Printed electronics for multifunctional composite structure

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ABSTRACT

A multifunctional composite laminate which can harvest and store a solar energy was fabricated using printed electrodes: The integrated PCB was co-cured with a carbon/epoxy composite laminate by the vacuum bag molding process in an autoclave; a silicon solar cell and a thin film solid state lithium-ion battery were adhesively joined and electrically connected to a thin flexible printed circuit board (PCB); and then the passive components such as resistor and diode were electrically connected to the printed circuit board by silver pasting. The structural and functional performance of the final energy harvesting/storage composite laminate was tested under mechanical loading.

INTRODUCTION

Multifunctional composite structure is defined as the structure which can not only bear the load but also perform several electronic functions such as energy harvesting and storing, sensing and actuating, and more. In order to perform multi-functional electronic functions, a conducting pattern should be embedded within the load bearing structure. As for the patterning of conductive circuits, the conventional photolithographic method used for printed circuit boards (PCBs) is time consuming, expensive, and environmentally undesirable. As an alternative, Kim et al. and Park et al. used an ink containing nano-sized Ag or Cu particles in an inkjet printer to print conductive path on a polymer substrate.[1,2] Although the melting temperature of bulk copper is 1084.62 ˚C, the authors have shown that when the particle size is in the few-nanometer range, the printed film can have as high conductivity as a conventionally produced film at a much lower sintering temperature.

In this research, the conducting circuits are placed on the laminate using an inkjet printing technique. In order to show the feasibility of the printed electrode for multifunctional composite structure, an energy harvesting and storing composite laminate was made using printed electrodes as interconnection between a thin-film solar cell and a thin-film battery. The cross-section view is shown in Fig. 1. The performance of this laminate was studied under mechanical loading.

APPLICATION OF THE PRINTED ELECTRODE

Both of I-V curves and fill factors of the solar cell in the power laminate hardly changed up to 1% strain, which is similar to the result of Sugar et al.[3] For the charge cycle, a constant voltage of 4.2 V was applied until the current drop to 0.1 mA. For the discharge cycle, the current was maintained at 1 mA until the voltage drops to 3 V. The charge and discharge capacities were then calculated by integrating the measured current over time to the cut-off point. It was found that there was no difference of charging characteristics between at no strain and 0.4 % strain. It could be concluded that the energy harvested by the integrated solar cell could be stored to the embedded battery successfully through the printed electrical connection on the power laminate up to 0.4 % strain. However, the battery performance is seen to degrade drastically at about 0.45% strain, similarly to the result of Pereira et al.[4] The 0.45% strain for the battery failure might be too low for composite structures. Therefore, further research is required to develop batteries with high strain capability.

REFERENCES

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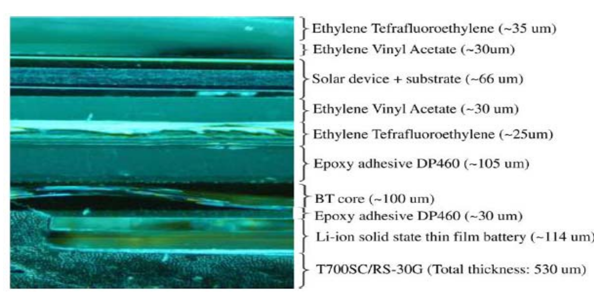

Figure 1: Cross-section view of the power laminate