necessary for very thin structures. In addition to the high degree of yield loss with trying to achieve low thickness with woven glass, notwithstanding the very high cost of the thin fabrics, weave skew and planarity is still an issue with woven fabrics.

SUMMARY

In an aspect, the present disclosure refers to a printed circuit board, comprising:

at least one dielectric material layer comprising a non-woven, inorganic fabric reinforcement, the at least one dielectric material layer having a thickness of less than about 125 microns.

In an aspect, the present disclosure refers to a high speed board, high frequency board or chip packaging substrate comprising the printed circuit board of the above aspect.

In an aspect, the present disclosure refers to a method of facilitating preparation of a printed circuit board, comprising:

providing at least one dielectric material layer comprising a non-woven, inorganic fabric reinforcement, the at least one dielectric material layer having a thickness of less than about 125 microns.

In an aspect, the present disclosure refers to a method of making a dielectric material, comprising:

providing a non-woven, inorganic fabric reinforcement;

impregnating the reinforcement with a low-density thermosetting polymer resin;

drying the impregnated reinforcement; and

pressing the dried impregnated reinforcement to form a dielectric material having a thickness of less than about 125 microns.

In accordance with one or more examples, a printed circuit board is disclosed. The printed circuit board may include at least one dielectric material layer comprising a non-woven, inorganic fabric reinforcement, the at least one dielectric layer material having a thickness of less than about 125 microns.

In some examples, the at least one dielectric material layer may have a thickness of less than about 100 microns. For example, the at least one dielectric material layer may have a thickness of less than about 75 microns. In some non-limiting examples, the at least one dielectric material layer may have a thickness of less than about 50 microns. In some non-limiting examples, the at least one dielectric material layer may have a thickness of less than about 40 microns. In at least some non-limiting examples, the at least one dielectric material layer may have a thickness of less than about 25 microns. The at least one dielectric material layer may have a thickness of less than about 15 microns.

In some examples, the at least one dielectric material layer may comprise a prepreg or a laminate.

In some examples, the non-woven, inorganic fabric reinforcement may be impregnated with a crosslinked thermosetting polymer resin. The crosslinked thermosetting polymer resin may comprise an epoxy resin, a bismaleimide resin, a cyanate ester resin, a BT resin, a polybutadiene resin, or a PPE/PPO resin. The crosslinked thermosetting polymer resin may comprise at least one resin selected from the group consisting of: a vinyl functional PPE resin, an OPE resin, a Bismaleimide resin, a Triallyl Cyanurate resin and a Tri Allyl Isocyanurate resin.

In some examples, the crosslinked thermosetting polymer resin may be substantially halogen free. The crosslinked thermosetting polymer resin may further include at least one of a flame retardant, a curing agent, a hardener, a filler, and an additive.

In some examples, the at least one dielectric material may be less than about 20% filler by weight. The at least one dielectric material may be copper clad.

In some examples, the non-woven, inorganic fabric reinforcement may be higher DK (>5.0) glass such as E-glass, S-2 Glass, R Glass, or ECR Glass. In other examples, the non-woven, inorganic fabric reinforcement may be Quartz, L-glass, NE Glass, or D Glass.

In some examples, the at least one dielectric material may be characterized by a glass transition temperature (Tg) of greater than about 150 ºC.

In some examples, the at least one dielectric material is characterized by a dielectric constant (DK) of less than about 3.5. For example, the at least one dielectric material may be characterized by a dielectric constant (DK) of less than about 3.0. In some non-limiting examples, the at least one dielectric material may be characterized by a dielectric constant (DK) of less than about 2.8. In at least some non-limiting examples, the at least one dielectric material may be characterized by a dielectric constant (DK) of less than about 2.5.

In some examples, the at least one dielectric material may be characterized by a tensile modulus in the planar directions of less than about 5 GPa.

In some examples, the coefficient of thermal expansion (CTE) of the at least one dielectric material may be less than about 35 ppm in either of the planar directions over a temperature range of about 50 ºC to about 220 ºC.

In some examples, the printed circuit board may be a high density interconnect (HDI) printed circuit board.

In accordance with one or more examples, a high speed board, high frequency board or chip packaging substrate including any printed circuit board as described herein is disclosed.

In accordance with one or more examples, a method of facilitating preparation of a printed circuit board is disclosed. The method may involve providing at least one dielectric material layer comprising a non-woven, inorganic fabric reinforcement, the at least one dielectric material layer having a thickness of less than about 125 microns.

In some examples, the method may further involve providing instructions for integrating the at least one dielectric material layer into the printed circuit board.

In accordance with one or more examples, a method of making a dielectric material is disclosed. The method may involve providing a non-woven, inorganic fabric reinforcement, impregnating the reinforcement with a low-density thermosetting polymer resin, drying the impregnated reinforcement and pressing the dried impregnated reinforcement to form a dielectric material having a thickness of less than about 125 microns.

In some examples, the non-woven, inorganic fabric reinforcement may have a thickness of less than about 220 microns.

In some examples, the non-woven, inorganic fabric reinforcement may be E-glass, Quartz, L-glass, NE Glass, or D Glass.

In some examples, the resin may include an epoxy resin, a bismaleimide resin, a cyanate ester resin, a BT resin, a polybutadiene resin, or a PPE/PPO resin, a vinyl functional PPE resin, an OPE resin, a Bismaleimide resin, a Triallyl Cyanurate resin or a Tri Allyl Isocyanurate resin.

In some examples, the resin may further include at least one of a flame retardant, a curing agent, a hardener, a filler, and an additive.

In some examples, the density of the resin is less than about 1.6 g/cc. For example, the density of the resin may be less than about 1.2 g/cc. In some specific non-limiting examples, the density of the resin may be less than about 1.05 g/cc.

In some examples, the viscosity of the resin may be between about 50 cPs and about 1500 cPs.

In some examples, drying may be performed in a horizontal oven at a temperature of from about 100 ºC to about 200 ºC.

In some examples, the method may further involve controlling a thickness of the impregnated reinforcement prior to drying with a squeeze roll, slot die, doctor blade or gravure. The method may further involve copper cladding the dielectric material. The method may further involve supporting the dielectric material with a foil, release, or carrier film.

In some examples, the dielectric material layer may have a thickness of less than about 25 microns.

Described herein are inorganic non-woven fabric reinforced dielectric materials and copper clad laminates for use in printed circuit boards for high speed digital applications including HDI boards. In the current state of the art, it is conventionally understood that non-woven reinforced dielectric materials result in high thickness not suitable for high layer count boards. In accordance with one or more examples of the present disclosure, lower thickness is surprisingly achieved with non-woven fabrics making them suitable for use in printed circuit boards.

One example of the disclosure is the use of non-woven reinforced dielectric layers, with inorganic non-woven fabric, with a pressed thickness of below 125 microns for use in a single or multiple layers of printed circuit boards.

In some examples the original thickness of the non-woven fabric is below 220 microns.

In some examples, the dielectric materials may or may not be clad with copper.

In preferred examples, the Tg of the non-woven reinforced dielectric materials is greater than about 150 ºC. The non-woven fabric reinforced dielectrics of the present disclosure also have high Tg, e.g., greater than about 150 ºC and as high as about 300 ºC in some examples. In some examples, the dielectrics may have a low dielectric constant.

It is also conventionally understood in the current state of the art that non-woven reinforced dielectric materials have undesirably high CTEs in the planar direction and, in the case of low Tg systems, very high CTEs in the thickness or z-direction. The non-woven fabric reinforced dielectrics in accordance with the present disclosure beneficially have low CTEs in the planar direction and low Z-axis expansion. In some examples, the non-woven fabric reinforced materials have a planar CTE less than 35 ppm/c.

Likewise, it is expected in the relevant art that printed circuit board materials in general have dielectric constants higher than 3.5. In the present disclosure, some examples may beneficially have a dielectric constant lower than about 3.2. In some specific non-limiting examples, the non-woven fabric reinforced material may have a dielectric constant of less than about 2.8. In other examples the DK can be lower than 2.6. The lower DK provides a major advantage such that the line widths required to achieve the same impedance are wider for the same thickness thereby reducing the insertion loss significantly. The insertion loss comprises of dielectric loss and conductor loss. The conductor loss is inversely proportional to the line width, which, for the same thickness, is wider for a lower DK. A DK reduction, therefore, directly reduces the conductor loss. The dielectric loss is directly proportional to the square root of the dielectric constant and therefore a lower dielectric constant reduces the dielectric loss. The lower dielectric constant is typically not possible with woven glass fabric due to the fact that woven fabrics cannot easily achieve very high resin contents. In the example below, the insertion loss is simulated using commercially available Gauss 2D Software, for a 127 micron Dielectric with 50 Ohm impedance.

Insertion Loss for a Single ended Stripline 50 Ohm 127 Micron dieletric 35 micron trace height				
DK	DF	Line Width for 50 Ohms Stripline	Insertion loss dB/m	% Difference from 3.5 DK
3.50	0.002	102.7	21.85	0.0%
3.20	0.002	114.2	20.15	7.8%
3.00	0.002	122.6	19.05	12.8%
2.80	0.002	132.1	17.97	17.8%
2.60	0.002	141.9	16.93	22.5%

In some examples, the thickness of the pressed dielectric material layer may be lower than about 15 microns.

In accordance with one or more examples, a higher density resin leads to higher thickness. It is known in the art that halogenated resins have higher density and adding filler increases the density. In some examples of the disclosure, the laminate resin is substantially halogen free, and at least some examples include use of no to low inorganic filler(s). For example, inorganic filler(s) may constitute less than about 20% by weight of the total weight of non-woven fabric and the curing resin in accordance with one or more examples. Such examples may advantageously provide for low thickness and improved dimensional stability even after several lamination cycles.

In some specific examples, the non-woven inorganic fabric is quartz veil using an epoxy, phenolic, styrene or Polyimide binder. In other specific examples, the non-woven inorganic fabric is comprised of Glass including E-Glass, L-glass, or D-Glass using binders such as polyvinyl alcohol (PVA).

The disclosure contemplates all combinations of any one or more of the foregoing examples, as well as combinations with any one or more of the examples set forth in the detailed description and any examples.

DETAILED DESCRIPTION

In accordance with one or more embodiments, non-woven inorganic fabrics which are impregnated with a low-density resin may deliver a dielectric material layer having a thickness in the range of about 5 to about 125 microns. Such dielectric materials may be particularly suitable for use in high layer count applications as well as in HDI printed circuit boards. The fabrics may have a starting thickness of greater than about 50 microns, wherein a thickness reduction of up to