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Thermal and RF Characterization of Novel PLA/Flax Based Biodegradable Printed Circuit Boards

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ABSTRACT

1. INTRODUCTION

It is important to explore alternative paths for traditional electronics, in order to assess arising environmental issues. Electronic waste is a continuously investigated aspect, which is increasing in its impact from year to year. Biodegradables in electronics are still not common, while such plastics might offer a possible solution for PCBs in the greener mindset. Such materials were investigated from many different aspects recently, based on different substitutes of traditional glass-fiber reinforced epoxies. Banana stems [1], rice husk [2], flax-fibres with linseed oil [3, 4], other times polylactic-acid (PLA) [5] or Cellulose-Acetate (CA) [6] was used for experiments.

2. METHODOLOGY

In this paper we present one- and two-sided bio-based PCBs, which are based on a PLA/Flax composite with flame retardancy. PLA/Flax composites are used as bio-based prepregs (PLA-matrix with flame retardant additives and woven flax with added flame retardancy). The adhesive bond between layers were produced with flame retarded PLA powder. The starting copper layer is 35 μm thick, 1,5 and 2 mm substrate thickness was chosen for sample preparation. Basic designs were realized with traditional subtractive technology, but this paper mainly focuses on the thermal and RF characterizations. Figure 1 shows an example of an educational blinker circuit produced from the material before and after surface mounting, soldered with experimental vapour phase soldering reflow method at low temperature.



Figure 1. – Test circuit produced from PLA/Flax substrates (before – top, and after – bottom assembly).

The method we used for thermal characterization was focusing on the thermal diffusivity, with heat-pulse method, a widely used approach for determining this parameter. The method consists of exciting the surface of the sample with a flashlight (thermal pulse) and measuring the change in temperature of the sample on the other side. For the radio frequency (RF) characterization of the dielectric, the dielectric constant and the loss tangent of the PLA substrate were evaluated by mean of the resonant cavity method between 0.93 and 65 GHz.

3. RESULTS

The results obtained from the heat-pulse procedure resulted in the following plot (Figure 2.) It can be seen that the measured and the curves generated from the fitted Fourier-model fit almost perfectly. This equation typically gives an accurate approximation for homogeneous materials. The material we measured was not homogeneous, yet the model approximates it well with a similarity to the thermal diffusivity of bulk PLA materials [7]. We obtained an average value of $5.65 \cdot 10^{-8}$ m²/s (from seven measurements) for the thermal diffusivity (which is in line with the data from [7]).

The RF losses in the PLA are evaluated with the delta tangent which corresponds at a given frequency to the ratio of the imaginary part of the permittivity of the material by its real part (Table 1). They are 5 times lower than paper-based substrates because of the moisture content of papers and of the order of magnitude of the losses in FR4 substrates. Despite the fact that the losses are higher than in classical RF substrates, by optimizing the design of the antenna, it is possible to obtain comparable performances to a similar design realized on a conventional RF substrate.

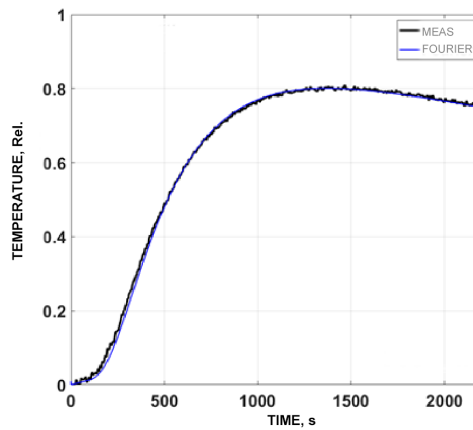


Figure 2. – Heat pulse validation of the PLA/Flax substrate.

Table 1. – Losses of paper and PLA/Flax-based substrates (5% err.)

Material	Thickness(μm)	Frequency(GHz)	eps'	Tan(delta)
Paper	128	0,93	3,28 \pm 0,04	0,122 \pm 0,008
Paper	128	2,48	2,92 \pm 0,02	0,101 \pm 0,003
Paper	128	4,3	3,2 *	0,1 *
Paper	128	4,7	3,1 *	0,1 *
Paper	128	8,3	3,1 *	0,09 *
Paper	128	10,3	3 *	0,09 *
PLA	1300	0,93	2,49 \pm 0,17	0,05 \pm 0,01
PLA	1600	2,48	2,31 \pm 0,16	0,04 \pm 0,01
PLA	800	55	3 *	0,02 *
PLA	800	65	3 *	0,03 *
PLA	1250	55	2 *	0,015 *
PLA	1250	65	2 *	0,08 *
PLA	1500	55	2,2 *	0,02 *
PLA	1500	65	2,2 *	0,03 *

4. NOVELTY and IMPACT

In this paper we present a novel multilayered (two-sided, two-layered) bio prepreg-based PCB and its thermal and RF characterization. We produced successful, working demonstration PCBs with one sided surface mounting, and compatibility with traditional PCB and assembly methodologies. The results point to a very promising path for the future in establishing an environmental mindset.

We showed that the thermal diffusivity of the substrates are very similar to PLA. It was also found that the losses are better than traditional paper-based eco-friendly and similar to FR4 PCB substrates. An initial antenna design on PLA/Flax substrate resulted in a good compromise, meeting IPC standards with better environmental impact as shown by LCA.

We also reached an improved, second generation of material, where the layer- and assembly quality is improved from the original substrates. These samples are currently under evaluation.

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