Experimental Analysis of Nano-Carbon Doped Alumina for Industrial Applications

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Abstract

In this paper, nano-carbon doped aluminum oxide has been synthesized by chemical vapour deposition (CVD) methodology. The electrical properties of developed samples were measured by Auto-lab PGSTAT with frequency range 10μHz – 32MHz with resolution 0.003% whereas fractographical analysis of the samples was performed by scanning microscopy from Zeiss evo eighteen. The experimental frequency response plots illustrated that nano-carbon doped alumina may be utilized as Low pass filter for top frequency discontinue at 9000 Hz in electronic industrial applications. The energy dispersive X-ray chemical analysis (EDS or EDX) of nano- carbon doped alumina showed a metal- insulator transition development happens to be at 30% nano carbon mass doping in aluminum. The fractographical analysis of nano-carbon doped alumina revealed the minimum voids, defects and porousness that cause marginal deviation in electrical properties at higher temperature.

Keywords: Low pass filter, Metal- insulator transition, Fractographical analysis.

1. Introduction

Recently, the shifting from 4G to 5G technologies needs multiband operations using complicated radio frequency modules for wireless communication systems. The RF shift technologies are then needed with high isolation, high dimensionality and high dependableness [1]. The figure of merit (FOM) that is usually referred to as cut-off frequency for RF switches are of many orders of magnitude beyond solid state devices [2]. Vanadium oxide (VO_2) as a metal-insulator transition (MIT) and Germanium Telluride (GeTe) as a state change materials (PCM) draw attention towards RF shift materials due to their distinctive properties and transitions from insulator to metal (amorphous to crystal for PCM) or vice- versa at room temperature along with high OFF/ON resistance ratio was observed [3-5]. Transformation metal oxides get appreciable interest in physics engineering applications for over few decades. These materials showed metal insulator transition (MIT) triggered by external stimuli [6-10].

In this analysis work, the experimental verification of the metal-insulator transition (MIT) property of nano-carbon doped alumina has been demonstrated. Moreover, the fractographical analysis was additionally performed by scanning microscopy images.

2. Experimental

Filters in circuits are being used to get rid of unwanted frequency elements from a signal. Filters are helpful for rising signal-to-noise ratio and rejecting unwanted signals. Practically low pass filters will be engineered up by using solely passive devices like resistors, capacitors and inductors that are costly circuit elements and are physically massive for low frequency designs. It is doable to eliminate the necessity of inductors by using active devices like op- amps. In this way devising of filters are referred to as active filters. They can save area, weight and additional typically the price abundant than passive designed filters. It additionally eliminates filter loss and is easier to use since they need high input resistance and low output resistance. Active filters can even have variable voltage gain and permit straight forward tuning of the cut-off frequency.

Low pass filters or high cut-off filters for passing lower frequency signals are on the far side a particular cut-off frequency and attenuate higher frequency signals beyond cut-off frequency. The selected filter material or designing is a vital parameter for signal attenuation amount of every frequency. In a series RC circuit, the cut-off frequency f_C in Hertz in terms of resistance R in ohms and capacitance C are often obtained as,

$$f_c = \frac{1}{2\pi RC} = \frac{1}{2\pi\tau} \quad (1)$$

Where, the product of resistance and capacitance is a time constant in τ seconds.

The nano-carbon doped alumina has been synthesized by chemical vapour deposition (CVD) technique. The aluminium material is then placed within the CVD chamber and was heated at 700^0C. A methane series gas is allowed to flow within the chamber to deposit nano carbon molecules over aluminum material with nitrogen gas as a catalyst. The remaining carbon dioxide gas is blown aloof from the furnace chamber. The nano-carbon doped aluminum is currently cooled at room temperature for the synthesis of nano-carbon doped alumina. Finally, the developed nano-carbon doped alumina sample was cut-down as per ASTM D 638-03 size for the testing of electrical properties as shown in figure 1.

Figure 1 Developed nano-carbon doped aluminium oxide sample as per ASTM D 638-03 size.

3. Results and discussion

The electrical properties of the above prepared nano-carbon doped aluminium oxide samples were measured by autolab PGSTAT in the frequency range 10μHz – 32MHz with resolution 0.003%.The experimentally obtained bode plots or frequency response plots are shown in figure 2 and figure 3.

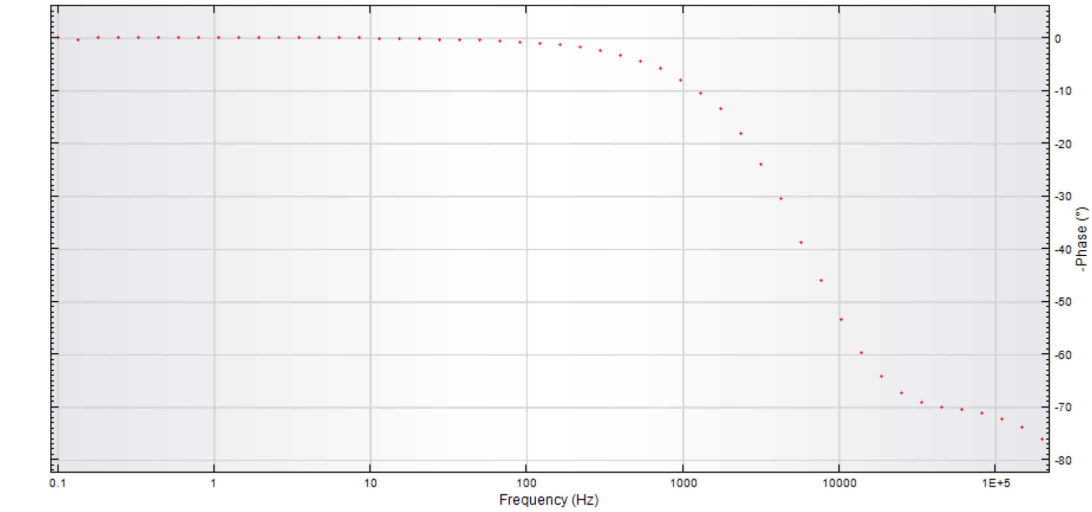

Figure 2 Frequency versus phase plot of nano-carbon doped aluminium oxide.

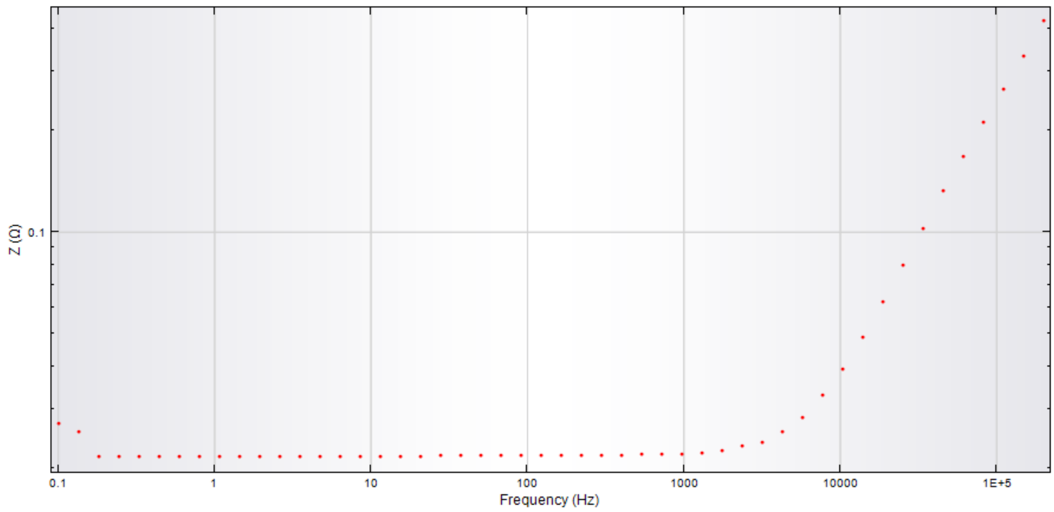

Figure 3 Frequency versus impedance plot of nano-carbon doped aluminium oxide.

Figure 2 illustrates that the lower frequency signals upto 9 KHz can easily pass through sample while the upper frequency signals over 9 kHz are eliminated due to metal- insulator transition in nano-carbon doped alumina. Figure 3 illustrates that the impedance is minimum within the nano-carbon doped alumina up to 9 kHz cut-off frequency that behaves as metal to pass alternating current signals through the sample whereas for cut-off frequency more than 9KHz the impedance suddenly becomes maximum within the nano-carbon doped alumina that behaves as insulator to attenuate alternating current signals through it.

The energy dispersive X-ray spectroscopy (EDS or EDX) or chemical microanalysis technique used with scanning electron microscopy (SEM) of nano-carbon doped aluminium oxide samples were measured by JEOL EDS system which are shown in figure 4 and table 1.

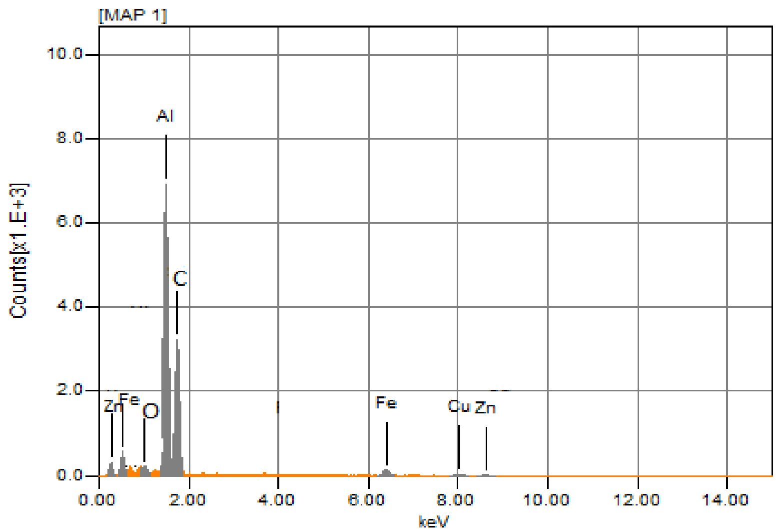

Figure 4 Energy dispersive X-ray spectroscopy of nano-carbon doped aluminium oxide.

Table 1 Chemical mass percentage composition of nano-carbon doped Aluminium oxide.

S.No.	Chemical	Mass%
1	C	30
2	Al	69.10
3	Fe	0.60
4	Cu	0.04
5	Zn	0.26
	Total	100

Figure 4 and table 1 are illustrating that 30% of nano-carbon mass in the developed aluminum sample produces the metal- insulator transition phenomenon in nano-carbon doped aluminum oxide at 9 KHz operating frequency. Furthermore, the fractured surface micro analysis of nano-carbon doped aluminium oxide using scanning electron microscopy revealed the minimum voids, defects and porosity as shown in figure 5 which in turn causes minimal deviation in electrical properties at higher temperature.

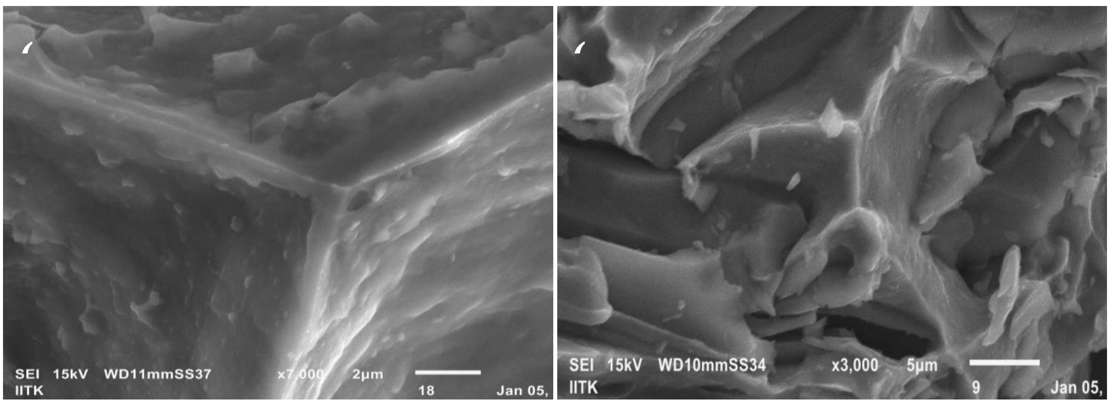

Figure 5 Scanning electron microscopic image of nano-carbon doped aluminium oxide (a) Magnification 7000 (b) Magnification 3000.

4. Conclusions

This analysis paper reports a flourishing development of nano- carbon doped aluminum oxide material by chemical vapour deposition (CVD) methodology. The electrical properties and its analysis of nano- carbon doped aluminum oxide results in the conclusion that the nano- carbon doped aluminum oxide acts as a metal-insulator transition material at cut-off frequency 9 kHz as shown in figure 2 and figure 3. Moreover, the energy dispersive X-ray spectroscopic analysis (EDS or EDX) of nano- carbon doped aluminum oxide discovered that metal- insulator transition development happens at 30% nano-carbon mass doping in aluminium as shown in figure 4 and table 1. Furthermore, fractured surface analysis of by scanning electron microscopic images has revealed that the minimum voids, defects and porosity cause minimal deviation in electrical properties at higher temperature. Consequently, this nano- carbon doped aluminium oxide material can be the future alternatives of engineering material for electronic industries as a high frequency switches. In future, the potential nano-carbon doped other metal oxides can be explored for higher cut-off frequency switches.

Acknowledgments

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