Ročník 2019 electroscope Číslo II

Nonstandard unidirectional lamination for Face down technology

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Abstract:
This research is focused on analysing mechanical properties of materials which can be used for lamination of multilayer PCBs with embedded components by face down technology. Mechanical properties were analysed by 3-point bend test on various types of substrate material. Materials with low Tg and high Tg was used for testing. Laminate material, laminated prepreg material and also sandwich structure (combination of prepreg and laminate material) was tested. Lamination of prepreg materials was done by one step lamination and also by two step lamination. Sandwich structure has great potential for the purpose of components embedding and miniaturization of PCBs (Printed Circuit Boards) by face down technology.

INTRODUCTION

Unstoppable development of electronics has made significant progress in recent decades. In modern electronics, high performance and reliability are required and miniaturization of these electronic devices is an inseparable part of the development of electronics. Miniaturization of electronics was in recent years based on reducing dimensions of electronic components, reducing the width of conductive traces, reducing insulation gaps or using smaller diameters of vias, but these miniaturization possibilities are close to their physical limitations. Therefore, considerable attention is paid to the search for other possibilities of miniaturization [1, 3, 4].

Embedding of the components into the multilayer PCBs (Printed Circuit Boards) is one of these progressive ways of miniaturization. Embedded components allow reducing width and length of PCB, with just slightly increase of the PCB thickness as well as electrical properties improvement can be achieved. There are many ways of embedding components. Embedded components can be created as planar resistor or capacitors, electronic components in SMD (Surface Mount Device) package or even unpackaged chips. There are a few different technologies for embedding components based on used technological steps [1-3].

Thickness of multilayer PCBs with embedded components may vary depending on thickness of embedded components. Thickness of inner layers of multilayer PCBs can be achieved by implementing PCB laminate of required thickness or by many layers of prepreg. This paper is focused on analysing properties of multilayer PCBs with prepreg based core.

Face down technology (Fig. 1) belongs to technologies for embedding components. This technology is used for embedding components in SMD packages, so there is no need for special substrates or additional technological steps. Face down technology is used to assembly components on a base substrate, these components are then covered by prepreg layers and laminated to multilayer PCB with embedded components [3].

The most important issues, which must be considered are thermal and mechanical stability of this multilayer structure. These properties are important because multilayer PCBs usually contains inner layers interconnections, which are the principal issues, that must be considered in relationship to components embedding. Furthermore, it is also necessary to consider inner layers thickness of multilayer PCBs, that may vary depending on thickness of embedded components.

In our research we analyse possibilities of implementation of multilayer prepreg layers, which were laminated in two steps. First step of this lamination (pre-lamination) creates solid structure of prepreg layers and allows manipulation with this structure as well as creating holes and vias in this structure. Final lamination of two PCB laminates and pre-laminated multilayer prepregs in the middle creates thermal stable and robust structure called sandwich structure. Two types of prepreg materials combinated with two types of PCB laminates were tested in our experiments. Mechanical stiffness of these materials was analysed, which also gives assumption of thermal properties stability. Mechanical properties of multilayer prepregs laminated by one step lamination as well as multilayer prepregs laminated by two step lamination were analysed. Three-point bend test seems like the most suitable test for sandwich structure testing as was shown in our past experiments.

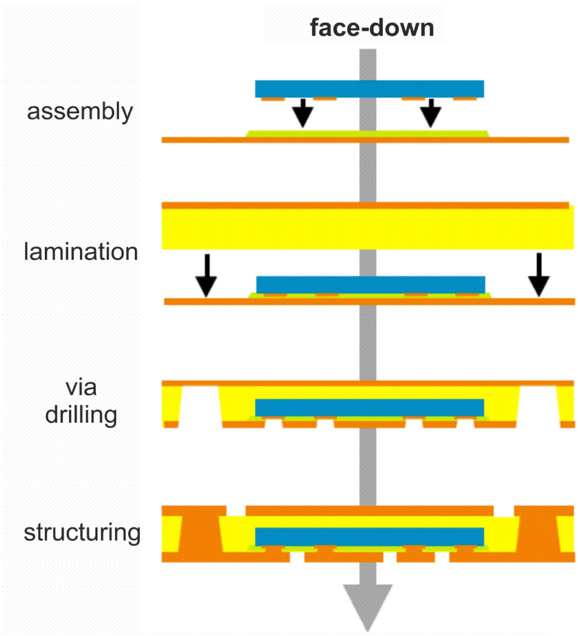

Fig. 1 Face down technology

MATERIALS AND TECHNOLOGY

This research was focused on different PCB materials which were laminated to multilayer structure. Different conditions of lamination were also used (Fig. 2). Lamination of tested materials was done by one step lamination cycle as well as by two-step lamination cycle. One step lamination cycle was done by conditions (temperature and pressure) given by a manufacturer of used materials. Two-step lamination was divided into two lamination cycles, by which, first lamination cycle (pre-lamination) was done by 70 °C and pressure given by the manufacturer and second lamination cycle was same as one step lamination cycle.

Laminate materials with low Tg and high Tg and prepreg material with low Tg and high Tg were used for this research (Table 1).

Table 1: Basic properties of used materials [6, 7]

Type	**Glass cloth style**	**Catalogue thickness of 1 layer (mm)**	**T_g (°C)**	**T_d (°C)**
DE 104 (laminate)	2116	0.565	135	315
PCL370HR (laminate)	7626	0.565	180	340
DE 104 (prepreg)	2116	0.105	135	315
DE 104 (prepreg)	7626	0.197	135	315
PCL370HR (prepreg)	7626	0.172	180	340

Number of layers was chosen to achieve approximately the same thickness of samples. Every prepreg material was laminated by one step lamination (samples marked as ”A”) as well as by two step lamination (samples marked as ”B”). Sandwich structures (samples marked as ”M”) were laminated by two-step lamination (Table 2).

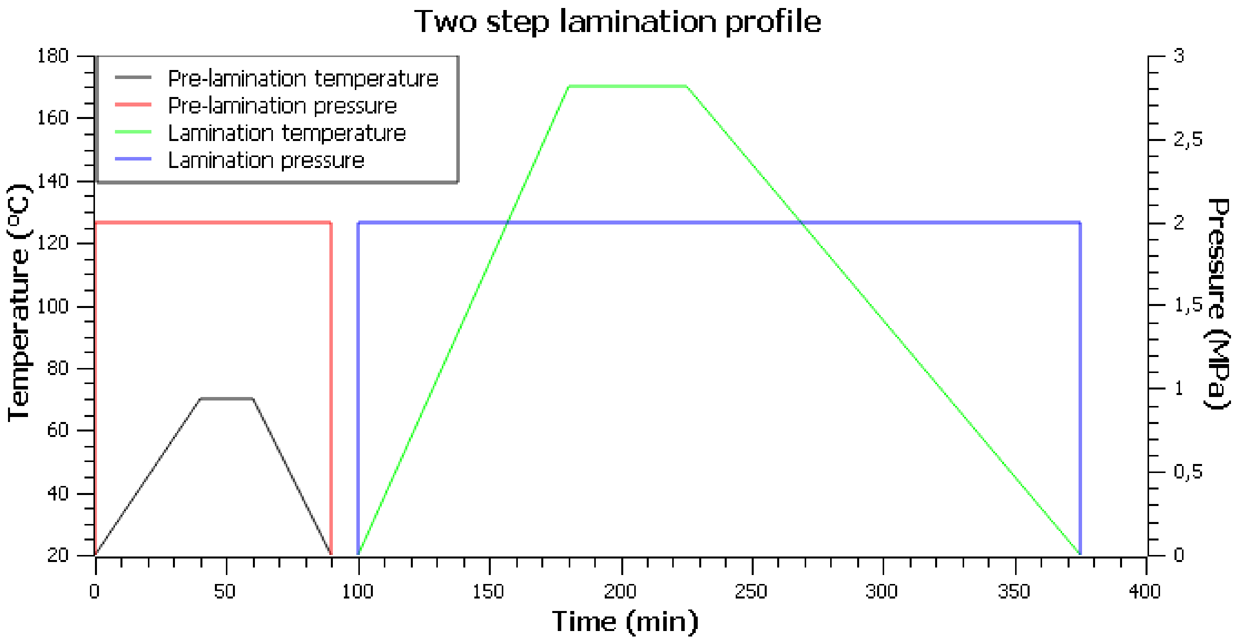

Fig. 2 Lamination profile

Table 2: Types of samples used in experiments

Sample	Material	Layers	T_g (°C)	Thickness (mm)
L1	DE104 laminate	1	135	0.56
L2	PCL370HR laminate	1	135	0.56
1A	DE104 prepreg 2116	10	135	1.21
1B	DE104 prepreg 2116	5+5	135	1.16
2A	DE104 prepreg 7626	6	135	1.27
2B	DE104 prepreg 7626	3+3	135	1.22
3A	PCL370HR prepreg 7626	6	180	1.36
3B	PCL370HR prepreg 7626	3+3	180	1.32
M1	Combination of L1 and 1B	10+2	135	2.22
M2	Combination of L2 and 1B	10+2	135-180	2.23
M3	Combination of L2 and 3B	6+2	180	2.44

Mechanical properties of samples were tested by 3-point bend test (Fig. 3). 3-point bend test was realized by Testometric M250-2.5CT. Samples dimensions were 7 mm × 40 mm and thickness of samples varies based on measured sample (Table 2). Samples were loaded by constant speed of 0.4 mm/min and applied force was measured.

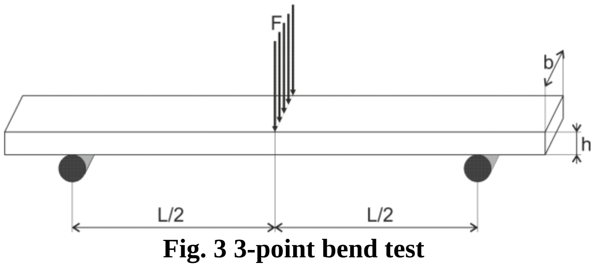

Fig. 3 3-point bend test

RESULTS AND DISCUSSION

This research was focused on analysing mechanical properties of different material, which was laminated by different conditions. Laminate materials with low Tg and high Tg and prepreg material with low Tg and high Tg were used for this research. Mechanical properties of non-laminated laminate material, laminated prepreg material and laminated combination of laminate and prepreg materials (sandwich structure) were analysed. Prepreg materials were laminated by one step lamination as well as by two step lamination. Effect of two step lamination on mechanical properties of prepregs were also analysed. Mechanical properties were analysed based on flexural strength (Fig. 4) and bending stiffness (Fig. 5). Flexural strength is given by:

$$R_{max} = 3F_{max}L/2bh^2 \quad (1)$$

where F_{max} is maximum applied force, L is length between outside points of 3-point bend test b is sample width and h is sample thickness.

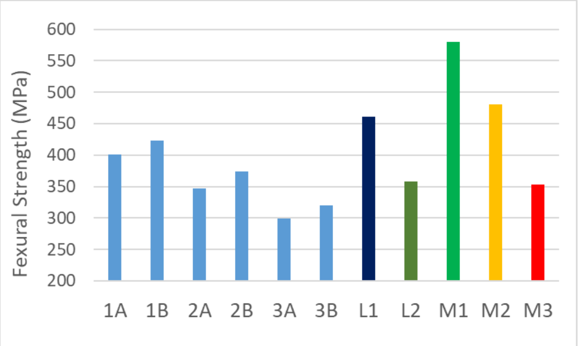

Fig. 4 Flexural strength of various composite materials

Fig. 4 shows that flexural strength of prepregs laminated by two step lamination is even better then flexural strength of prepregs laminated by one step lamination. Fig. 4 also shows that Low Tg material has better flexural strength than high Tg material. Sample M1 (combination of thin low Tg prepreg layers and low Tg laminate) shows the highest flexural strength. Bending stiffness of tested samples is given by [5]:

$$k = F_{max}/w_0 \quad (2)$$

where F_{max} is maximum applied force and w0 is deflection given by equation [5]:

$$w_0 = F_{flex}L^3/48E_fI \quad (3)$$

where F_{flex} is flexural load at max. extension, L is length between outside points of 3-point bend test E_f is flexural modulus of elasticity and I is moment of inertia given by equation [5]:

$$I = h^3b/12 \quad (4)$$

where h is thickness of the sample and b is width of the sample.

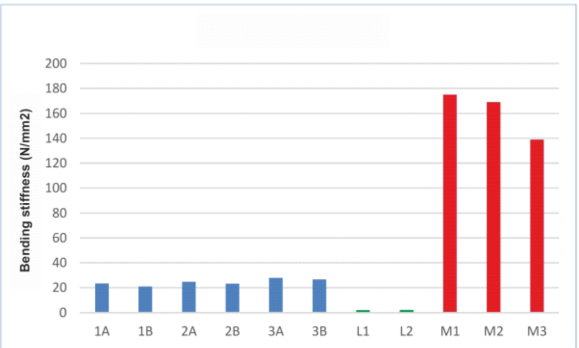

Fig. 5 Bending stiffness of various composite materials

Bending stiffness of prepregs laminated by two step lamination is comparable to prepregs laminated by one step lamination as is shown in Fig. 5. Sandwich structures shows significantly higher bending stiffness of tested samples.

CONCLUSION

This research shows advantageous mechanical properties of sandwich structures, which were compared in terms of combinations of low Tg and high Tg laminates and also low Tg and high Tg prepreg materials. Sandwich structures based on multilayer prepregs has shown incomparable bending stiffness and are suitable material for application of face down technology. Furthermore, two step lamination of prepreg materials did not have impact on mechanical properties of multilayer structures.

ACKNOWLEDGMENT

This paper was supported by grant of Faculty of Electrical Engineering and Informatics, Technical University of Kosice no. FEI-2018-53.

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