Development of Passive Component using Carbon Powder for Electronic Circuit Board

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Abstract

A circuit board is made from a polymer material and includes a predetermined portion which has magnetic or dielectric or resistive properties. The portion with the magnetic, dielectric or resistive properties is firstly made and arranged within a carbon based mould. A polymer-bonded carbon is then applied to the mould to form a board incorporating the portion with the magnetic, dielectric or resistive properties. The circuit board can also be integrated with polymer-bonded magnetic materials to also form magnetic devices. The carbon material forms capacitor based components and the magnetic material forms the inductive and transformer types of components. The paper discusses the above new methods of constructing a total integrated circuit board with all passive components developed by carbon and magnetic components. The magnetic and capacitive components are made by metal coating. The capacitive is made by layer of metals as the electrode. The magnetic winding was made by developing the winding through printed circuit board techniques. A new winding method is also proposed to give excellent ways to reduce the leakage and enhance the overall efficiency.

Introduction

Classically the electronic components are mounted on the printed circuit board (PCB) using through-hole or surface mounted devcies. The electronic components are usually discrete components that are produced separately. Another desire from the research and development needs is that the components can be integrated with the PCB, the cost and space can be reduced. The electronic circuit including power electronics circuit (Cheng, 2002), the power components including the capacitor, inductor and resistor are the three basic passive components that are considered to develop the techniques for the integrated in the PCB. There are many resistors that are constructed using carbon materials such as carbon film resistor. Therefore the integration or to develop the techniques of embedding of the carbon materials on a PCB to construct a PCB is a right direction of development.

The magnetic devices usually consist of a magnetic core and the copper winding. The magnetic core is usually made of power iron, ferrites and other magnetic materials. Recently there is a technique of using polymer-bonded magnetic for the construction of the magnetic devices (Cheng, Tang 2002; Wu 2006; Ding 2006). The method is to use polymer bonded with magnetic materials which is a very small powder with size down to micrometer for the construction of the polymer-bonded magnetic devices. Because the polymer-bonded magnetic materials can be produced by injection moulding and hot press machines, therefore it can be integrated with the PCB.

Capacitor is basically constructed by two parallel metal plate of conductive plate with some dielectric between the metal plates. The metal is called electrode of the capacitor. The dielectric material can also be embedded in the PCB and the electrode can be plated on the PCB. Alternatively it can also be replaced by carbon film. Therefore the three major passive components can be constructed and embedded with the PCB.

This paper is to discuss the implementation of the above three passive components on a PCB. The active semiconductor components cannot be developed directly in the PCB and they are procured in a surface mounted format and embedded in the PCB. An experiment using the new polymer-bonded magnetic has been used. Good permeability has been achieved and it gives a good indication of the polymer to be embedded in a PCB.

The Magnetic Device Embedded Method

The inductor is constructed by a magnetic core and windings. The magnetic core is a polymer bonded material that is embedded in the PCB. The windings are constructive materials that provide the source of the magnetic field core. There are a number of topology for the core such as solenoids, ring, E, U, or even air-core. Fig 1 and Fig 2 show the solenoid and the ring types.

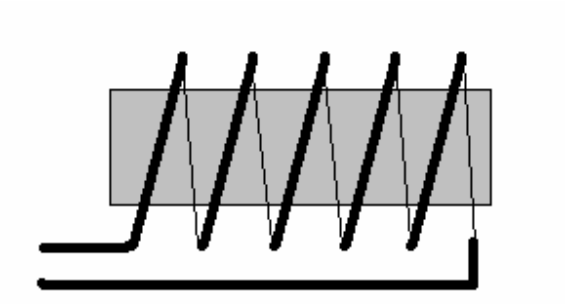

Figure 1. The construction of the solenoidal inductor where grey colour is embedded on the PCB. The winding is plated on the PCB and shown with thick black line for upper conductor wire and thin black wire for underneath wire.

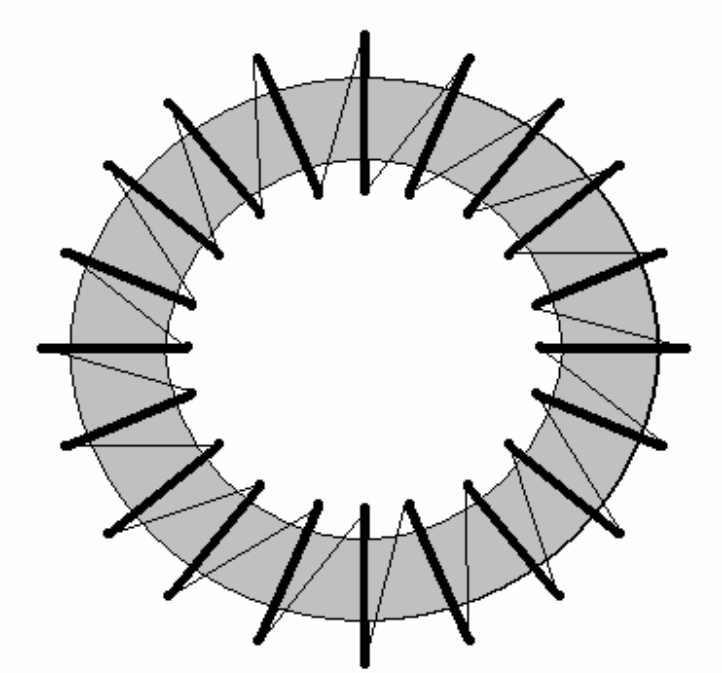

Figure 2. The construction of the ring core inductor where grey colour is embedded on the PCB. The winding is plated on the PCB and shown with thick black line for upper conductor wire and thin black wire for underneath wire.

Figure 3. Two types of structure of the spiral core inductor using air-core and the wing is just painted on the circuit board.

The winding is basically using copper as the conductor. The copper wire can be obtained by the conventional PCB techniques such that the copper is plated in the circuit board and the use the etching to obtain the suitable geometry of the connection wires. Alternatively the wire can also be obtained by conductive polymer (Tang 2003). Also direct bonding of conductive carbon can be plated on the circuit board to replace the copper wire. This method can also reduce the usage as the copper cost has been raised by 3 times in last 2 years. Although the conductivity of the carbon is not as good as the copper, the method presents a simple and cost effective for wiring connection in a PCB.

The Capacitor Embedded Method

The capacitor is basically constructed by two parallel plates of conductor and the dielectric material is between the two plate. The dielectric materials are for example polyester, KF polymer, polycarbonate, kapton, polypropylene, polysulfone, polystyrene, Teflon.

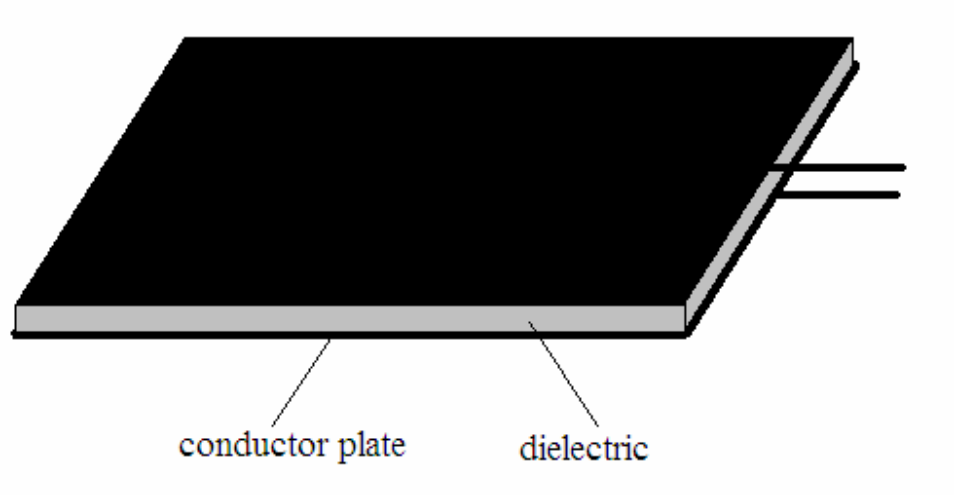

Figure 4. The construction of the capacitor

The capacitor using carbon as the electrode is sometimes called the electrochemical capacitor (Lipka 1997, Kinoshita 2001). The carbon electrodes attract the chargers to from double layers. However, the loss and the performance also depend on the resistance of the electrode. Using carbon will be not as good as other metal electrode.

The Resistor Embedded Method

The graphite is rod that is used to be the electrode because of the chemical stability and low cost. Its structure is a hexagonal structure, with the carbon atoms arranged in layer planes. Therefore it is used as conductor as discussed above. It is useful to control the conductivity of the materials by using composite. This can be done by using polymer, ceramic to mix with carbon. For example, the alumina-matrix TiO_2 particulate composite has resistivity of $5x10^5\Omega cm$ and composite of carbon and silica fume has resistivity of $8x10^2\Omega cm$ (Chung 2004).

The Passive Component Embedded Circuit Board

The circuit

A PCB with the above three materials used has been examined for a circuit design. The initial study is intended to work at very high frequency so that the capacitance and the inductance used are in low values. Therefore the polymer bonded magnetic device is designed to work at low permeability in order to achieve low value of inductance. A typical circuit as shown in Fig 5 is used for the examination. The circuit is called switched-capacitor (Cheng 2001). Q_1 and Q_2 are the switching devices or transistors which are responsible for the high frequency switching of the power conversion. C_r is the capacitor work works with the inductor L_r to form the resonant tank. C_o is the output filter. R the load resistor. Another circuit that can use higher value of inductance L as the filter is shown in Fig 6. It is a buck converter (Cheng 2002).

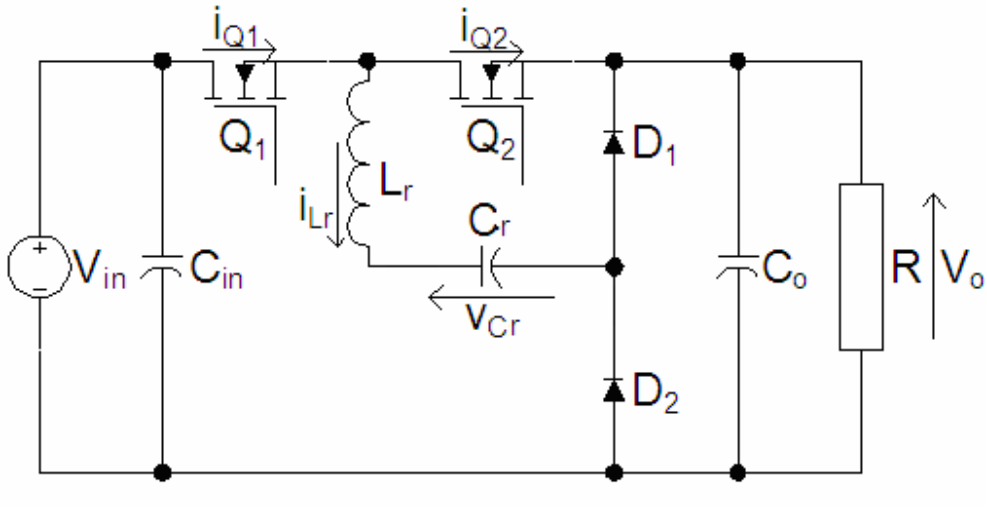

Figure 5. An electronic circuit called switched-capacitor under test

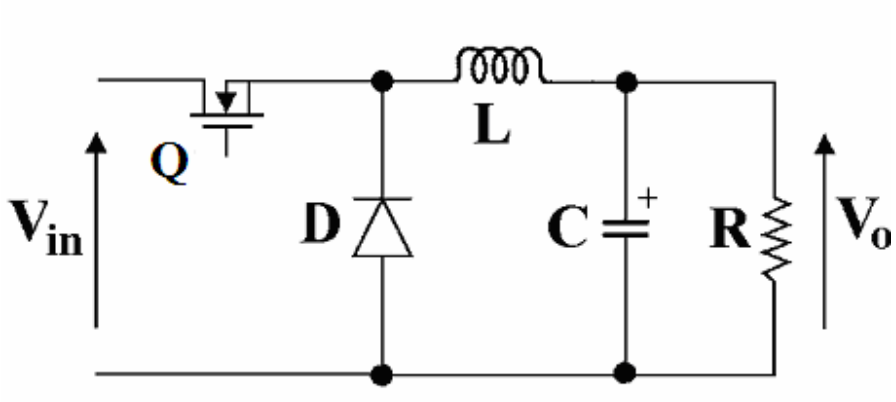

Figure 6. An electronic circuit Buck converter under test

The characteristics measurement

The polymer bonded magnetics $9x10^{-6}m^2$ and length $7.06x10^{-2}$m. of core for the construction. The inductor is constructed using 45 turns. Difference composites of PE or PMMA, NiZn are used. The results under difference frequency test are shown in Table 1.

Table 1. Results o the frequency test of the magnetic composite

		5kHz	50kHz	100kHz	500kHz	1MHz
10%PE, 90%NiZn	L(μH)	44.0	42.6	42.4	42.0	41.98
	μ_r	13.6	13.1	13.1	13.0	13.0
10%PE, 10%PMMA, 80%NiZn	L(μH)	42.4	41.5	41.3	40.9	40.9
	μ_r	13.1	12.7	12.7	12.6	12.6
30%PE, 70%NiZn	L(μH)	16.4	16	15.9	15.7	15.7
	μ_r	5.06	4.94	4.91	4.85	4.85
40%PMMA, 60%NiZn	L(μH)	13.7	9.95	9,84	9.69	9.65
	μ_r	4.21	3.07	3.04	2.99	2.98

Fig 7 shows some samples of the polymer bonded materials. They are initially tested using copper wire for the windings. The polymer-bonded composite is the grey ring surrounded by the copper wire. Fig 8 shows the measurement of the resistance and inductance versus frequency test.

Figure 7. The composite using 10%PE-10%PMMA-80%NiZn to construct a sample

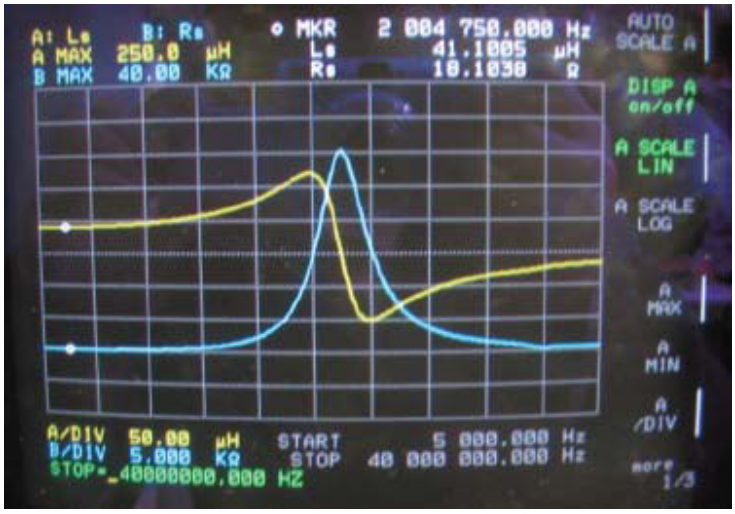

Figure 8. Measured variation of the resistance and inductance of the inductor.

The embedded board

The material for the polymer-bonded magnetics was then used to embed into a circuit board. The number of turns cannot be made too many as in the test because the etching resolution for many turns with power current through is not simple. In the test, only less than 10 turns was used. Using carbon materials and copper materials as the windings have also been tried. It can be seen that the loss for the carbon is relative high because the coating thickness cannot be very thick and it reduces the conductivity. However, the copper turns are very good and the inductor constructed can be used for actual circuit implementation.

The capacitor is constructed as in previous section and the dielectric using polycarbonate. The capacitance achieved is low as multiple surface areas have not been used. In order to increase the capacitance, a large electrode area should be used and a multiple layer techniques for the circuit board can be used.

The resistor is not a primary device for power converter as it consumes power. For small circuit test, it can be construed as the load resistance for the demonstration. A carbon based film is used for the embed resistor. For the transistor and diode, they cannot be developed by the above techniques and they are using surface mounted components and mounted directly on the PCB to form the whole circuit.

The overall performance of the circuit is satisfactory especially the polymer-bonded magnetic device performs well. It can be a good design for the future embedded passive components instead of the through-hole or surface mounted components.

CONCLUSION

The passive components including the inductive, capacitive and resistive components have been discussed in the paper for the use as embedded components. The intention is to construct and embedded them in a PCB so that the overall size can be reduced. The result PCB is just a piece of sheet. The magnetic components can be constructed using polymer-bonded magnetic device. The core is embedded in the POCB and the windings are painted on the PCB. For the capacitor, the capacitor dielectric are embedded in the OCB with the electrode plate on the PCB. However, the initial device can only achieve low value and an improved method such as multiple layers of capacitor techniques should be used.

ACKNOWLEDGEMENT

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