example, a plastic film or sheet having a mold release agent applied thereon) to form the temporary adhesive layer 12, and then transferring the temporary adhesive layer 12 to a predetermined surface of the substrate. Meanwhile, the temporary adhesive layer 12 may be in the form of a single layer or may have a laminated form.

[0051] The thickness of the temporary adhesive layer 12 is not particularly limited; however, when the thickness is 2 μm or more, it is excellent from the viewpoint of the tack force, and the thickness is more preferably 5 μm or more. When the thickness is 15 μm or less, excellent pick-up performance is obtained, and the thickness is more preferably 10 μm or less.

[0052] The temporary adhesive tape 15 is such that the sum of the sum total of derivative values of the thermal deformation rate in the MD (Machine Direction) direction per 1°C between 40°C and 80°C as measured at the time of raising temperature by means of a thermomechanical characteristics testing machine, and the sum total of derivative values of the thermal

deformation rate in the TD (Transverse Direction) direction per 1°C between 40°C and 80°C as measured at the time of raising temperature by means of a thermomechanical characteristics testing machine, is a negative value, that is, less than zero. The MD direction is a direction of flow during film formation, and the TD direction is a direction perpendicular to the MD direction.

[0053] When the sum of the sum total of derivative values of the thermal deformation rate in the MD direction of the temporary adhesive tape 15 per 1°C between 40°C and 80°C as measured at the time of raising temperature by means of a thermomechanical characteristics testing machine, and the sum total of derivative values of the thermal deformation rate in the TD direction per 1°C between 40°C and 80°C as measured at the time of raising temperature by means of a thermomechanical characteristics testing machine, is adjusted to a negative value, the tape for glass processing 10 can be caused to shrink by heating at a low temperature for a short period of time. Therefore, even in a case in which a method of heat-shrinking a slackened part of the tape for glass processing 10 by causing a pair of hot air nozzles to orbit around the slackened part is used, the slack produced by expansion can be eliminated in a short period of time without heat-shrinking several times while reducing the quantity of expansion, and an appropriate kerf width can be maintained.

[0054] The thermal deformation rate can be calculated by the following Formula (1) by measuring the quantity of temperature-induced deformation according to JIS K7197:2012.

Thermal deformation rate TMA (%) = (Quantity of deformation in length of sample/length of sample before measurement) × 100 (1)

Meanwhile, regarding the quantity of deformation, the direction of expansion of the sample is indicated as a positive direction, and the direction of shrinkage is indicated as a negative direction.

[0055] The sum total of derivative values of the thermal deformation rate corresponds to the area surrounded by the curve in the MD direction or the curve in the TD direction and the x-axis as show in Fig. 7, and the sum of the sum total of the derivative values in the MD direction and the sum total of the derivative values in the TD direction becomes the sum of the areas including the signs. Therefore, when it is said that the sum has a negative value, it is implied that the temporary adhesive tape generally exhibits a behavior of shrinkage between 40°C and 80°C.

In order to adjust the sum of the sum total of the derivative values in the MD direction and the sum total of the derivative values in the TD direction to a negative value, a step of stretching the resin film after film formation may be added, and thus, the thickness of the temporary adhesive tape

15 or the amount of stretch in the MD direction or the TD direction may be adjusted depending on the type of the resin that constitutes the temporary adhesive tape 15. Examples of the method of stretching the temporary adhesive tape in the TD direction include a method of using a tenter, a method involving blow molding (inflation), and a method of using an expanding roll. Examples of the method of stretching the temporary adhesive tape in the MD direction include a method of pulling at the time of extruding from a mold, and a method of pulling within conveying rolls. Regarding the method of obtaining the temporary adhesive tape 15 of the invention, any method may be used.

[0056] <Adhesive layer>

In the tape for glass processing 10 of the invention, the adhesive layer 13 is such that after glass is attached and diced, when chips are picked up, the adhesive layer 13 is detached from the temporary adhesive layer 12 and adheres to the chips. Then, the adhesive layer is used as an adhesive for fixing the chips onto a substrate or a lead frame.

[0057] The adhesive layer 13 is not particularly limited; however, the adhesive layer 13 may be any film-like adhesive that is generally used for glass, and examples thereof include film-like adhesives containing thermoplastic resins and thermally polymerizable components. The thermoplastic resin

used for the adhesive layer 13 of the invention is preferably a resin having thermoplasticity, or a resin which has thermoplasticity in an uncured state and forms a crosslinked structure after being heated. There are no particular limitations; however, according to an embodiment, a thermoplastic resin having a weight average molecular weight of 5,000 to 200,000 and a glass transition temperature of 0°C to 150°C may be used. Furthermore, according to another embodiment, a thermoplastic resin having a weight average molecular weight of 100,000 to 1,000,000 and a glass transition temperature of -50°C to 20°C may be used.

[0058] Examples of the former thermoplastic resin include a polyimide resin, a polyamide resin, a polyetherimide resin, a polyamideimide resin, a polyester resin, a polyesterimide resin, a phenoxy resin, a polysulfone resin, a polyether sulfone resin, a polyphenylene sulfide resin, and a polyether ketone resin. Among them, it is preferable to use a polyimide resin or a phenoxy resin. Regarding the latter thermoplastic resin, it is preferable to use a polymer containing a functional group.

[0059] A polyimide resin can be obtained by subjecting a tetracarboxylic acid dianhydride and a diamine to a condensation reaction by a known method. That is, an addition reaction is carried out in an organic solvent using a tetracarboxylic acid dianhydride and a diamine in equimolar amounts or in almost equimolar amounts (the order of adding the

various components is arbitrary) at a reaction temperature of 80°C or lower, and preferably 0°C to 60°C. As the reaction progresses, the viscosity of the reaction liquid slowly increases, and a polyamide acid, which is a precursor of polyimide, is produced. For this polyamide acid, its molecular weight can be regulated by subjecting the polyamide acid to depolymerization by heating the compound at a temperature of 50°C to 80°C. The polyimide resin can be obtained by subjecting the reaction product (polyamide acid) to dehydration cyclization. The dehydration cyclization can be carried out by a thermal cyclization method of performing a heat treatment, and a chemical cyclization method of using a dehydrating agent.

[0060] The tetracarboxylic acid dianhydride used as a raw material of a polyimide resin is not particularly limited, and for example, 1,2-(ethylene)bis(trimellitic anhydride), 1,3-(trimethylene)bis(trimellitic anhydride), 1,4-(tetramethylene)bis(trimellitic anhydride), 1,5-(pentamethylene)bis(trimellitic anhydride), 1,6-(hexamethylene)bis(trimellitic anhydride), 1,7-(heptamethylene)bis(trimellitic anhydride), 1,8-(octamethylene)bis(trimellitic anhydride), 1,9-(nonamethylene)bis(trimellitic anhydride), 1,10-(decamethylene)bis(trimellitic anhydride), 1,12-(dodecamethylene)bis(trimellitic anhydride), 1,16-(hexadecamethylene)bis(trimellitic anhydride),

1,18-(octadecamethylene)bis(trimellitic anhydride),
 pyromellitic dianhydride, 3,3',4,4'-biphenyltetracarboxylic
 acid dianhydride, 2,2',3,3'-biphenyltetracarboxylic acid
 dianhydride, 2,2-bis(3,4-dicarboxyphenyl)propane dianhydride,
 2,2-bis(2,3-dicarboxyphenyl)propane dianhydride,
 1,1-bis(2,3-dicarboxyphenyl)ethane dianhydride,
 1,1-bis(3,4-dicarboxyphenyl)ethane dianhydride,
 bis(2,3-dicarboxyphenyl)methane dianhydride,
 bis(3,4-dicarboxyphenyl)methane dianhydride,
 bis(3,4-dicarboxyphenyl)sulfone dianhydride,
 3,4,9,10-perylenetetracarboxylic acid dianhydride,
 bis(3,4-dicarboxyphenyl) ether dianhydride,
 benzene-1,2,3,4-tetracarboxylic acid dianhydride,
 3,4,3',4'-benzophenonetetracarboxylic acid dianhydride,
 2,3,2',3'-benzophenonetetracarboxylic acid dianhydride,
 3,3,3',4'-benzophenonetetracarboxylic acid dianhydride,
 1,2,5,6-naphthalenetetracarboxylic acid dianhydride,
 1,4,5,8-naphthalenetetracarboxylic acid dianhydride,
 2,3,6,7-naphthalenetetracarboxylic acid dianhydride,
 1,2,4,5-naphthalenetetracarboxylic acid dianhydride,
 2,6-dichloronaphthalene-1,4,5,8-tetracarboxylic acid
 dianhydride,
 2,7-dichloronaphthalene-1,4,5,8-tetracarboxylic acid
 dianhydride,
 2,3,6,7-tetrachloronaphthalene-1,4,5,8-tetracarboxylic acid

dianhydride, phenanthrene-1,8,9,10-tetracarboxylic acid
 dianhydride, pyrazine-2,3,5,6-tetracarboxylic acid
 dianhydride, thiophene-2,3,5,6-tetracarboxylic acid
 dianhydride, 2,3,3',4'-biphenyltetracarboxylic acid
 dianhydride, 3,4,3',4'-biphenyltetracarboxylic acid
 dianhydride, 2,3,2',3'-biphenyltetracarboxylic acid
 dianhydride, bis(3,4-dicarboxyphenyl)dimethylsilane
 dianhydride, bis(3,4-dicarboxyphenyl)methylphenylsilane
 dianhydride, bis(3,4-dicarboxyphenyl)diphenylsilane
 dianhydride,
 1,4-bis(3,4-dicarboxyphenyldimethylsilyl)benzene
 dianhydride,
 1,3-bis(3,4-dicarboxyphenyl)-1,1,3,3-tetramethyldicyclohexa
 ne dianhydride, p-phenylene bis(trimellitic anhydride),
 ethylenetetracarboxylic acid dianhydride,
 1,2,3,4-butanetetracarboxylic acid dianhydride,
 decahydronaphthalene-1,4,5,8-tetracarboxylic acid
 dianhydride,
 4,8-dimethyl-1,2,3,5,6,7-hexahydronaphthalene-1,2,5,6-tetra
 carboxylic acid dianhydride,
 cyclopentane-1,2,3,4-tetracarboxylic acid dianhydride,
 pyrrolidine-2,3,4,5-tetracarboxylic acid dianhydride,
 1,2,3,4-cyclobutanetetracarboxylic acid dianhydride,
 bis(exo-bicyclo[2,2,1]heptane-2,3-dicarboxylic acid
 dianhydride,

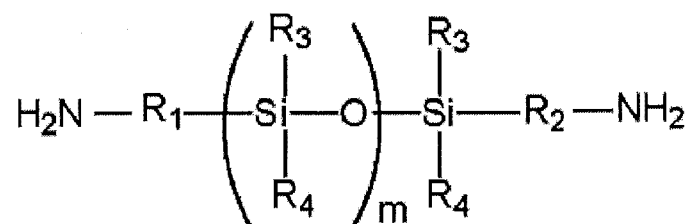
bicyclo[2,2,2]-oct-7-ene-2,3,5,6-tetracarboxylic acid
 dianhydride, 2,2-bis(3,4-dicarboxyphenyl)hexafluoropropane
 dianhydride,
 2,2-bis[4-(3,4-dicarboxyphenyl)phenyl]hexafluoropropane
 dianhydride, 4,4'-bis(3,4-dicarboxyphenoxy)diphenyl sulfide
 dianhydride, 1,4-bis(2-hydroxyhexafluoroisopropyl)benzene
 bis(trimellitic anhydride),
 1,3-bis(2-hydroxyhexafluoroisopropyl)benzene
 bis(trimellitic anhydride),
 5-(2,5-dioxotetrahydrofuryl)-3-methyl-3-cyclohexene-1,2-dic
 arboxylic acid dianhydride,
 tetrahydrofuran-2,3,4,5-tetracarboxylic acid dianhydride,
 and the like can be used. These compounds can be used singly
 or in combination of two or more kinds thereof.

[0061] The diamine used as a raw material of polyimide is
 not particularly limited, and for example, aromatic diamines
 such as o-phenylenediamine, m-phenylenediamine,
 p-phenylenediamine, 3,3'-diaminodiphenyl ether,
 3,4'-diaminodiphenyl ether, 4,4'-diaminodiphenyl ether,
 3,3'-diaminodiphenylmethane, 3,4'-diaminodiphenylmethane,
 4,4'-diaminodiphenyl ether methane,
 bis(4-amino-3,5-dimethylphenyl)methane,
 bis(4-amino-3,5-diisopropylphenyl)methane,
 3,3'-diaminodiphenyldifluoromethane,
 3,4'-diaminodiphenyldifluoromethane,

4,4'-diaminodiphenyldifluormethane,
3,3'-diaminodiphenylsulfone, 3,4'-diaminodiphenylsulfone,
4,4'-diaminodiphenylsulfone, 3,3'-diaminodiphenyl sulfide,
3,4'-diaminodiphenyl sulfide, 4,4'-diaminodiphenyl sulfide,
3,3'-diaminodiphenyl ketone, 3,4'-diaminodiphenyl ketone,
4,4'-diaminodiphenyl ketone, 2,2-bis(3-aminophenyl)propane,
2,2'-(3,4'-diaminodiphenyl)propane,
2,2-bis(4-aminophenyl)propane,
2,2-bis(3-aminophenyl)hexafluoropropane,
2,2-(3,4'-diaminodiphenyl)hexafluoropropane,
2,2-bis(4-aminophenyl)hexafluoropropane,
1,3-bis(3-aminophenoxy)benzene,
1,4-bis(3-aminophenoxy)benzene,
1,4-bis(4-aminophenoxy)benzene,
3,3'-(1,4-phenylenebis(1-methylethylidene))bis(aniline),
3,4'-(1,4-phenylenebis(1-methylethylidene))bis(aniline),
4,4'-(1,4-phenylenebis(1-methylethylidene))bis(aniline),
2,2-bis(4-(3-aminophenoxy)phenyl)propane,
2,2-bis(4-(4-aminophenoxy)phenyl)propane,
2,2-bis(4-(3-aminophenoxy)phenyl)hexafluoropropane,
2,2-bis(4-(4-aminophenoxy)phenyl)hexafluoropropane,
bis(4-(3-aminophenoxy)phenyl) sulfide,
bis(4-(4-aminophenoxy)phenyl) sulfide,
bis(4-(3-aminophenoxy)phenyl) sulfone,
bis(4-(4-aminophenoxy)phenyl) sulfone, and 3,5-diaminobenzoic

acid; and aliphatic diamines such as 1,2-diaminoethane, 1,3-diaminopropane, 1,4-diaminobutane, 1,5-diaminopentane, 1,6-diaminohexane, 1,7-diaminoheptane, 1,8-diaminooctane, 1,9-diaminononane, 1,10-diaminodecane, 1,11-diaminoundecane, 1,12-diaminododecane, 1,2-diaminocyclohexane, a diaminopolysiloxane represented by the following General Formula (1), 1,3-bis(aminomethyl)cyclohexane, and polyoxyalkylenediamines such as JEFFAMINE D-230, D-400, D-2000, D-4000, ED-600, ED-900, ED-2001 and EDR-148 manufactured by Sun Techno Chemical Co., Ltd.; and the like can be used. These compounds can be used singly or in combination of two or more kinds thereof. The glass transition temperature of the polyimide resin is preferably 0°C to 200°C, and the weight average molecular weight is preferably 10,000 to 200,000.

[Chemical Formula 1]



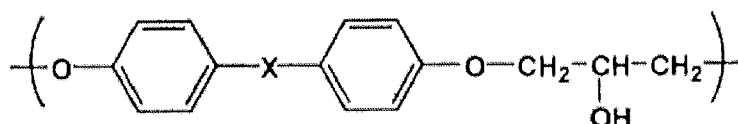
wherein R₁ and R₂ each represent a divalent hydrocarbon group having 1 to 30 carbon atoms and may be respectively identical or different; R₃ and R₄ each represent a monovalent hydrocarbon group and may be respectively identical or different; and m represents an integer of 1 or greater.

[0062] Regarding the phenoxy resin, which is one of the

preferred thermoplastic resins in addition to those described above, a resin obtainable by a method of reacting various bisphenols with epichlorohydrin, or a method of reacting a liquid epoxy resin with a bisphenol is preferred. Examples of the bisphenol include bisphenol A, bisphenol-bisphenol AF, bisphenol AD, bisphenol F, and bisphenol S. Since a phenoxy resin has a structure analogous to that of an epoxy resin, a phenoxy resin has high compatibility with epoxy resins and is suitable for imparting satisfactory adhesiveness to an adhesive film.

[0063] An example of the phenoxy resin used for the invention is a resin having a repeating unit represented by the following General Formula (2):

[Chemical Formula 2]



[0064] In General Formula (2) described above, X represents a single bond or a divalent linking group. Examples of the divalent linking group include an alkylene group, a phenylene group, -O-, -S-, -SO-, and -SO₂-. Here, the alkylene group is preferably an alkylene group having 1 to 10 carbon atoms, and more preferably -C(R₁)(R₂)-. R₁ and R₂ each represent a hydrogen atom or an alkyl group. The alkyl group is preferably a linear or branched alkyl group having 1 to 8 carbon atoms,

and examples thereof include methyl, ethyl, n-propyl, isopropyl, isooctyl, 2-ethylhexyl, and 1,3,3-trimethylbutyl.

Furthermore, the alkyl group may be substituted with a halogen atom, and examples thereof include a trifluoromethyl group. X is preferably an alkylene group, -O-, -S-, a fluorene group, or -SO₂-, and more preferably an alkylene group or -SO₂-. Among them, -C(CH₃)₂-, -CH(CH₃)-, -CH₂-, and -SO₂- are preferred; -C(CH₃)₂-, -CH(CH₃)-, and -CH₂- are more preferred; and -C(CH₃)₂- is particularly preferred.

[0065] When the phenoxy resin represented by General Formula (2) has repeating units, the phenoxy resin may be a resin having a plurality of repeating units with different X's of the above-described General Formula (2), or the phenoxy resin may be composed only of repeating units with identical X's. According to the invention, a resin composed only of repeating units with identical X's is preferred.

[0066] Furthermore, when a polar substituent such as a hydroxyl group or a carboxyl group is incorporated into the phenoxy resin represented by General Formula (2), compatibility with a thermally polymerizable component is enhanced, and a uniform external appearance or uniform characteristics can be imparted.

[0067] When the mass average molecular weight of the phenoxy resin is 5,000 or more, it is excellent from the viewpoint of the film-forming properties. The mass average

molecular weight is more preferably 10,000 or more, and even more preferably 30,000 or more. Furthermore, when the mass average molecular weight is 150,000 or less, it is preferable from the viewpoints of fluidity at the time of thermal pressure bonding, and compatibility with other resins. The mass average molecular weight is more preferably 100,000 or less.

Furthermore, when the glass transition temperature is -50°C or higher, it is excellent from the viewpoint of film-forming properties, and the glass transition temperature is more preferably 0°C or higher, and even more preferably 50°C or higher. When the glass transition temperature is 150°C , excellent adhesive force of the adhesive layer 13 is obtained at the time of die bonding, and the glass transition temperature is more preferably 120°C or lower, and even more preferably 110°C or lower.

[0068] On the other hand, examples of the functional group for the above-described polymer containing a functional group include a glycidyl group, an acryloyl group, a methacryloyl group, a hydroxyl group, a carboxyl group, an isocyanurate group, an amino group, and an amide group, and among them, a glycidyl group is preferred.

[0069] Examples of the high-molecular weight component containing a functional group include (meth)acrylic copolymers containing functional groups such as a glycidyl group, a hydroxyl group, and a carboxyl group.

[0070] Regarding the (meth)acrylic copolymers, for example, a (meth)acrylic ester copolymer and an acrylic rubber can be used, and an acrylic rubber is preferred. An acrylic rubber is a rubber which contains an acrylic acid ester as a main component and is mainly formed of a copolymer of butyl acrylate and acrylonitrile or the like, or a copolymer of ethyl acrylate and acrylonitrile or the like.

[0071] In a case in which the compound contains a glycidyl group as a functional group, the amount of a glycidyl group-containing repeating unit is preferably 0.5% to 6.0% by weight, more preferably 0.5% to 5.0% by weight, and particularly preferably 0.8% to 5.0% by weight. A glycidyl group-containing repeating unit is a constituent monomer for a (meth)acrylic copolymer containing glycidyl groups, and specific examples thereof include glycidyl acrylate and glycidyl methacrylate. When the amount of the glycidyl group-containing repeating unit is in this range, adhesive force can be secured, and also, gelation can be prevented.

[0072] Examples of the constituent monomer for the (meth)acrylic copolymer other than glycidyl acrylate and glycidyl methacrylate, include ethyl (meth)acrylate and butyl (meth)acrylate, and these can be used singly or in combination of two or more kinds thereof. Meanwhile, according to the invention, ethyl (meth)acrylate represents ethyl acrylate and/or ethyl methacrylate. The mixing ratio in the case of

using functional monomers in combination may be determined in consideration of the glass transition temperature of the (meth)acrylic copolymer. When the glass transition temperature is adjusted to -50°C or higher, it is preferable from the viewpoint that excellent film-forming properties are obtained, and excessive tack at normal temperature can be suppressed. When the tack force at normal temperature is excessive, handling of the adhesive layer becomes difficult. The glass transition temperature is more preferably -20°C or higher, and even more preferably 0°C or higher. Also, when the glass transition temperature is adjusted to 30°C or lower, it is excellent from the viewpoint of the adhesive force of the adhesive layer at the time of die bonding, and the glass transition temperature is more preferably 20°C or lower.

[0073] In a case in which a high-molecular weight component containing a functional monomer is produced by polymerizing the above-mentioned monomers, the polymerization method therefor is not particularly limited, and for example, methods such as pearl polymerization and solution polymerization can be used. Above all, pearl polymerization is preferred.

[0074] According to the invention, when the weight average molecular weight of the high-molecular weight component containing a functional monomer is 100,000 or more, it is excellent from the viewpoint of the film-forming properties, and the weight average molecular weight is more preferably

200,000 or more, and even more preferably 500,000 or more. Furthermore, when the weight average molecular weight is adjusted to 2,000,000 or less, it is excellent from the viewpoint that the hot fluidity of the adhesive layer at the time of die bonding is increased. When the hot fluidity of the adhesive layer at the time of die bonding is increased, the adhesion between the adhesive layer and the adherend is improved, and the adhesive force can be increased. Also, the surface unevenness of the adherend is embedded, and thus voids can be easily suppressed. The weight average molecular weight is more preferably 1,000,000 or less, and still more preferably 800,000 or less, and when the weight average molecular weight is adjusted to 500,000 or less, superior effects can be obtained.

[0075] Furthermore, the thermally polymerizable component is not particularly limited as long as the thermally polymerizable component can be polymerized by heat, and examples thereof include compounds having functional groups such as a glycidyl group, an acryloyl group, a methacryloyl group, a hydroxyl group, a carboxyl group, an isocyanurate group, an amino group, and an amide group; and trigger materials. These compounds can be used singly or in combination of two or more kinds thereof; however, when the heat resistance of the adhesive layer is considered, it is preferable that the adhesive layer contains a thermosetting resin that is cured by heat and exerts an adhesive action, together with a curing agent and an

accelerator. Examples of the thermosetting resin include an epoxy resin, an acrylic resin, a silicone resin, a phenolic resin, a thermosetting polyimide resin, a polyurethane resin, a melamine resin, and a urea resin. Particularly, from the viewpoint of obtaining an adhesive layer having excellent heat resistance, workability, and reliability, it is most preferable to use an epoxy resin.

[0076] The epoxy resin is not particularly limited so long as the epoxy resin is cured and acquires adhesive action, and a bifunctional epoxy resin such as bisphenol A epoxy, or a novolac type epoxy resin such as a phenol novolac type epoxy resin or a cresol novolac type epoxy resin can be used. Also, generally known epoxy resins such as a polyfunctional epoxy resin, a glycidylamine type epoxy resin, a heterocyclic ring-containing epoxy resin, and an alicyclic epoxy resin can be applied.

[0077] Examples of the bisphenol A type epoxy resin include EPIKOTE series (EPIKOTE 807, EPIKOTE 815, EPIKOTE 825, EPIKOTE 827, EPIKOTE 828, EPIKOTE 834, EPIKOTE 1001, EPIKOTE 1004, EPIKOTE 1007, and EPIKOTE 1009) manufactured by Mitsubishi Chemical Corp.; DER-330, DER-301, and DER-361 manufactured by Dow Chemical Co.; and YD8125 and YDF8170 manufactured by Nippon Steel & Sumikin Chemical Co., Ltd. Examples of the phenol novolac type epoxy resin include EPIKOTE 152 and EPIKOTE 154 manufactured by Mitsubishi Chemical Corp.; EPPN-201

manufactured by Nippon Kayaku Co., Ltd.; and DEN-438 manufactured by Dow Chemical Co. Examples of the o-cresol novolac type epoxy resin include EOCN-102S, EOCN-103S, EOCN-104S, EOCN-1012, EOCN-1025, and EOCN-1027 manufactured by Nippon Kayaku Co., Ltd.; and YDCN701, YDCN702, YDCN703 and YDCN704 manufactured by Nippon Steel & Sumikin Chemical Co., Ltd. Examples of the polyfunctional epoxy resin include Epon1031S manufactured by Mitsubishi Chemical Corp.; ARALDITE 0163 manufactured by Ciba Specialty Chemicals Corp.; and DENACOL EX-611, EX-614, EX-614B, EX-622, EX-512, EX-521, EX-421, EX-411 and EX-321 manufactured by Nagase Chemtex Corp. Examples of the amine type epoxy resin include EPIKOTE 604 manufactured by Mitsubishi Chemical Corp.; YH-434 manufactured by Tohto Chemical Industry Co., Ltd.; TETRAD-X and TETRAD-C manufactured by Mitsubishi Gas Chemical Co., Inc.; and ELM-120 manufactured by Sumitomo Chemical Co., Ltd. Examples of the heterocyclic ring-containing epoxy resin include ARALDITE PT810 manufactured by Ciba Specialty Chemicals Corp.; ERL4234, ERL4299, ERL4221 and ERL4206 manufactured by Union Carbide Corp. These epoxy resins can be used singly or in combination of two or more kinds thereof.

[0078] In order to cure the thermosetting resin, additives can be added thereto as appropriate. Examples of such additives include a curing agent, a curing accelerator, and a catalyst. In the case of adding a catalyst, a co-catalyst can be used as

necessary.

[0079] In a case in which an epoxy resin is used as the thermosetting resin, it is preferable to use an epoxy resin curing agent or a curing accelerator, and it is more preferable to use these in combination. Examples of the curing agent include a phenolic resin, dicyandiamide, a boron trifluoride complex compound, an organic hydrazide compound, an amine, a polyamide resin, an imidazole compound, a urea or thiourea compound, a polymercaptan compound, a polysulfide resin having mercapto groups at the terminals, an acid anhydride, and a light/ultraviolet curing agent. These can be used singly or in combination of two or more kinds thereof.

Among these, examples of the boron trifluoride complex compound include boron trifluoride-amine complexes with various amine compounds (preferably, primary amine compounds), and examples of the organic hydrazide compound include isophthalic acid dihydrazide.

[0080] Examples of the phenolic resin include novolac type phenolic resins such as a phenol novolac resin, a phenol aralkyl resin, a cresol novolac resin, a tert-butylphenol novolac resin, and a nonylphenol novolac resin; a resol type phenolic resin, and a polyoxystyrene such as poly(para-oxystyrene). Among them, a phenolic compound having at least two phenolic hydroxyl groups in the molecule is preferred.

[0081] Examples of the phenolic compound having at least

two phenolic hydroxyl groups in the molecule include a phenol novolac resin, a cresol novolac resin, a t-butylphenol novolac resin, a dicyclopentadiene cresol novolac resin, a dicyclopentadiene phenol novolac resin, a xylylene-modified phenol novolac resin, a naphthol novolac resin, a trisphenol novolac resin, a tetrakisphenol novolac resin, a bisphenol A novolac resin, a poly(p-vinylphenol) resin, and a phenol aralkyl resin. Furthermore, among these phenolic resins, a phenol novolac resin and a phenol aralkyl resin are particularly preferred, and these can enhance the connection reliability.

[0082] Examples of the amine include chain-like aliphatic amines (diethylenetriamine, triethylenetetramine, hexamethylenediamine, N,N-dimethylpropylamine, benzyldimethylamine, 2-(dimethylamino)phenol, 2,4,6-tris(dimethylaminomethyl)phenol, m-xylenediamine, and the like), cyclic aliphatic amines (N-aminoethylpiperazine, bis(3-methyl-4-aminocyclohexyl)methane, bis(4-aminocyclohexyl)methane, menthenediamine, isophoronediamine, 1,3-bis(aminomethyl)cyclohexane, and the like), heterocyclic amines (piperazine, N,N-dimethylpiperazine, triethylenediamine, melamine, guanamine, and the like), aromatic amines (meta-phenylenediamine, 4,4'-diaminodiphenylmethane, diamino-4,4'-diaminodiphenylsulfone, and the like), polyamide resins (polyamidoamine is preferred; condensation product of

a dimer acid and a polyamine), imidazole compounds (2-phenyl-4,5-dihydroxymethylimidazole, 2-methylimidazole, 2,4-dimethylimidazole, 2-n-heptadecylimidazole, 1-cyanoethyl-2-undecylimidazolium trimellitate, an epoxy-imidazole adduct, and the like), urea or thiourea compounds (an N,N-dialkylurea compound, an N,N-dialkylthiourea compound, and the like), polymercaptan compounds, polysulfide resins having mercapto groups at the terminals, acid anhydrides (tetrahydrophthalic anhydride and the like), and light/ultraviolet curing agents (diphenyliodonium hexafluorophosphate, triphenylsulfonium hexafluorophosphate, and the like).

[0083] The curing accelerator is not particularly limited so long as it is capable of curing a thermosetting resin, and examples thereof include an imidazole, a dicyandiamide derivative, a dicarboxylic acid dihydrazide, triphenylphosphine, tetraphenylphosphonium tetraphenylborate, 2-ethyl-4-methylimidazole-tetraphenylborate, and 1,8-diazabicyclo[5.4.0]undecene-7-tetraphenylborate.

Examples of the imidazole include imidazole, 2-methylimidazole, 2-ethylimidazole, 2-ethyl-4-methylimidazole, 2-phenylimidazole, 2-phenyl-4-methylimidazole, 1-benzyl-2-methylimidazole, 1-benzyl-2-ethylimidazole, 1-benzyl-2-ethyl-5-methylimidazole,

2-phenyl-4-methyl-5-hydroxydimethylimidazole, and
2-phenyl-4,5-dihydroxymethylimidazole.

[0084] The content of the curing agent for an epoxy resin or the curing accelerator in the adhesive layer is not particularly limited, and the optimal content varies depending on the type of the curing agent or the curing accelerator.

[0085] Regarding the mixing proportions of the epoxy resin and the phenolic resin, for example, it is preferable that the resins are mixed such that the mixing proportion of hydroxyl groups in the phenolic resin is 0.5 to 2.0 equivalents per equivalent of epoxy groups in the epoxy resin components. The proportion of hydroxyl groups is more preferably 0.8 to 1.2 equivalents. That is, it is because when the mixing proportions of the two components are not in the range described above, the curing reaction does not proceed sufficiently, and the characteristics of the adhesive layer are easily deteriorated. Regarding the other thermosetting resins and the curing agent, according to an embodiment, the mixing proportion of the curing agent is 0.5 to 20 parts by mass with respect to 100 parts by mass of the thermosetting resins, and according to another embodiment, the mixing proportion of the curing agent is 1 to 10 parts by mass. It is preferable that the content of the curing accelerator is smaller than the content of the curing agent, and the content of the curing accelerator is preferably 0.001 to 1.5 parts by mass, and more preferably 0.01 to 0.95

parts by mass, with respect to 100 parts by mass of the thermosetting resins. When the content of the curing accelerator is adjusted to the range described above, the curing accelerator can assist sufficient progress of the curing reaction. The content of the catalyst is preferably 0.001 to 1.5 parts by mass, and more preferably 0.01 to 1.0 part by mass, with respect to 100 parts by mass of the thermosetting resins.

[0086] Furthermore, the adhesive layer 13 of the invention can have a filler incorporated therein as appropriate according to the use. Thereby, enhancement of diceability, enhancement of handleability, adjustment of the melt viscosity, and impartment of thixotropy can be promoted for the adhesive layer in an uncured state, and impartment of the thermal conductivity and enhancement of the adhesive force can be promoted for the adhesive layer in a cured state.

The filler used for the invention is preferably an inorganic filler. The inorganic filler is not particularly limited, and for example, aluminum hydroxide, magnesium hydroxide, calcium carbonate, magnesium carbonate, calcium silicate, magnesium silicate, calcium oxide, magnesium oxide, alumina, aluminum nitride, aluminum borate whiskers, boron nitride, crystalline silica, amorphous silica, and antimony oxide can be used. Also, these can be used as single substances or as mixtures of two or more kinds thereof.

[0087] Furthermore, among the inorganic fillers described

above, from the viewpoint of enhancing thermal conductivity, it is preferable to use alumina, aluminum nitride, boron nitride, crystalline silica, amorphous silica, or the like.

Furthermore, from the viewpoint of adjusting the melt viscosity or imparting thixotropy, it is preferable to use aluminum hydroxide, magnesium hydroxide, calcium carbonate, magnesium carbonate, calcium silicate, magnesium silicate, calcium oxide, magnesium oxide, alumina, crystalline silica, amorphous silica, or the like. Also, from the viewpoint of enhancing diceability, it is preferable to use alumina or silica.

[0088] The adhesive layer of the invention may contain two or more kinds of fillers having different average particle sizes as the filler. In this case, compared to the case of using a single filler, a viscosity increase in a case in which the content proportion of the filler is high in the raw material mixture before film formation, or a viscosity decrease in a case in which the content proportion of the filler is low, can be easily prevented. Satisfactory film-forming properties can be easily obtained, and the fluidity of an uncured adhesive layer can be optimally controlled. In addition, after curing of the adhesive layer, excellent adhesive force is easily obtained.

[0089] Furthermore, regarding the adhesive layer of the invention, the average particle size of the filler is preferably 2.0 μm or less, and more preferably 1.0 μm or less. When the average particle size of the filler is 2.0 μm or less, thickness

reduction of the film is easily achieved. Here, a thin film suggests a thickness of 20 μm or less. Also, when the average particle size is 0.01 μm or more, satisfactory dispersibility is obtained.

Moreover, from the viewpoint of preventing any increase or decrease in the viscosity of the raw material mixture before film formation, optimally controlling the fluidity of an uncured adhesive layer, and increasing the adhesive force after curing of the adhesive layer, it is preferable that the adhesive layer contains a first filler having an average particle size in the range of 0.1 to 1.0 μm , and a second filler having an average particle size of the primary particle size in the range of 0.005 to 0.03 μm . It is preferable that the adhesive layer contains a first filler which has an average particle size in the range of 0.1 to 1.0 μm and in which 99% or more of the particles are distributed within the particle size range of 0.1 to 1.0 μm , and a second filler which has an average particle size of the primary particle size in the range of 0.005 to 0.03 μm and in which 99% or more of the particles are distributed within the particle size range of 0.005 to 0.1 μm .

The average particle size according to the invention means the D50 value of a cumulative volume distribution curve, at which 50% by volume of particles have diameters smaller than this value. According to the invention, the average particle size or the D50 value is measured by a laser diffraction method,

for example, using Malvern Mastersizer 2000 manufactured by Malvern Instruments, Ltd. According to this technology, the size of particles in a liquid dispersion is measured using the diffraction of laser light based on the application of any one of the Fraunhofer theory or the Mie theory. According to the invention, the Mie theory is utilized or a modified Mie theory for non-spherical particles is utilized, and the average particle size or the D50 value relates to a scattering analysis measured in the range of 0.02° to 135° with respect to incident laser light.

[0090] According to an embodiment of the invention, the temporary adhesive composition that constitutes the adhesive layer 13 may include 10% to 40% by mass of a thermoplastic resin having a weight average molecular weight of 5,000 to 200,000; 10% to 40% by mass of a thermally polymerizable component; and 30% to 75% by mass of a filler, relative to the total amount of the temporary adhesive composition. In this embodiment, the content of the filler may be 30% to 60% by mass or may be 40% to 60% by mass. Furthermore, the mass average molecular weight of the thermoplastic resin may be 5,000 to 150,000 or may be 10,000 to 100,000.

According to another embodiment, the temporary adhesive composition that constitutes the adhesive layer 13 may include 10% to 20% by mass of a thermoplastic resin having a weight average molecular weight of 200,000 to 2,000,000; 20% to 50%

by mass of a thermally polymerizable component; and 30% to 75% by mass of a filler, with respect to the total amount of the temporary adhesive composition. In this embodiment, the content of the filler may be 30% to 60% by mass or may be 30% to 50% by mass. Furthermore, the mass average molecular weight of the thermoplastic resin may be 200,000 to 1,000,000 or may be 200,000 to 800,000.

The storage modulus and fluidity after curing of the adhesive layer 13 can be optimized by adjusting the mixing ratio, and there is also a tendency that sufficient heat resistance at high temperature is obtained.

[0091] It is preferable that the adhesive layer 13 has a light transmittance of 90% or higher to light having a wavelength of 550 nm. In the case of a device having a structure in which glass is laminated on top of an image sensor, with an adhesive layer interposed therebetween, when the light transmittance is lower than 90%, there is a possibility that the sensor may not work reliably. The light transmittance can be generally adjusted by means of the mixing composition of the adhesive layer, and particularly by selecting an appropriate base resin and an appropriate filler, mounting reliability and high transmittance can be obtained in a well-balanced manner. The light transmittance can be adjusted by making the filler particle size small and thereby suppressing the scattering of light, increasing the transmittance, and the like. As a resin

having a high transmittance, for example, an epoxy resin or a silicone resin is preferably used, and in order to obtain both high transmittance and mounting reliability, a bisphenol type epoxy resin is particularly preferably used; however, the resins are not limited to these.

[0092] The light transmittance can be determined by measuring the amount of transmitted light using a spectrophotometer (manufactured by Hitachi High-Technologies Corp., spectrophotometer U-4100 type solid sample measurement system). Specifically, an adhesive layer having a thickness of 20 μm is laminated to glass, light is allowed to penetrate in a normal direction with respect to the glass surface, and the light transmittance to glass at 550 nm at 25°C is determined. Specifically, the light transmittance is calculated by the following formula (2).

$$\text{Light transmittance } I \text{ (\%)} \text{ of adhesive layer} = I_1/I_0$$

(2)

I_1 (%): Light transmittance of glass including the adhesive layer

I_0 (%): Light transmittance of glass

[0093] With regard to the tape for glass processing 10 of the invention, the adhesive layer 13 may be formed by laminating a layer that has been formed into a film in advance (hereinafter, referred to as an adhesive film) directly or indirectly on the substrate film 11. It is preferable that the temperature at

the time of lamination is adjusted to the range of 10°C to 100°C, and a linear pressure of 0.01 to 10 N/m is applied to the laminate. Meanwhile, such an adhesive film may be an adhesive layer 13 formed on a release film, and in that case, the release film may be peeled off after lamination, or the release film may be used directly as a cover film for the tape for glass processing 10 and peeled off at the time of laminating glass thereto.

[0094] The adhesive film may be laminated over the entire surface of the temporary adhesive layer 12; however, an adhesive film that has been cut out in advance (precut) into a shape corresponding to the shape of the glass to be laminated may be laminated on the temporary adhesive layer 12. As such, in a case in which an adhesive film corresponding to glass is laminated, as illustrated in Fig. 3, in the area where glass W is to be laminated, there is the adhesive layer 13. In the area where a ring frame 20 is to be laminated, there is only the temporary adhesive layer 12, without the adhesive layer 13. Generally, since the adhesive layer 13 is not easily detached from an adherend, when a precut adhesive film is used, the ring frame 20 can be laminated to the temporary adhesive layer 12. Thus, an effect that adhesive residue is not likely to be generated on the ring frame 20 at the time of peeling the tape after use, is obtained.

[0095] <Use applications>

The tape for glass processing 10 of the invention is to

be used for a method for processing glass, the method including at least an expansion step of dividing the adhesive layer 13 through expansion. Therefore, there are no limitations on other additional steps, the order of the steps, and the like. For example, the tape for glass processing 10 can be suitably used for the following methods (A) to (C) for processing glass.

[0096] Method (A) for processing glass

A method for processing glass, the method including:

(a) a step of laminating an adhesive film that is laminated to the temporary adhesive layer of the tape for glass processing, to glass in a state in which the glass has been heated to 70°C to 80°C;

(b) a step of irradiating intended splitting parts of the glass with laser light, and forming regions modified by multiphoton absorption in the interior of the glass;

(c) a step of expanding the tape for semi-glass processing, thereby dividing the glass and the adhesive film along dividing lines, and obtaining a plurality of adhesive film-attached chips;

(d) a step of eliminating any slack produced during the expansion step by heat-shrinking parts of the tape for glass processing, the parts not overlapping with the chips, and maintaining the distances between the chips; and

(e) a step of picking up the chips having the adhesive layer adhered thereon, from the temporary adhesive layer of the

tape for glass processing.

The present method for processing glass is a method of using stealth dicing.

[0097] Method (B) for processing glass

A method for processing glass, the method including:

(a) a step of laminating the adhesive film laminated to the temporary adhesive layer of the tape for glass processing to glass in a state in which the glass has been heated to 70°C to 80°C;

(b) a step of irradiating the glass with laser light through the front surface along dividing lines, and dividing the glass into individual chips;

(c) a step of expanding the tape for glass processing, thereby dividing the adhesive film correspondingly to the chips, and obtaining a plurality of adhesive film-attached chips;

(d) a step of eliminating any slack produced during the expansion step by heat-shrinking parts of the tape for glass processing, the parts not overlapping with the chips, and maintaining the distances between the chips; and

(e) a step of picking up the chips having the adhesive layer adhered thereon, from the temporary adhesive layer of the tape for glass processing.

The present method for processing glass is a method of using full-cut laser dicing.

[0098] Method (C) for processing glass

A method for processing glass, the method including:

(a) a step of laminating an adhesive film laminated to the temporary adhesive layer of the tape for glass processing to glass in a state in which a wafer has been heated to 70°C to 80°C;

(b) a step of cutting the glass along dividing lines using a dicing blade, and dividing the glass into individual chips;

(c) a step of expanding the tape for glass processing, thereby dividing the adhesive film correspondingly to the chips, and obtaining a plurality of adhesive film-attached chips;

(d) a step of eliminating any slack produced during the expansion step, by heat-shrinking parts of the tape for glass processing, the parts not overlapping with the chips, and maintaining the distances between the chips; and

(e) a step of picking up the chips having the adhesive layer adhered thereon, from the temporary adhesive layer of the tape for glass processing.

The present method for processing glass is a method of using full-cut blade dicing.

[0099] <Method of use>

The method of using the tape for glass processing 10 according to the invention in a case in which the tape is applied to the method (A) for processing glass as described above, will be described with reference to Fig. 2 to Fig. 5.

[0100] As illustrated in Fig. 2, glass W is placed on a

heater table 25 of a wafer mounter, with the front surface side facing downward, and then a tape for glass processing 10 is laminated to the back surface of the glass W. The tape for glass processing 10 used herein is an adhesive tape obtained by laminating adhesive films that have been cut in advance (precut) into a shape corresponding to the shape of the glass W to be laminated, and on the surface that is to be laminated to the glass W, a temporary adhesive layer 12 is exposed in the periphery of the region where an adhesive layer 13 is exposed. This part where the adhesive layer 13 of the tape for glass processing 10 is exposed and the back surface of the glass W are laminated together, and also, the part where the temporary adhesive layer 12 is exposed in the periphery of the adhesive layer 13 and a ring frame 20 are laminated together. At this time, the heater table 25 is set to 70°C to 80°C, and thereby laminating by heating is carried out. Accidentally, in the present embodiment, a tape for glass processing 10 having a temporary adhesive tape 15 composed of a substrate film 11 and a temporary adhesive layer 12 provided on the substrate film 11; and an adhesive layer 13 provided on the temporary adhesive layer 12, is used; however, it is also acceptable to use a temporary adhesive tape and a film-like adhesive separately. In this case, first, a film-like adhesive is laminated to the back surface of glass to form an adhesive layer, and a temporary adhesive layer of a temporary adhesive tape is laminated to this

adhesive layer. At this time, the temporary adhesive tape 15 according to the invention is used as the temporary adhesive tape.

[0101] Next, the glass W having the tape for glass processing 10 laminated thereon is taken out from the top of the heater table 25, and as illustrated in Fig. 3, intended splitting parts of the glass W are irradiated with laser light so that regions 32 modified by multiphoton absorption are formed in the interior of the glass W.

[0102] Next, as illustrated in Fig. 4(a), the tape for glass processing 10, to which the glass W and the ring frame 20 are laminated, is placed on a stage 21 of an expansion apparatus, with the substrate film 11 side facing downward.

[0103] Next, as illustrated in Fig. 4(b), a hollow cylindrical-shaped thrust member 22 of the expansion apparatus is raised, in a state in which the ring frame 20 is fixed, and the tape for glass processing 10 is expanded (expansion). Regarding the conditions for expanding, the rate of expansion is, for example, 5 to 500 mm/sec, and the quantity of expansion (thrust quantity) is, for example, 5 to 25 mm. As the tape for glass processing 10 is stretched in the diameter direction of the glass W as such, the glass W is divided into individual units of chips 34, with the modified regions 32 acting as starting points. At this time, in the adhesive layer 13, elongation (deformation) caused by expansion is suppressed in the part that

is adhered to the back surface of the glass W, and fracture does not occur; however, at the positions between the chips 34, tension caused by expansion of the tape is concentrated, and fracture occurs. Therefore, as illustrated in Fig. 4(c), the adhesive layer 13 is also divided together with the glass W. Thereby, a plurality of chips 34 having the adhesive layer 13 adhered thereto can be obtained.

[0104] Next, as illustrated in Fig. 5, the thrust member 22 is returned to the original position, and a step of eliminating any slack in the tape for glass processing 10 produced during the previous expansion step and thereby stably maintaining the distances between the chips 34, is carried out. In this step, for example, an annular-shaped heat-shrinking region 28 between the ring frame 20 and the region where a chip 34 exists in the tape for glass processing 10, is exposed to hot air at 40°C to 120°C using a hot air nozzle 29, thereby the substrate film 11 is caused to heat-shrink, and the tape for glass processing 10 is brought into a taut state. Subsequently, the temporary adhesive layer 12 is subjected to an energy ray curing treatment, a thermal curing treatment, or the like, and the temporary adhesive force of the temporary adhesive layer 12 to the adhesive layer 13 is weakened. Then, the chips 34 are picked up.

[0105] The tape for glass processing 10 according to the present embodiment is configured to include an adhesive layer

13 on a temporary adhesive layer 12; however, the tape for glass processing 10 may also be configured not to include an adhesive layer 13. In this case, the tape for glass processing may be used in order to divide glass only, by laminating the glass onto the temporary adhesive layer 12, or it is also acceptable that at the time of using the tape for glass processing, an adhesive film produced in the same manner as in the case of the adhesive layer 13 is laminated onto the temporary adhesive layer 12 together with the glass, and the glass and the adhesive film are divided.

<Examples>

Next, in order to further clarify the effects of the invention, Examples and Comparative Examples will be described in detail; however, the invention is not intended to be limited to these Examples.

[0106] [Production of tape for glass processing]

(1) Production of substrate film

<Substrate film A>

Resin beads of a zinc ionomer of an ethylene-methacrylic acid-ethyl methacrylate copolymer synthesized by a radical polymerization method (methacrylic acid content: 15%, ethyl methacrylate content: 5%, softening point: 72°C, melting point: 90°C, density: 0.96 g/cm³, zinc ion content: 5% by mass) were melted at 230°C, and the molten resin beads were molded into a long film having a thickness of 150 μm using an extruder.

Subsequently, this long film was stretched in the TD direction so as to adjust the thickness to 90 μm , and thereby substrate film A was produced.

[0107] <Substrate film B>

Substrate film B was produced in the same manner as in the case of substrate film A, except that the long film was produced to have a thickness of 180 μm , and this long film was stretched in the TD direction so as to adjust the thickness to 90 μm .

[0108] <Substrate film C>

Substrate film C was produced in the same manner as in the case of substrate film A, except that the long film was produced to have a thickness of 215 μm , and this long film was stretched in the TD direction so as to adjust the thickness to 90 μm .

[0109] <Substrate film D>

Resin beads of a zinc ionomer of an ethylene-methacrylic acid-isobutyl methacrylate copolymer synthesized by a radical polymerization method (methacrylic acid content: 11%, isobutyl methacrylate content: 9%, softening point: 64°C, melting point: 83°C, density: 0.95 g/cm³, zinc ion content: 4% by mass) were melted at 230°C, and the molten resin beads were molded into a long film having a thickness of 150 μm using an extruder. Subsequently, this long film was stretched in the TD direction so as to adjust the thickness to 90 μm , and thereby substrate

film D was produced.

[0110] <Substrate film E>

Resin beads obtained by mixing a hydrogenated styrene-based thermoplastic elastomer and homopropylene (PP) at a mixing ratio of 52:48 were melted at 200°C, and the molten resin beads were molded into a long film having a thickness of 150 μm using an extruder. Subsequently, this long film was stretched in the TD direction so as to adjust the thickness to 90 μm , and thereby, substrate film E was produced.

[0111] <Substrate film F>

Resin beads obtained by mixing a hydrogenated styrene-based thermoplastic elastomer and homopropylene (PP) at a mixing ratio of 64:36 were melted at 200°C, and the molten resin beads were molded into a long film having a thickness of 150 μm using an extruder. Subsequently, this long film was stretched in the TD direction so as to adjust the thickness to 90 μm , and thereby, substrate film F was produced.

[0112] <Substrate film G>

Substrate film G was produced in the same manner as in the case of substrate film A, except that the long film was produced to have a thickness of 150 μm , and this long film was stretched in the MD direction so as to adjust the thickness to 90 μm .

[0113] <Substrate film H>

Substrate film H was produced in the same manner as in

the case of substrate film D, except that the long film was produced to have a thickness of 150 μm , and this long film was stretched in the MD direction so as to adjust the thickness to 90 μm .

[0114] <Substrate film I>

Substrate film I was produced in the same manner as in the case of substrate film A, except that the long film was produced to have a thickness of 90 μm , and this long film was not subjected to a stretching treatment.

[0115] <Substrate film J>

Substrate film J was produced in the same manner as in the case of substrate film D, except that the long film was produced to have a thickness of 90 μm , and this long film was not subjected to a stretching treatment.

[0116] <Substrate film K>

Substrate film K was produced in the same manner as in the case of substrate film E, except that the long film was produced to have a thickness of 90 μm , and this long film was not subjected to a stretching treatment.

[0117] <Substrate film L>

Substrate film L was produced in the same manner as in the case of substrate film F, except that the long film was produced to have a thickness of 90 μm , and this long film was not subjected to a stretching treatment.

[0118] <Substrate film M>

Substrate film M was produced in the same manner as in the case of substrate film A, except that the long film was produced to have a thickness of 110 μm , and this long film was stretched in the TD direction so as to adjust the thickness to 90 μm .

[0119] <Substrate film N>

Substrate film N was produced in the same manner as in the case of substrate film A, except that the long film was produced to have a thickness of 120 μm , and this long film was stretched in the TD direction so as to adjust the thickness to 90 μm .

[0120] (2) Preparation of acrylic copolymer

As an acrylic copolymer (A1) having functional groups, a copolymer comprising 2-ethylhexyl acrylate, 2-hydroxyethyl acrylate, and methacrylic acid, the copolymer having a proportion of 2-ethylhexyl acrylate of 60 mol% and a mass average molecular weight of 700,000, was prepared. Next, 2-isocyanatoethyl methacrylate was added thereto so as to obtain an iodine value of 25, and thereby an acrylic copolymer having a glass transition temperature of -50°C , a hydroxyl group value of 10 mg KOH/g, and an acid value of 5 mg KOH/g was prepared.

[0121] (3-1) Preparation of adhesive composition A

100 parts by mass of an epoxy resin, "1256" (manufactured by Mitsubishi Chemical Corp., bisphenol A type phenoxy resin, epoxy equivalent: 7,500), 100 parts by mass of an epoxy resin,

"828" (manufactured by Mitsubishi Chemical Corp., trade name, bisphenol A type liquid epoxy resin, epoxy equivalent: 220, specific gravity: 1.17), 4 parts by mass of a curing agent, "DICY7" (manufactured by Mitsubishi Chemical Corp., dicyandiamide), and 0.4 parts by mass of a curing accelerator, "CUREZOL 2PZ" (manufactured by Shikoku Chemical Corp., trade name, 2-phenyl-4,5-dihydroxymethylimidazole) were introduced, MEK was added thereto, and the resulting mixture was stirred and mixed until the mixture became uniform. Furthermore, this was filtered through a 100-mesh filter and subjected to vacuum defoaming, and thereby a varnish of an adhesive composition was obtained.

[0122] (3-2) Preparation of adhesive composition B

To a composition comprising 40 parts by mass of an epoxy resin, "1002" (manufactured by Mitsubishi Chemical Corp., solid bisphenol A type epoxy resin, epoxy equivalent: 600); 100 parts by mass of an epoxy resin, "806" (manufactured by Mitsubishi Chemical Corp., trade name, bisphenol F type epoxy resin, epoxy equivalent: 160, specific gravity: 1.20); 5 parts by mass of a curing agent, "Dyhard 100SF" (manufactured by Degussa AG, trade name, dicyandiamide); 200 parts by mass of a silica filler, "SO-C2" (manufactured by Admatechs Co., Ltd., trade name, average particle size: 0.5 μm); and 3 parts by mass of a silica filler, "AEROSIL R972" (manufactured by Nippon Aerosil Co., Ltd., trade name, average particle size of primary particle size:

0.016 μm), MEK was added, and the resulting mixture was stirred and mixed. Thus, a uniform composition was obtained.

To this, 100 parts by mass of a phenoxy resin, "PKHH" (manufactured by INCHEM Corp., trade name, mass average molecular weight: 52,000, glass transition temperature: 92°C), 0.6 parts by mass of "KBM-802" (manufactured by Shin-Etsu Silicone Co., Ltd., trade name, mercaptopropyltrimethoxysilane) as a coupling agent, and 0.5 parts by mass of "CUREZOL 2PHZ-PW" (manufactured by Shikoku Chemical Corp., trade name, 2-phenyl-4,5-dihydroxymethylimidazole, decomposition temperature: 230°C) as a curing accelerator were added, and the resulting mixture was stirred and mixed until the mixture became uniform. This was further filtered through a 100-mesh filter and subjected to vacuum defoaming, and thereby a varnish of an adhesive composition was obtained.

[0123] <Example 1>

A mixture obtained by adding 5 parts by mass of CORONATE L (manufactured by Nippon Polyurethane Industry Co., Ltd.) as a polyisocyanate and 3 parts by mass of Esacure KIP 150 (manufactured by Lamberti S.p.A.) as a photopolymerization initiator to 100 parts by mass of the above-mentioned acrylic copolymer, was dissolved in ethyl acetate, and the solution was stirred. Thus, a temporary adhesive composition was prepared.

Next, this temporary adhesive composition A was applied

on a release liner formed of a release-treated polyethylene terephthalate film to obtain a thickness after drying of 10 μm . The temporary adhesive composition was dried for 3 minutes at 110°C, and then this was laminated to a substrate film. Thus, a temporary adhesive sheet in which a temporary adhesive layer was formed on a substrate film was produced.

[0124] Next, the aforementioned adhesive composition A was applied on a release liner formed of a release-treated polyethylene terephthalate film to obtain a thickness after drying of 20 μm , and the adhesive composition was dried for 5 minutes at 110°C. Thus, an adhesive film in which an adhesive layer was formed on a release liner was produced.

[0125] The temporary adhesive sheet was cut into the shape shown in Fig. 3 and the like, such that the temporary adhesive sheet could be attached to a ring frame so as to cover the opening. Also, the adhesive film was cut into the shape shown in Fig. 3 and the like, such that the adhesive film could cover the back surface of glass. Then, the temporary adhesive layer side of the temporary adhesive sheet and the adhesive layer side of the adhesive film were attached together such that parts where the temporary adhesive layer 12 was exposed were formed in the periphery of the adhesive film as shown in Fig. 3 and the like, and thus a tape for glass processing was produced.

[0126] <Examples 2 to 8 and Comparative Examples 1 to 6>

Tapes for glass processing related to Examples 2 to 8 and

Comparative Examples 1 to 6 were produced by the same technique as that used in Example 1, except that the substrate films and the adhesive compositions described in Table 1 were used.

[0127] Each of the temporary adhesive tapes of the tapes for glass processing related to Examples and Comparative Examples was cut into a length of 24 mm (direction in which the quantity of deformation is to be measured) and a width of 5 mm (direction orthogonally intersecting the direction in which the quantity of deformation is to be measured), and the cut tape was used as a specimen. For the specimens thus obtained, temperature-induced deformation in two directions, namely, MD and TD, was measured using a thermomechanical characteristics testing machine (manufactured by Rigaku Corp., trade name: TMA8310) by a tensile loading method under the following measurement conditions.

(Measurement conditions)

Measurement temperature: -60°C to 100°C

Rate of temperature increase: 5°C/min

Measurement load: 19.6 mN

Atmosphere gas: nitrogen atmosphere (100 ml/min)

Sampling: 0.5 s

Distance between chucks: 20 mm

[0128] Then, the thermal deformation rate was calculated by the following Formula (1), the integral values calculated from the sum totals of the thermal deformation rates in the MD

direction and the TD direction, respectively, per 1°C between 40°C and 80°C were determined, and the sum of the integral values was calculated. The results are presented in Tables 1 and 2.

Thermal deformation rate TMA (%) = (Displacement in length of sample/sample length before measurement) × 100

(1)

[0129] [Evaluation of pick-up failure]

For each of the tapes for glass processing of the Examples and the Comparative Examples described above, glass was divided into chips, and the pick-up failure was evaluated, by the method described below.

[0130] The following steps were carried out:

(a) a step of irradiating intended splitting parts of the glass with laser light, and forming regions modified by multiphoton absorption in the interior of the glass;

(b) a step of laminating the adhesive layer of the tape for glass processing to the glass, in a state in which the glass has been heated to 70°C to 80°C;

(c) a step of expanding the tape for glass processing, thereby dividing the glass and the adhesive layer along dividing lines, and obtaining a plurality of adhesive film-attached chips;

(d) a step of eliminating any slack produced during the expansion step of (c), by heating and shrinking parts of the tape for glass processing, the parts not overlapping with the

chips (annular-shaped regions each formed between the ring frame and the region where a chip exists), and maintaining the distances between the chips; and

(e) a step of picking up the chips having the adhesive layer adhered thereto from the temporary adhesive layer of the tape for glass processing.

[0131] Incidentally, in step (b), glass was laminated to the tape for glass processing such that the dividing lines of the glass conformed to the MD direction and the TD direction of the substrate film.

[0132] In step (c), expansion was performed with DDS2300 manufactured by Disco Corp., by pressing down a ring frame for dicing that was laminated to the tape for glass processing, using an expansion ring of DDS2300 manufactured by Disco Corp., and thus pressing the part that did not overlap with the glass in the outer periphery of the glass- laminated site of the tape for glass processing, against a circular-shaped thrust member. Regarding the conditions for step (c), the quantity of expansion was adjusted so as to obtain a rate of expansion of 300 mm/sec and a height of expansion of 10 mm. Here, the quantity of expansion refers to the amount of change in the relative positions between the ring frame and the thrust member before pressing down and after pressing down. The chip size was adjusted to be 1 × 1 mm on the sides.

[0133] In step (d), expansion was performed again under

the conditions of a rate of expansion of 1 mm/sec and a height of expansion of 10 mm at room temperature, and then a heat-shrinking treatment was carried out under the following conditions.

[Conditions 1]

Set temperature of heater: 220°C

Amount of hot air: 40 L/min

Distance between heater and tape for glass processing:
20 mm

Speed of heater rotation: 7°/sec

[Conditions 2]

Set temperature of heater: 220°C

Amount of hot air: 40 L/min

Distance between heater and tape for glass processing:
20 mm

Speed of heater rotation: 5°/sec

[0134] With regard to the tapes for glass processing of Examples 1 to 8 and Comparative Examples 1 to 6, after the step (g), picking up was performed, and the presence or absence of pick-up failure, by which adjoining chips were simultaneously picked up, was evaluated. A tape which did not have the occurrence of pick-up failure at the time of pick-up under both the conditions 1 and the conditions 2 of the above-described step (g) was considered as an excellent product and was rated as "◎"; a tape which did not have the occurrence of pick-up

failure under the conditions 1 but had the occurrence of pick-up failure under the conditions 2, with the occurrence rate being less than 1%, was considered as a good product and was rated as "O"; a tape which did not have the occurrence of pick-up failure under the conditions 1 but had the occurrence of pick-up failure under the conditions 2, with the occurrence rate being 1% or more and less than 3%, was considered as an acceptable product and was rated as " Δ "; and a tape which had the occurrence of pick-up failure at an occurrence rate of 3% or more under both the conditions 1 and the conditions 2 was considered as a defective product and was rated as "X". The results are presented in Tables 1 and 2.

During the evaluation, as shown in Fig. 6, one hundred chips were picked up and evaluated from each of the periphery of a chip 50a at the right-most end in Fig. 6, which was free of chipping in the MD direction of the temporary adhesive tape, and similarly, from the periphery of a chip 50b at the left-most end in Fig. 6, which was free of chipping in the MD direction of the temporary adhesive tape, the periphery of chips 51 at the two farthest ends, which were free of chipping in the TD direction of the temporary adhesive tape, as well as the periphery of a chip 52 positioned at the center.

[0135] [Measurement of transmittance of adhesive layer]

For the adhesive layers of the Examples and the Comparative Examples, the transmittance was measured by the

method described below.

An adhesive layer having a thickness of 20 μm formed on a release liner was laminated to glass, subsequently the release liner was peeled off, and this was used as a sample of glass including an adhesive layer. Light was caused to penetrate glass and the glass including an adhesive layer such that light would penetrate in the normal direction with respect to the glass surface, and the light transmittance to glass at 550 nm at 25°C was measured using a spectrophotometer (manufactured by Hitachi High-Technologies Corp., spectrophotometer U-4100 type solid sample measurement system). Thus, the transmittance of the adhesive layer was calculated by the following Formula (2). The results are presented in Tables 1 and 2.

$$\text{Light transmittance } I \text{ (\%)} \text{ of adhesive layer} = I_1/I_0$$

(2)

I_1 (%): Light transmittance of glass including an adhesive layer

I_0 (%): Light transmittance of glass

	Example 1	Example 2	Example 3	Example 4	Example 5	Example 6	Example 7	Example 8
Substrate film	A	B	C	D	E	F	G	H
Adhesive composition	A	A	A	A	A	A	A	B
Thickness before processing [μm]	150	180	215	150	150	150	150	150
Thickness after processing [μm]	90	90	90	90	90	90	90	90
Sum total of derivative values of thermal deformation rate in MD direction	-9	-5	-3	1	2	1	-23	-7
Sum total of derivative values of thermal deformation rate in TD direction	-13	-13	-13	-13	-12	-8	11	6
Sum of sum totals of derivative values of thermal deformation rates in MD and TD directions	-22	-19	-351	-16	-10	-7	-12	-1
Pick-up failure evaluation results	⊙	⊙	⊙	○	△	△	○	△
Transmittance of adhesive layer	90%	90%	90%	90%	90%	90%	90%	5%

	Comparative Example 1	Comparative Example 2	Comparative Example 3	Comparative Example 4	Comparative Example 5	Comparative Example 6
Substrate film	I	J	K	L	M	N
Adhesive composition	A	A	A	A	A	A
Thickness before processing [μm]	90	90	90	90	110	120
Thickness after processing [μm]	90	90	90	90	90	90
Sum total of derivative values of thermal deformation rate in MD direction	-9	-3	0	1	-9	-9
Sum total of derivative values of thermal deformation rate in TD direction	11	6	1	1	10	10
Sum of sum totals of derivative values of thermal deformation rates in MD and TD directions	2	3	1	2	1	1
Pick-up failure evaluation results	×	×	×	×	×	×
Transmittance of adhesive layer	90%	90%	90%	90%	90%	90%

[0138] As shown in Table 1, with regard to the tapes for glass processing related to Examples 1 to 8, the sum of the sum total of derivative values of the thermal deformation rate in the MD direction of the temporary adhesive tape per 1°C between 40°C and 80°C as measured at the time of raising temperature by means of a thermomechanical characteristics testing machine, and the sum total of derivative values of the thermal deformation rate in the TD direction per 1°C between 40°C and 80°C as measured at the time of raising temperature by means of a thermomechanical characteristics testing machine, was a negative value, and therefore, the occurrence of pick-up failure by which adjoining chips were simultaneously picked up could be suppressed.

[0139] On the other hand, with regard to the tapes for glass processing related to Comparative Examples 1 to 6, as shown in Table 2, the sum of the sum total of derivative values of the thermal deformation rate in the MD direction of the temporary adhesive tape per 1°C between 40°C and 80°C as measured at the time of raising temperature by means of a thermomechanical characteristics testing machine, and the sum total of derivative values of the thermal deformation rate in the TD direction per 1°C between 40°C and 80°C as measured at the time of raising temperature by means of a thermomechanical characteristics testing machine, was not a negative value, and therefore, pick-up failure occurred at the time of pick-up.

EXPLANATIONS OF LETTERS OR NUMERALS

[0140] 10 TAPE FOR GLASS PROCESSING

 11 SUBSTRATE FILM

 12 TEMPORARY ADHESIVE LAYER

 13 ADHESIVE LAYER

 22 THRUST MEMBER

 28 HEAT-SHRINKING REGION

 29 HOT AIR NOZZLE

CLAIMS

1. A tape for glass processing, the tape comprising a temporary adhesive tape having a substrate film and a tacky adhesive layer formed on at least one surface side of the substrate film,

wherein regarding the temporary adhesive tape, the sum of the sum total of derivative values of the thermal deformation rate in the MD direction per 1°C between 40°C and 80°C as measured at the time of raising temperature by means of a thermomechanical characteristics testing machine, and the sum total of derivative values of the thermal deformation rate in the TD direction per 1°C between 40°C and 80°C as measured at the time of raising temperature by means of a thermomechanical characteristics testing machine, is a negative value, and

the tape for glass processing is used for glass processing including an expansion step of expanding the tacky adhesive tape,

wherein the tape for glass processing is used for stealth dicing using a laser

wherein an adhesive layer is laminated on the temporary adhesive layer side, and the adhesive layer has a light transmittance of 90% or higher to light having a wavelength of 550 nm.

2. A tape for glass processing, the tape comprising a temporary adhesive tape having a substrate film and a tacky adhesive layer formed on at least one surface side of the

substrate film,

wherein the substrate film is formed of an ionomer resin or a mixed resin composition of polypropylene and a styrene-butadiene copolymer, and

regarding the temporary adhesive tape, the sum of the sum total of derivative values of the thermal deformation rate in the MD direction per 1°C between 40°C and 80°C as measured at the time of raising temperature by means of a thermomechanical characteristics testing machine, and the sum total of derivative values of the thermal deformation rate in the TD direction per 1°C between 40°C and 80°C as measured at the time of raising temperature by means of a thermomechanical characteristics testing machine, is a negative value,

wherein the tape for glass processing is used for stealth dicing using a laser

wherein an adhesive layer is laminated on the temporary adhesive layer side, and the adhesive layer has a light transmittance of 90% or higher to light having a wavelength of 550 nm.