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Fabrication of Continuous Fire Wire Detection Sensor using Negative Temperature Coefficient Material

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ABSTRACT

Manganese-based spinel semiconducting ceramic was mixed with lanthanum oxide powder and the mixture was characterised for the reproducible negative temperature coefficient (NTC) of resistance behaviour. The same mixture was used for the fabrication of 15 m long continuous thermal detector. The addition of La_2O_3 leads to decrease in thermistor constant and activation energy values, thus giving freedom to fabricate thermal sensors for various temperature applications. A 3 m long continuous thermal detector for application in the temperature range 275 - 350 °C was fabricated and later coupled to form a continuous unit of 15 m length.

Keywords: Negative temperature coefficient, thermistor, temperature coefficient of resistance

1. INTRODUCTION

The initial work on negative temperature coefficient thermistor first took off in Philips Laboratories for controlling resistivity of semiconducting oxide materials, a large number of articles have appeared for its properties, preparation, and applications[1]. Multicomponent transition metal oxide (TMO) comprising oxides of manganese, nickel, and cobalt has higher temperature coefficient of resistance (TCR) and medium resistance of few hundred kilo ohms. Hence, it is prominising material for development of temperature sensors and for infrared detector devices[2]. Negative temperature coefficient (NTC) materials are mainly oxide mixtures of metals such as *Mn*, *Ni*, *Co* in a proper proportion and sintered at high temperature during which the spinel phase with thermistor characteristics is formed. The dependence of resistance on temperature follows an exponential law[3]. Manganese-based spinel semiconducting ceramics have been studied as NTC thermistor since these possess interesting electrical properties[4-7].

Heat detection systems have been widely used on installations to harness the heat generation source and for security against fire hazards by developing early warning systems. The salient features for these devices vary with the application and advancement of technology. Point detectors using fusible alloys and thermocouples came into being as early as 1930's. To overcome their limited-area coverage, continuous detectors were developed which resembled long continuous wires and were routed through the length of the engine. The continuous thermal detectors comprised long parallel thermocouple wires placed inside a stainless steel tube and the space inside the tube and in between the wires was filled with a NTC material. It acts as a continuous thermocouple where any portion heated acted as a hot junction due to semiconducting nature of the filled powder. On connecting with an alarm system functioning

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at NTC temperature, it can be used as an early warning system for fire hazards.

The study on the NTC behaviour of powder mixture Mn_3O_4 and La_2O_3 powder mixture over a temperature range of 100-400 °C has been reported[10]. The paper highlights NTC mixture used to fabricate continuous thermal detectors of 3 m length. The current study is an extension to the previous work which highlighted the method to couple 3 m long continuous wires to make a continuous length of 15 m. It was seen that with the increase in temperature, the resistance values of 15 m long sensors showed same decrease (from mega ohms values at room temperature to ohm value at higher temperature), as it was evident in the characterisation of test pallets and 3 m long sensors.

2. EXPERIMENTAL PROCEDURE

The manual fabrication of continuous detector was limited to 3 m length due to physical restrictions in the method of filling[10]. Hence, the option of coupling two 3 m detectors and so on, to make a length of 15 m was decided. Figure 1 shows the requirements and Fig. 2 shows how the coupling of 3 m sensors was used to suffice the 15 m length.

3. DESIGN CONCEPT

The coupling of sensing tube was done using connectors comprising two identities – a male part named plug and a female part called socket. The salient prerequisites for the connector units are– there should be no or minimal loss in the electrical conductivity or change in potential value at the connecting junction. Any type of short-circuiting among the wires and casing should be avoided. Besides, the end coupling should be able to withstand a temperature of the order of 1100 °C. To enhance the versatility, the interchangeability among plugs or sockets must be conceived.

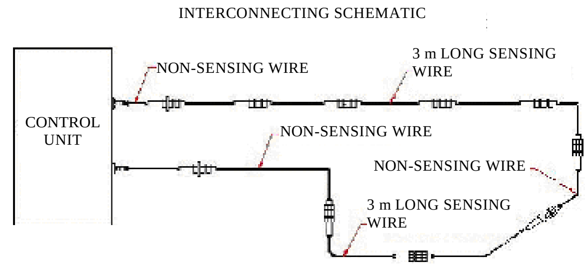

Figure 2. Coupling of 3 m sensors to make 15 m and 6 m long units.

The plugs were made of SS 316 covering with brass terminals inside, and the space between the cover and terminals was filled with quartz mixed with sodium silicate binder. The mixture acted as insulator between the terminals as well as between the terminals and the SS 316 covering. Besides the mixture showed required thermal stability at the elevated temperature.

The brass terminals minimised the electrical losses. Both the terminals were perforated to small length used for manual crimping of the sensor wires with the terminals. The other end in case of male terminal was solid while in case of female, it was hollow and these ends were used in mating when the two 3 m sensors were coupled together [Figs 3(a) and 3(b)]. The male and female terminals

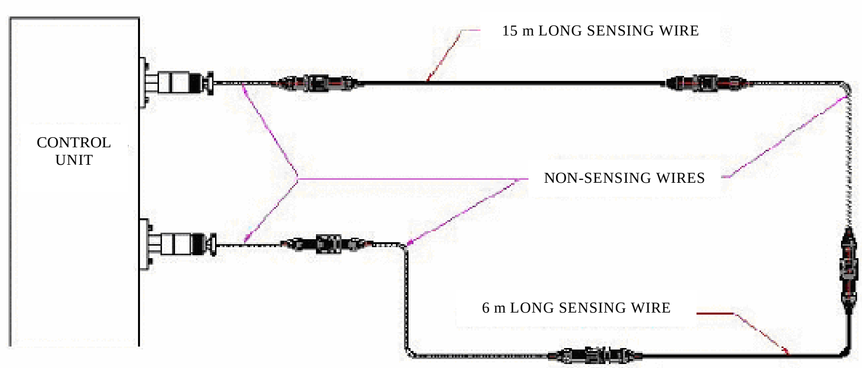

Figure 1. Requirement of 15 m and 6 m long sensing wires without any joint.

were placed in male plug and the female socket, respectively [Figs 4(a) and 4(b)]. Figure 5 shows the crimping of wires of 3 m long thermal detector with the terminals both of male plug and female socket. The crimping joint being fragile was given added strength through a cap (Fig. 6) which is Tungsten Inert Gas (TIG) welded to the SS sensor tube on one end and to the male plug/ female socket on the other end (Fig. 7). After welding, five numbers of such 3 m long continuous thermal detectors were coupled as in Fig. 2 to make a length of 15 m long. Similarly, 6 m long thermal detectors were also fabricated.

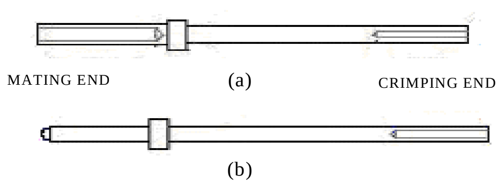

Figure 3. (a) Female terminal, (b) male terminal.

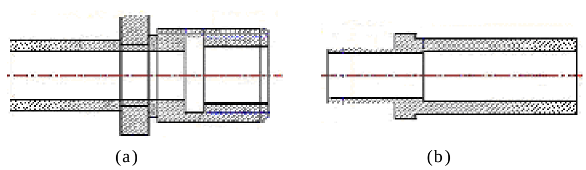

Figure 4. (a) Plug male, (b) socket female.

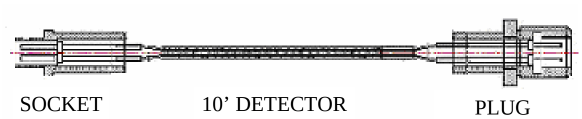

Figure 5. Crimping of sensor wires with terminals of end corrections.

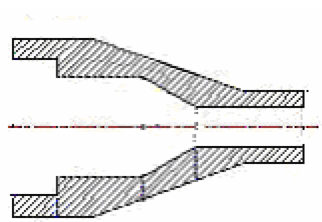

Figure 6. End cap.

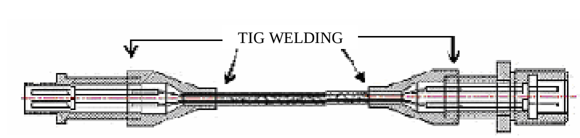

Figure 7. TIG welded joints to enhance crimping strength.

4. NTC CHARACTERISATION OF 15 METER LONG SENSOR

Resistance values were measured as shown in Fig. 8. The resistance values between the two thermocouple wires and also between each thermocouple wire and the body (SS 316 tube) were used to characterise both the individual 3 m sensors and the other 15 m single sensor formed by coupling of 3 m sensors. All the sensors showed resistance values of mega ohms at ambient temperature. With the increase in temperature to 100 °C, the resistance values fell to kilo ohms. On further increase in temperature, the resistance values of sensor dropped by 35-40 per cent of its value for every 20 °C increase in temperature. The plots for the resistance values between the thermocouple wires versus temperature in the range of 200 °C to 400 °C for 15 m thermal detector is shown in Fig. 9. Similar plots were observed for the resistance values in between SS tube and each individual wire of thermocouple for the 15 m long thermal detector. The test pallets, the individual thermal detector of 3 m and the thermal detector of 15 m formed by

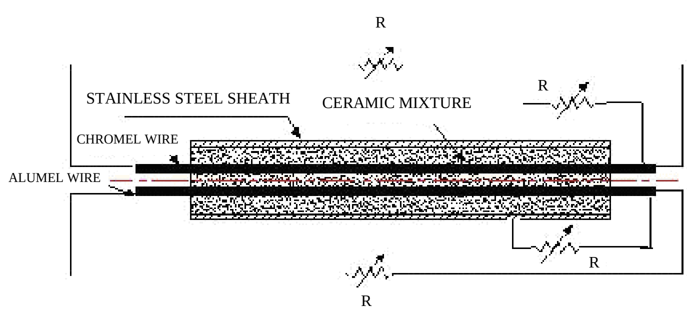

Figure 8. Three characterisation methods shown by symbol R.

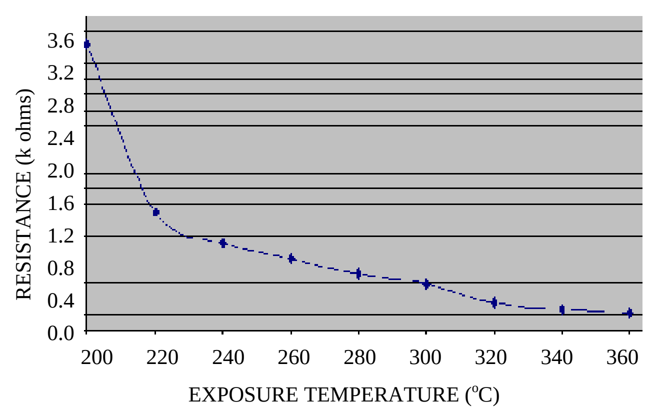

Figure 9. Resistance versus temerature between thermocouple wires for 50’ thermal detector.

joining, all showed NTC behaviour in the temperature range 100 °C -350 °C. A partial shift was observed in the resistance values at ambient temperature and at 100 °C, but the resistance values at 340 °C was almost the same. Similar behaviour was observed both on heating any six-inch portion of sensor as well as on heating the entire length of the sensors.

5. FUTURE WORK

The future research involves design of different environmental tests in consultations with the faculty working in this area. The thermal detector will have to undergo the severity of the tests before induction to serve the mankind. Initially, few environmental test condition have been designed and are underway. The same NTC characteristics are expected from the 15 m long thermal detectors, both before and after each test.

Another dimension to this work is to develop thermal detectors of different shape and sizes and for a range of temperature application.

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