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(54) **MOLDING COMPOUND INCLUDING A CARBON NANO-TUBE DISPERSION**

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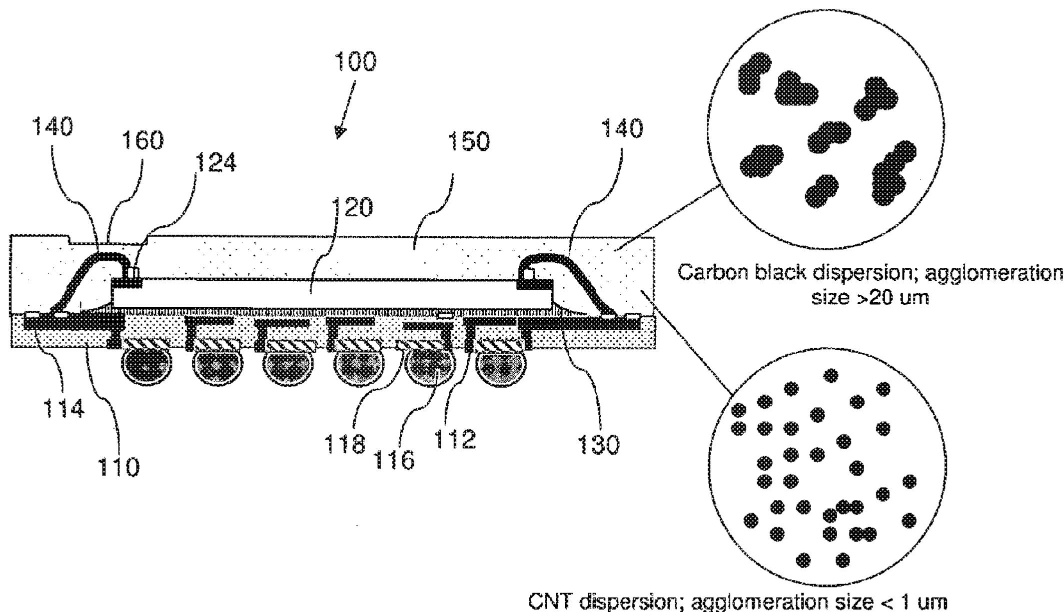
(57) **ABSTRACT**

A molding compound comprising a resin, a filler, and a carbon nano-tube dispersion is disclosed. The carbon nano-tube dispersion achieves a low average agglomeration size in the molding compound thereby providing desirable electro-mechanical properties and laser marking compatibility. A shallow laser mark may be formed in a mold cap with a maximum depth of less than 10 microns.



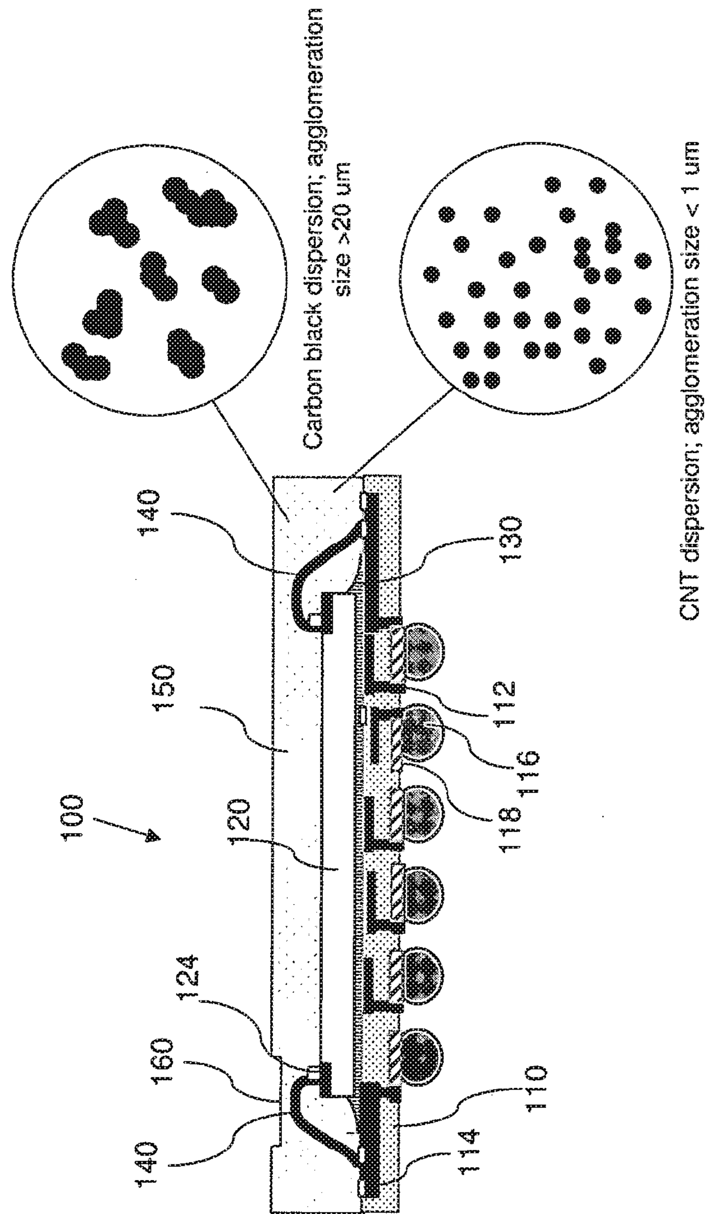


FIG. 1

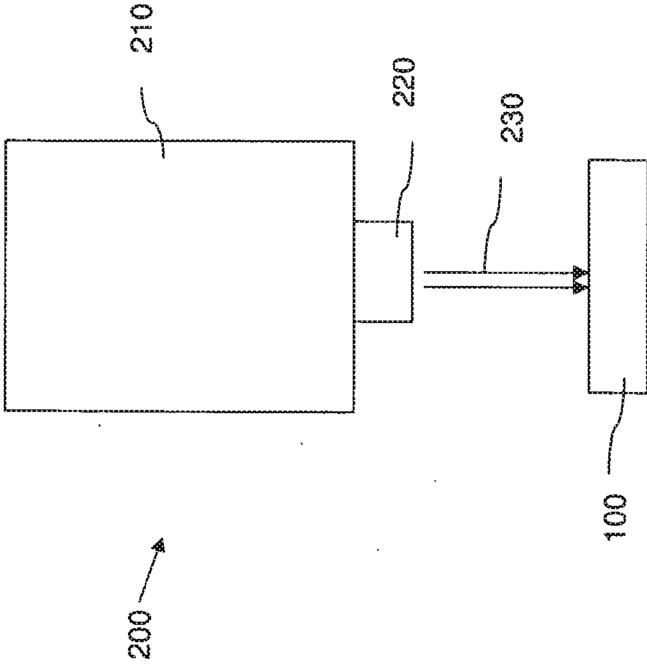


FIG. 2

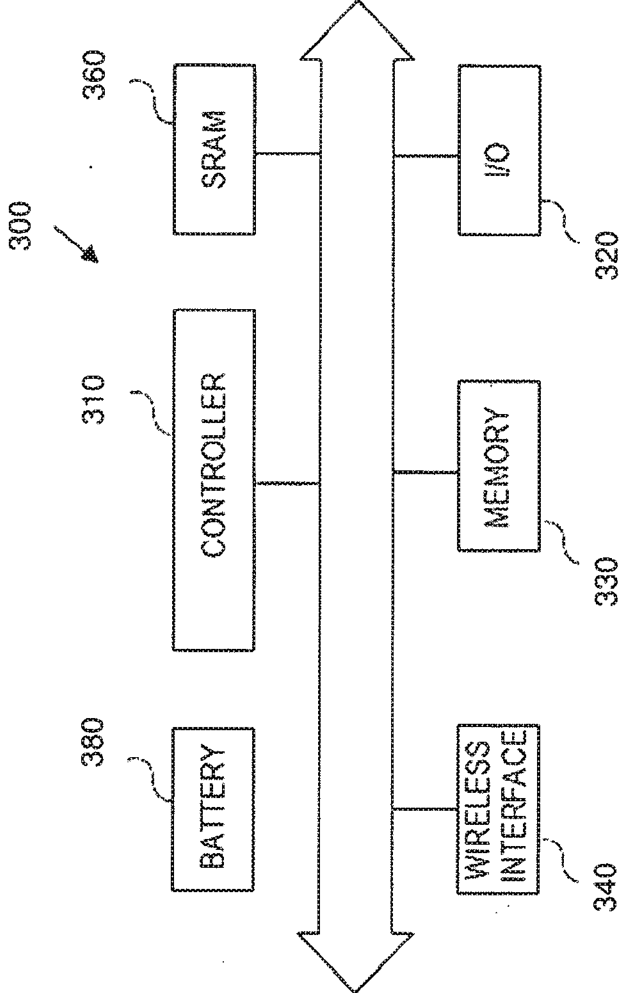


FIG. 3

MOLDING COMPOUND INCLUDING A CARBON NANO-TUBE DISPERSION

BACKGROUND

[0001] Embodiments of the invention relate to a molding compound including a carbon nano-tube dispersion. In particular, the present description refers to the manufacture of a molding compound for molded packages.

[0002] Epoxy resin molding compounds are widely used in microelectronic molded packages due to their inexpensive cost. For example, a lead frame with die bonding and wire bonding can be positioned in a mold cavity corresponding to a desired shape of a package to be produced, and an epoxy molding compound is charged into the mold cavity and a molding is then carried out. After molding, the molded package can be trimmed and further shaped for the outer leads.

[0003] The mold cap is then commonly laser marked with an alpha-numeric code for identification purposes. During laser marking an intense beam of light is scanned over the mold cap surface to write out the desired markings, or is projected onto the mold cap surface through a shadow mask containing an image of the desired markings. The intense beam of light bums, melts, ablates, or otherwise alters the surface of the mold cap to leave a visible imprint. The result is generally a color or texture change, or both.

BRIEF DESCRIPTION OF THE DRAWINGS

[0004] FIG. **1** is side view illustration of a molded chip package in accordance with an embodiment.

[0005] FIG. **2** is a side view illustration of a laser marking system in accordance with an embodiment.

[0006] FIG. **3** is an illustration of a system in accordance with an embodiment.

DETAILED DESCRIPTION

[0007] Embodiments of the invention relate to a molding compound including a carbon nano-tube dispersion. In particular, the present description refers to the manufacture of a molding compound for molded packages.

[0008] Various embodiments described herein are described with reference to figures. However, certain embodiments may be practiced without one or more of these specific details, or in combination with other known methods and configurations. Reference throughout this specification to "one embodiment" or "an embodiment" means that a particular feature, configuration, composition, or characteristic described in connection with the embodiment is included in at least one embodiment of the invention. Thus, the appearances of the phrase "in one embodiment" or "an embodiment" in various places throughout this specification are not necessarily referring to the same embodiment of the invention. Furthermore, the particular features, configurations, compositions, or characteristics may be combined in any suitable manner in one or snore embodiments.

[0009] Embodiments disclose a molding compound comprising: a resin, a filler, and a carbon nano-tube dispersion. In an embodiment, the carbon nano-tube dispersion includes a plurality of carbon nano-tubes with a 1-10 nm diameter and up to 100 nm length dispersed in the molding compound with an average agglomeration size less than one micron. In an embodiment, the carbon nano-tubes are functionalized to assist in inhibiting agglomeration by enhancing the compatibility between the carbon nano-tubes and surrounding resin. The molding compound composition provides desirable electro-mechanical properties such as low coefficient of thermal expansion (CTE), moderate glass transition temperature (Tg), low elastic modulus, low moisture absorption and high thermal conductivity. The molding compound may be formed into a mold cap for chip packaging. The molding compound allows the formation of a shallow laser mark in the mold cap with a maximum depth of less than 10 microns.

[0010] FIG. **1** is a side view illustration of a molded chip package in accordance with an embodiment. The molded chip package illustrated in FIG. **1** is a wire-bonded Plastic Ball Grid Array (PBGA) package, though embodiments of the present invention are not limited to such, and may be applied to other package designs such as, but not limited to, Molded Matrix Array Package (MMAP), Package on Package (PoP) and Thin Small Outline Package (TSOP), etc. As shown, the molded chip package **100** includes a substrate **110** upon which a chip **120** may be adhesively bonded with a die attach film **130** such as a filled epoxy, an unfilled epoxy, an acrylic, or a polyimide material.

[0011] The substrate **110** can be a printed wiring substrate with wire bonding pads **114** on a top surface and wiring **112** extending to a lower surface where solder balls **116** are mounted on ball bonding pads **118**. In an embodiment, the substrate **110** comprises an electrically insulating material such as an organic polymer resin reinforced with glass fibers. The wire bonding pads **114** can be plated with metals such as nickel and gold to facilitate the wire bonding process. The ball bonding pads **118** can also be plated with a solder flux to facilitate attachment of solder balls **116**.

[0012] Chip **120** may include a variety of devices. In an embodiment, chip **120** includes a volatile and/or nonvolatile memory device. For example, chip **120** may include any type of random access memory, a volatile memory, and/or a non-volatile memory such as a flash memory, phase change memory (PCM), phase-change random access memory (PRAM or PCRAM), ovonic unified memory (OUM) and chalcogenide random access memory (C-RAM). Chip **120** includes wire bonding pads **124**. Wire bonding pads **124** can be plated with metal such as nickel and gold to facilitate the wire bonding process. A wire bond loop **140**, such as a gold wire, connects a wire bonding pad **124** to wire bonding pad **114**.

[0013] The molding compound may be formed into a mold cap **150** covering chip **120**. The mold cap **150** may be formed from a variety of commercially available techniques such as injection molding. After formation of the mold cap **150**, a top surface of the mold cap **150** may be laser marked to identify product data, for example. In an embodiment, mold cap **150** includes a laser mark **160** on a top surface having a maximum depth of less than 10 microns into the mold cap **150**.

[0014] The mold cap **150** may be formed of a molding compound including a resin, a filler, and a carbon nano-tube dispersion. Suitable molding compound resins can be epoxies, silicones, and polyimides, for example. In an embodiment, the resin comprises approximately 10-30 wt % of the molding compound. Filler materials commonly used in molding compounds include silicon oxide in the form of powdered vitreous silica such as quartz, alumina and mixtures thereof. In an embodiment, the filler may comprise approximately 60-89 wt % of the molding compound.

[0015] The carbon nano-tube dispersion comprises a plurality of carbon nano-tubes. In an embodiment, the carbon nano-tubes have a diameter of 1-10 nm and a length of up to 100 nm. In an embodiment, the carbon nano-tube dispersion comprises 0.001-0.05 wt % of the molding compound. The substantially low concentration of carbon nano-tubes allows the ability to add a greater amount of filler if needed to control other properties of the molding compound, such as CTE.

[0016] In an embodiment, the carbon nano-tubes are functionalized to assist in inhibiting agglomeration. This can be done by chemical modification of the carbon nano-tube surfaces to chemically bridge the carbon surface and resin matrix. In an embodiment, the resin is an epoxy resin and the carbon nano-tubes are functionalized with epoxy group. For example a silane coupling agent is anchored to the surface of carbon nano-tubes with C—O—Si covalent bonding at the carbon nano-tube surface. A functional group such as an epoxy group can be bonded to the other end of the silane group to react with an epoxy curing agent in the molding compound. This surface functionalization improves the adhesion between individual carbon nano-tubes and the epoxy resin system and therefore improves the ultra-fine dispersion of carbon nano-tubes by inhibiting agglomeration of carbon nano-tubes.

[0017] The carbon nano-tube dispersions in accordance with embodiments of the present invention represent a significant improvement over state of the art molding compounds. A state of the art molding compound may typically comprise 0.1-5 wt % of a micron-sized carbon black powder or other masking pigment as a colorant and laser energy absorbing additive that decomposes, vaporizes or becomes colorless when exposed to laser energy. However, as shown in FIG. **1**, these particles form agglomerations greater than 20 microns which introduces several problems. As a foremost problem, the large agglomerations require laser markings of at least 15-23 microns in depth. Carbon ablates during laser marking, and the poorly dispersed large agglomerates tend to explode which creates laser mark defects and poor overall resolution of laser marks. The low resolution, and necessary laser mark depth of 15-23 microns in turn represents a lower limit on mold cap height above the chip. In addition, large agglomerations increase the risk of shorting through the mold cap.

[0018] Embodiments of the present invention allow the formation of laser markings **160** with greater resolution, lower defects, and a maximum depth of less than 10 microns into the mold cap **150**. The shallower depth of the laser markings **160** can additionally guard against unintentional exposure of a wire bond loop **140**, and allows for the formation of a thinner mold cap **150** height above chip **120**. In an embodiment, the height is within the range of approximately 50-150 microns. Embodiments of the present invention also provide the additional benefit of being able to provide and increased electrical resistance thereby lowering the risk of shorting. This is realized because of the lower overall wt %, nano-sized nano-tube, and agglomeration size of the carbon nano-tube dispersion. In an embodiment, functionalization of the carbon nano-tubes assists in dispersion of the carbon nano-tubes for reducing agglomeration size. Additional benefits include good colorization, good process compatibility, mechanical reliability including good warpage performance, electro-chemical reliability to low moisture absorption, higher thermal dissipation property when used for processor or logic device packaging, and good adhesion properties.

[0019] The molding compound according to embodiments of the invention can be formulated utilizing commercially available techniques. For example, carbon nano-tubes, filler, and epoxy curing agents can be mechanically mixed by ball milling or other manners for mixing known in the art. Typical epoxy curing agents include amine and imidazol curing agents. Additional additives such as adhesion promoters, coupling agents, dispersion agents, defoaming agents, and/or flame retardants may be included as is known in the art. The mixture may then be exposed to a low level partial cure and compressed into pellets. The pellets may then be fed into an injection molding apparatus for formation of the mold cap as is known in the art.

[0020] In an embodiment, functionalization of the carbon nano-tubes is done by chemical modification of carbon nano-tube surfaces to chemically bridge the carbon surface and resin matrix. Suitable chemical compounds include a silane coupling agent and 3-glycidoxypropyltrimethoxysilane (3-GPTMS; Aldrich, 99% purity). The silane process is done by purified and UV surface treated carbon nano-tubes immersed in silane solution during 6 hours at approximately 60-80 degree C. Then silane coupling agent is anchored to the surface of carbon nano-tubes and hydrolysis of silane coupling agent is performed resulting in C—O—Si covalent bonding at the carbon nano-tube surface. The other functional group, epoxy group for 3-GPTMS, is the other end, ready to react with epoxy curing agent in the compound. This surface functionalization improves the adhesion between individual carbon nano-tube and epoxy resin system and therefore improves the ultra-fine dispersion of carbon nano-tubes by inhibiting agglomeration of carbon nano-tubes. In an embodiment, the carbon nano-tubes are randomly dispersed in the epoxy resin system by mechanical mixing with the functionalized carbon nano-tubes in epoxy resin and epoxy curing agent.

[0021] In an embodiment, a mold cap comprising a molding compound in accordance with embodiments of the present invention is fabricated. An internal assembly is provided. The internal assembly may comprise a chip **120** adhesively bonded to a substrate **110**. The internal assembly is then placed in a mold cavity. A molding compound in accordance with embodiments of the present invention is then provided to the molding cavity. In an embodiment, the molding compound includes a resin, filler, and a plurality of carbon nano-tubes. In an embodiment, the carbon nano-tubes are functionalized. The molding compound is then cured. In an embodiment, the cured molding compound covers or encapsulates the chip **120**.

[0022] Curing of the molding compound may be performed with a thermal cure process, though is not so limited. In an embodiment, a microwave cure process may be used in place of, or in combination with, a typical thermal oven cure. In such an embodiment, the carbon nano-tube dispersion with an average agglomeration size below one micron can be o effective in heat absorption than a typical molding compound with micron sized carbon black having agglomerations of 20 microns or larger. During microwave heating the nano-sized carbon nano-tubes can serve as a uniform heating source, which provides for more uniform curing in less time than thermal oven curing, which is approximately 175 degree C. for more than 4 hours. This benefit is realized

by the improved dispersion of carbon nano-tubes which provides uniform heating throughout the mold cap, and allows for the application of a microwave cure process. As a result, utilizing embodiments of the invention the molding process time can be reduced,

[0023] In an embodiment, a molding compound in accordance with embodiments of the present invention is laser marked. The molding compound can be in the form of a mold cap. As shown in FIG. **2**, a package **100** such as that illustrated in FIG. **1** having a portion formed from a molding compound is provided to a laser marking system **200**. The laser marking system **200** may include a laser source **210** and lens **220** to direct a laser beam **230** to the top surface of package **100** having a portion formed from a molding compound. In an embodiment, the molding compound includes a resin, filler, and a plurality of carbon nano-tubes. In an embodiment, the carbon nano-tubes are functionalized. A portion of the molding compound is then irradiated with a radiation source to produce a laser mark **160**, as illustrated in FIG. **1**. In an embodiment, the radiation ablates the resin, the filler and the carbon nano-tube dispersion comprising the molding compound to form a laser mark having a maximum depth of less than 10 microns.

[0024] Turning to FIG. **3**, a portion of a system **300** in accordance with an embodiment of the present invention is described. System **300** may be used in wireless devices such as, for example, a personal digital assistant (PDA), a laptop or portable computer with wireless capability, a web tablet, a wireless telephone, a pager, an instant messaging device, a digital music player, a digital camera, or other devices that may be adapted to transmit and/or receive information wirelessly. System **300** may be used in any of the following systems: a wireless local area network (WLAN) system, a wireless personal area network (WPAN) system, a cellular network, although the scope of the present invention is not limited in this respect.

[0025] System **300** may include a controller **310**, an input/output (I/O) device **320** (e.g. a keypad, display), static random access memory (SRAM) **360**, a memory **330**, and a wireless interface **340** coupled to each other via a bus **350**. A battery **380** may be used in some embodiments. It should be noted that the scope of the present invention is not limited to embodiments having any or all of these components.

[0026] Controller **310** may comprise, for example, one or more microprocessors, digital signal processors, microcontrollers, or the like. I/O device **320** may be used by a user to generate a message. System **300** may use wireless interface **340** to transmit and receive messages to and from a wireless communication network with a radio frequency (RF) signal. Examples of wireless interface **340** may include an antenna or a wireless transceiver, although the scope of the present invention is not limited in this respect.

[0027] Memory **330** may be used to store messages transmitted to or by system **300**. Memory **330** may also optionally be used to store instructions that are executed by controller **310** during the operation of system **300**, and may be used to store user data. Memory **330** may be provided by one or more different types of memory. For example, memory **330** may comprise any type of random access memory, a volatile memory, and/or a non-volatile memory such as a flash memory, phase change memory (PCM), phase-change random access memory (PRAM or PCRAM), ovonic unified memory (OUM) chalcogenide random access memory (C-RAM).

[0028] In an embodiment, a chip including a nonvolatile memory array is packaged within any of the molding compounds described herein. Embodiments of the present invention are applicable to all molded packages such as, but not limited to, MMAP, PoP and TSOP etc. Volatile and nonvolatile memories may also be combined within a single chip or separate chips. For example, volatile and nonvolatile memories can be combined in a stacking process to reduce the footprint on a hoard, packaged separately, or placed in a multi-chip package with the memory component placed on top of the processor.

[0029] In the foregoing specification, various embodiments of the invention have been described. It will, however, be evident that various modifications and changes may be made thereto without departing from the broader spirit and scope of the invention as set forth in the appended claims. The specification and drawings are, accordingly, to be regarded in an illustrative sense rather than a restrictive sense. It is intended that the appended claims cover all such modifications and variations as fall within the true spirit and scope of this present invention.

What is claimed is:

1. A semiconductor package, comprising:

a molding compound, including:

a resin; and

a plurality of carbon nano-tubes with surfaces that are chemically modified by a functional group configured to chemically bridge surfaces of the carbon nano-tubes and the resin to improve adhesion therebetween, the functional group being further configured to reduce agglomeration between various ones of the plurality of carbon nano-tubes.

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