



Gel-cast—A promising technique to develop highly sensitive temperature sensor

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ABSTRACT

Higher thermal coefficient of resistance (TCR) for any sensing element is prerequisite to ensure best sensing performance, because the rest of the sensor parameters just follow the suit. In this paper, we report a simple, low cost technique, called 'gel-cast' for the preparation of tape/film from multi-walled carbon nanotubes (MWCNTs)-Alumina (Al_2O_3) composite and its potential use as temperature sensor. The composite was prepared by uniform dispersion of MWCNTs in alumina sol, prepared by sol-gel route. Sensors with varying concentration were subjected to moderate to high temperature ranges. Results show excellent sensing performance in terms of response-recovery time, sensitivity, and resolution. Sensor with 2% wt MWCNTs was found to have TCR value of around $-0.87\%/^\circ\text{C}$ which is quite high in comparison to works reported so far on MWCNTs-ceramic composite film deposited by other techniques. Besides, cyclic studies show good thermal stability without any significant thermal hysteresis loss and compositional breakdown.

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1. Introduction

Temperature has always been a crucial part of more or less all the processes that we come across in our day-to-day lives. To maintain a critical temperature required for a particular process, its measurement is a prerequisite. This has gained incessant focus from the research community around the world resulting in a relentless demand for a fitting material, having excellent thermal properties, which can be used to fabricate temperature sensors. One such material which has been (and is being) intensively investigated by the researchers around the world is carbon nanotubes (CNTs). Discovered by Iijima in 1991, they are being inexorably investigated for their unprecedented electrical, mechanical and thermal properties [1–4]. Structurally, CNTs come in two flavors: single-walled (SWCNTs) and multi-walled (MWCNTs). All types of CNTs show an excellent temperature dependent resistivity which can be utilized for temperature sensor fabrication [5–7].

Other types of sensors which can be used to measure temperature include thermocouple, metallic resistors, semiconductor diodes, infrared thermometry, thermistors, near field thermometry etc. each having different operational mechanism

and its own advantages and disadvantages. CNT's exceptional thermal as well as electrical conductivity in comparison to other materials can be used to improve the performance of temperature sensors fabricated out of CNTs [8–11].

Various research groups have demonstrated the use of CNTs as temperature sensors. These include, *but not limited to*, Kumari [12], Sibinski [13], Matzeu [14], Karimov [15,16], Shrestha [17], Hirotani [18], Riedel [19]. All these scattered studies have strong limitations vis-à-vis the fabrication of sensor, temperature range and TCR. One of the major issues encountered in a temperature sensing device is its poor TCR and thermal hysteresis loss, which can greatly affect its proper functioning. The problem that arises and needs to be confronted is how to reduce it to minimum possible level.

CNTs have already proved its candidature as fillers for composite materials [20–22]. It has high young's modulus, with good flexibility, high aspect ratio, high electrical conductivity, as well as good thermal and chemical stabilities. But CNTs processing as fillers, homogeneous dispersion in matrix materials and the interfacial bonding with ceramics are still a matter of concern. Although alumina, due to its hardness as well as good chemical and thermal stabilities, is one of the most widely used ceramics, it has low fracture toughness as well as low electrical conductivity. Therefore, if these factors can be improved, the ceramic would be expected to have a variety of possible applications [23–25].

In this manuscript, we have tried to address these issues in relation to a temperature sensor where the deposition technique is

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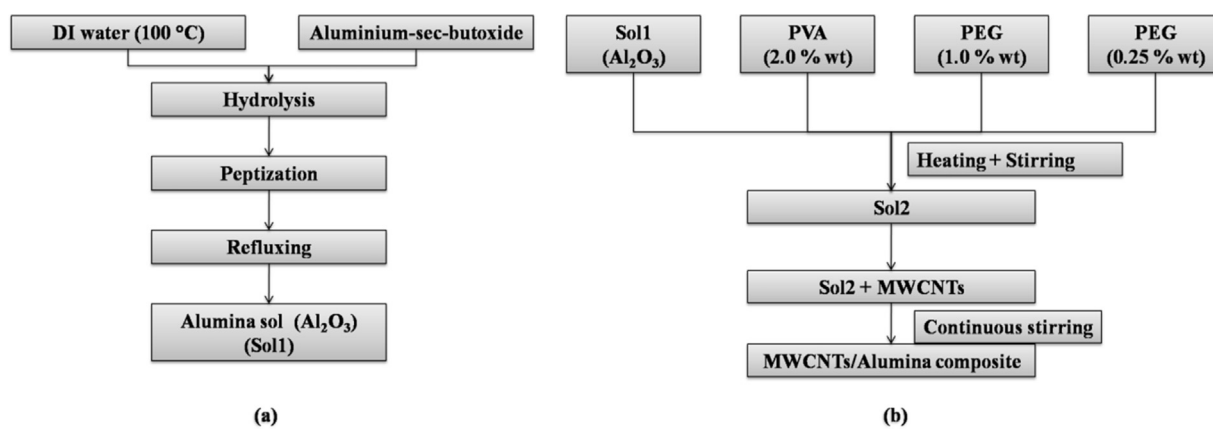


Fig. 1. (a) Sol-gel process flow and (b) process flow chart for MWCNTs-Alumina composite preparation.

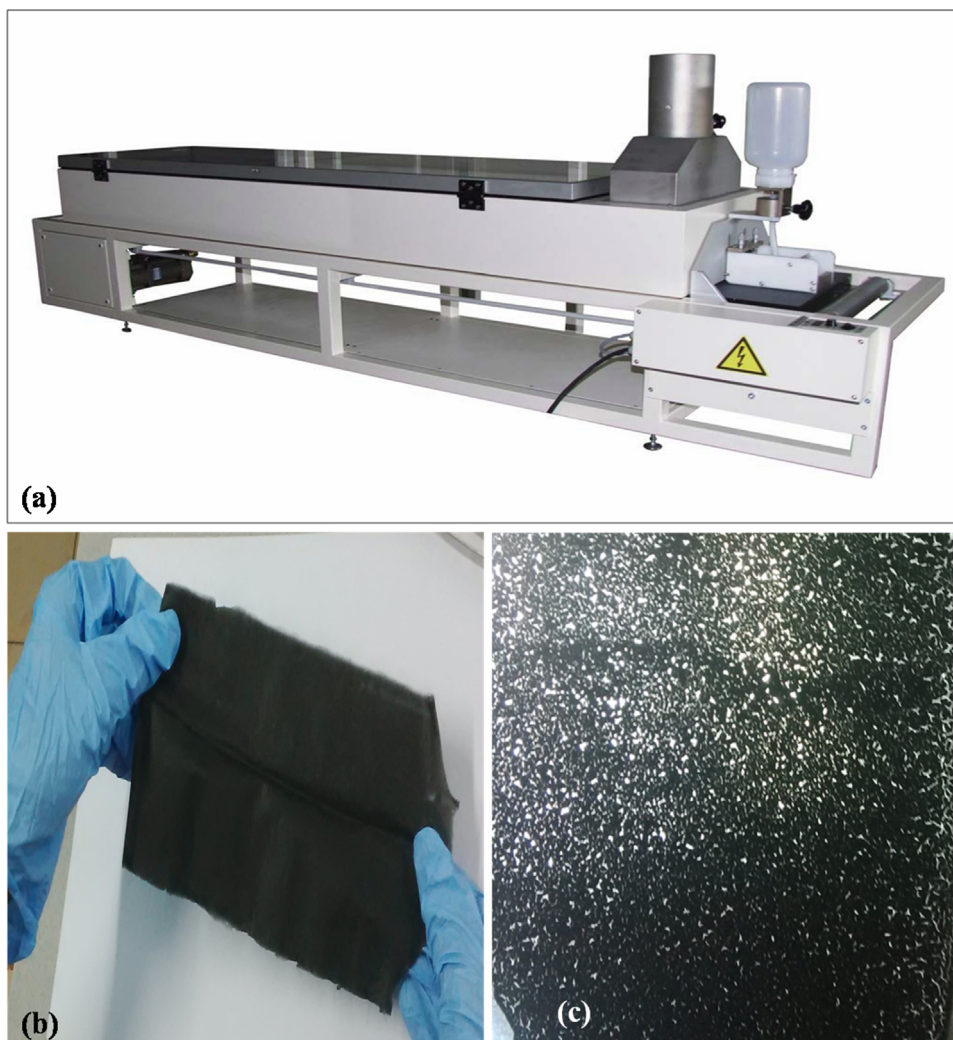


Fig. 2. (a) Tape-Cast equipment used for composite film preparation, (b) composite sample prepared by using gel-cast method and (c) composite showing formation of cracks in the samples for MWCNTs concentration greater than 3% wt.

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