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Technological aspects of electronic systems production on wood-based PCBs

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Abstract: *Technological aspects of electronic systems production on wood-based PCB*. In this paper the preliminary results of wood based panels applicability as printed circuit boards (PCB) are presented. HDF and plywood were tested for their thermal resistance while melting the soldering paste located on wood based PCB. Wood based PCB need some more time and energy, then conventional PCB, to allow solder paste to melt. HDF requires longer preheating than plywood, but they are more stable in shape.

Keywords: Printed Circuit Board, wood based PCB, soldering, PCB recycling

INTRODUCTION

The Printed Circuit Boards (PCB) are bases for almost all electronic systems used around the world. It supports electronic elements like: resistors, capacitors, diodes, integrated circuits, microchips etc. It also provides conduction thru designed conductive traces to ensure their functionality.

There are few types of PCB construction. The simplest is based on fiber reinforced epoxy resin covered on one or both sides with conductive copper pattern [1]. Elements might be mounted on PCB – SMD (Surface Mount Device) or loomed through holes in the PCB and soldered on the other side – THT (Through-Hole Technology). In both cases there are many techniques of soldering but oven reflow soldering is one of most popular and cost effective for today's solutions [2].

Nowadays PCBs fulfill most of operational requirements. However, they cause some difficulties at the end of their life cycle. Some works are known on recycling of epoxy PCB [3], but still disassembling (i.e. removing functional electronic elements from the PCB) is annoying.

For this reason it was decided to verify the possibilities of replacing epoxy PCB with Wood Based Printed Circuit Boards (WBPCB) which are easy degradable in high temperature or biologically by controlled fungi attack. In that case used electronic system could be easily disintegrated with negligible impact on the environment.

There are several mechanical and electrical requirements that a new base for PCB has to fulfill, but the first step to verify usability of wood based materials in electronic systems is their resistance to high temperatures. This is because the first step in PCB utilization is soldering the set of electronic components on it. Usually this is performed in a dedicated convection reflow oven following the pre-defined temperature profile reaching 250°C. This is rather high temperature for wood or wood based materials, so it requires verification is it applicable.

Present work is a preliminary study on technological aspects and possibilities of producing WBPCB. Its aim is to verify thermal resistance of WBPCB, needed in soldering process.

MATERIALS AND METHODS

As a possible replacement for conventional epoxy PCB, the following materials have been taken into consideration (table 1). The specimens of dimensions 150 x 100 mm were kept in normal conditions and at the time of experiment the moisture content was in the range of 4,8 – 6,2 %. No special surface finishing, fire retardant nor decay protection treatment was applied in order to ensure easy and eco-friendly post utilization degradation.

Table 1. Examined wood based materials characterization

Material	Thickness (mm)	Density (kg/m^3)
HDF (company 1)	3,05 ± 0,03	839 ± 5
HDF (company 2)	3,05 ± 0,04	903 ± 45
HDF (company 3)	2,92 ± 0,02	869 ± 29
HDF (company 4)	2,88 ± 0,01	892 ± 5
Plywood 1 (3-layer hardwood)	1,92 ± 0,01	645 ± 10
Plywood 2 (5-layer hardwood)	2,15 ± 0,04	761 ± 6
Plywood 3 (5-layer hardwood)	2,61 ± 0,04	770 ± 13
Plywood 4 (7-layer hardwood)	4,22 ± 0,01	753 ± 4

On each specimen of WBPCB a self-adhesive copper foil (conductive layer) was applied. Then a piece of AIM Solder NC257 SN100C solder paste [4] was put on it. Samples were then put into convection lead-free reflow oven – LPKF ProtoFlow (fig. 1).

Fig. 1. Convection Lead-Free Reflow Oven used in experiments

In order to melt the solder paste a specific temperature is needed, in current case the melting point of used solder paste is 227°C. In regular soldering process there are at least four phases of process: 1) oven worm-up (without PCB), 2) preheat - to heat up the whole system (PCB with electronic components and soldering paste), 3) reflow – apply the temperature peak and then 4) cool-down the PCB. This entire soldering process (profile) is designed to melt the solder paste without over-heating the electronic elements.

According to [4] the specific heat capacity of different wood in normal conditions is about 1,4 $kJ \cdot kg^{-1} \cdot K^{-1}$, when e.g. for glass reinforced epoxy laminates FR-4 it is about 0,6 $kJ \cdot kg^{-1} \cdot K^{-1}$ [5]. It means that wood (or wood based materials) need more energy to increase temperature to required level. Due to this it is necessary to elongate the preheat phase. The effect of soldering the WBPCB was verified for: 100, 150, 250, 300, 350 and 400s of preheating. Soldering profile used in current experiment is shown (without worm-up phase) on the figure 2.

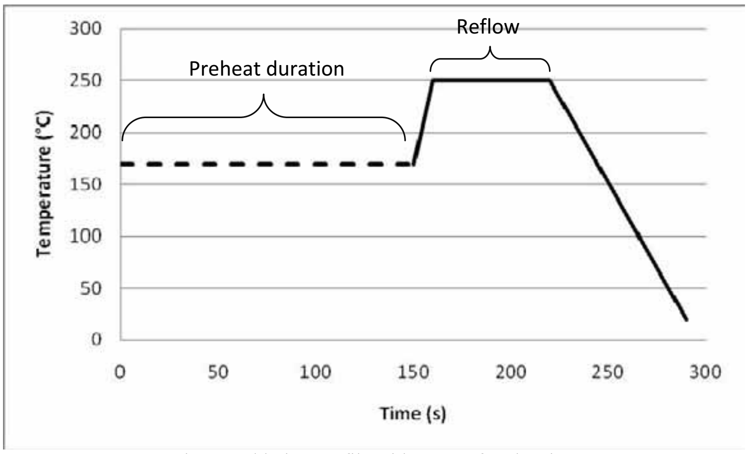

Fig. 2. Soldering profile with 150 s of preheating

After thermal treatment the specimens were visually inspected in order to verify if the solder was melt and then for each type of wood based panel the minimal preheat time was pointed out causing full melting of solder. The deformation of each WBPCB was rated qualitatively.

The high temperature causes darkening of the boards surfaces – it was measured by means of reflected light intensity measurement before and after heating. The darkening was evaluated as light intensity difference divided by native intensity of surface.

RESULTS

In current experiment the main criteria which determines a usability of wood based material in PCB application was whether the solder paste was melted or not. Figure 3 shows the difference.

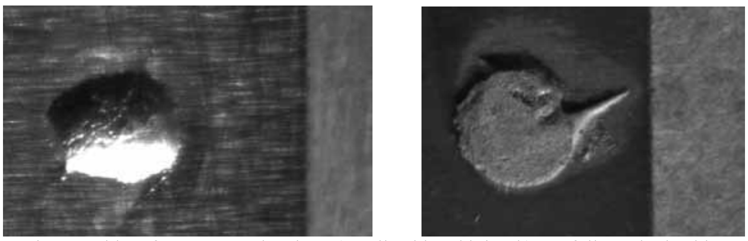
Fig. 3. Solder after WBPCB heating: a) well soldered joint, b) not fully melted solder

On the figure 4 the minimal preheat duration is presented, which in overall process has leaded to solder paste melting and creating high quality soldered joint. For each type of wood based panels an appropriate duration was found except for HDF 2 and Plywood 4 for which even 400 s did not give a good result. It might be stated that both cannot substitute epoxy PCB, because longer preheat time may lead to fire start and in real process to electronic elements over-heat. For the rest of samples the minimal duration has been found. In general HDFs needed more time to heat up than plywood sheets. Assuming quite constant specific heat capacity for wood biomass [6] one may explain this by higher density of HDF and therefore higher mass of specimens to be heat-up.

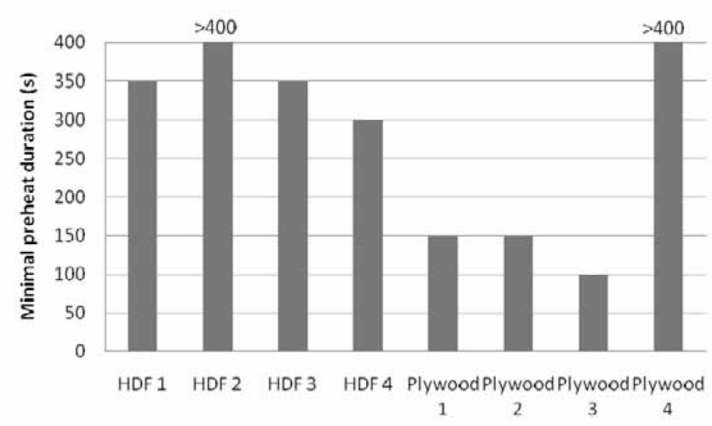

Fig. 4. Minimal preheat time at 170°C at the process causing solder to melt

In the scope of preheat time plywood has shown up to be better than HDF, but on the other side plywood seems to have inclinations to bend during heating. Thin plywood (1,9-2,6 mm) quite easily heats up to the melt point of solder paste but its twisting and bending disqualify it as a PBC base. Thicker plywood (4,2 mm) remains quite flat but, as it was mentioned, during experiments it was impossible to melt the solder paste, even while preheated for 400 seconds. HDF specimens have remained flat except of ones from producer 1 which showed small deformations.

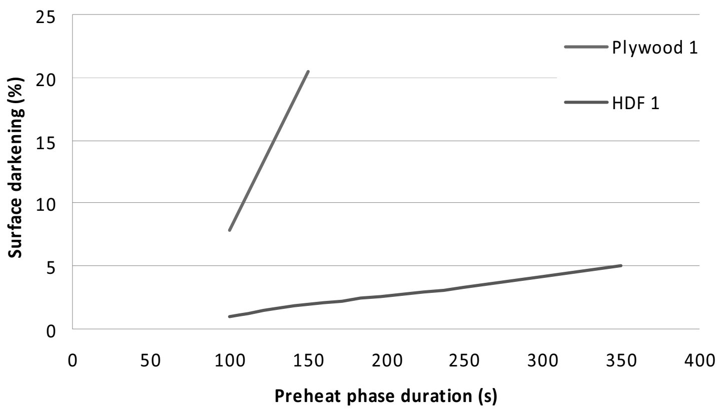

Fig. 5. Chosen WBPCB surface darkening after complete heating process with different phase duration

Figure 5 shows the surface darkening of two WBPCB; both plots stops at minimal duration of preheat phase (compare figure 4). It is visible that HDF even preheated for longer time (350 s) increase its darkening for maximum 5% while plywood preheated for only 100 s darkens for 7,5% and after 150 s for over 20%. A steep slope of plywood curve – intensive specimen darkening, might be caused by outstanding wood fibres which locally achieve higher temperatures than plywood in mass, causing burning. HDF colour is more resistant to heat because it has no outstanding fibres and because it is much darker before heating.

During this experiment WBPCB heating has never caused any fire, but it has to be mentioned that intensive evaporating and gasification had place in some cases, especially when longer preheat time were applied.

SUMMARY

The results obtained in these preliminary studies are promising. In general it might be stated that considering thermal resistance some WBPCB might take place of conventional epoxy PCB. They require however adopting soldering profiles and extra anti-fire care (e.g. the company LPKF producer of ProtoFlow oven delivers solution of heating in the nitrogen atmosphere).

LITERATURE:

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Streszczenie: *Technologiczne aspekty produkcji układów elektronicznych na płytkach z tworzyw drzewnych* W artykule opisano wstępne wyniki badań użyteczności płyt drewnopochodnych do produkcji pytek obwodów drukowanych (PCB). Płyty HDF i sklejki były badane pod względem ich odporności temperaturowej podczas topienia lutu. Drewnopochodne płytki PCB potrzebują więcej czasu i energii do stopienia pasty lutowniczej niż standardowe PCB. Płyty HDF wymagają dłuższego czasu wygrzewania wstępnego niż sklejki, ale ich kształt jest bardziej stabilny.

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