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Reduced graphene oxide nano particle based cryogenic sensor for measurement of liquid level and recording

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Abstract: For nearly a decade, liquid level sensors have been on the market as white food or beverage products, manufacturing, medical, residential, farming, automotive, aerospace, defense and liquid leak detection or level measurement devices. The nano material-resistive sensor based on reduced graphene oxide is highly sensitive and highly reactive to level measurement. This rGO liquid level sensor was developed, and using screen printing process, nano material film is printed on Al₂O₃ substratum. For safety purposes the sensor film was coated with Parylene-C. The rGO-based nano material was synthesized using Modified Hummer process. A linear relationship between the rGO film's resistances was observed due to the change in liquid level, which implies fast detection and therefore calibration. With its fast and cost-effective manufacturing process, this liquid level sensor has considerable potential in industries where liquid level sensing is mandatory e.g. pharmaceutical also, space, automotive and even for liquid storage, liquid levels using cryogenic fluids of H₂O icewater, LCO₂, LN₂, LH₂, LOX and LHe.

1. INTRODUCTION

A level sensor is an instrument used to assess the depth or quantity of sediment or other substances that flow through an open or closed structure. Substances that flow gravitationally through their vessels (or other physical limits) are essentially horizontal, while the solids of most children connect to the apex corners. Within a jar or in its natural form, the measurable material can be in (for example, a river, sea, well, or lake). Measurements of the levels may be continuous or point to point. Continuous level sensors calculate the level within a certain range and assess the exact amount of substance at a given point, whereas point level sensors simply indicate whether the substance is above or below the point of sensitiveness. The layers typically subsequently detect higher or lower amounts, and are also known as substrates.

The importance of proper level measurement within the process control industry contributes to the development of various detection technologies at different levels. Each of these technologies may be used in conjunction with the monitoring process (liquid / dense), storage form (open / closed tanks), installation simplification, cost, maintenance requirements etc., Index / control measurements, point level / continuous detection, etc. Technologies can be enjoyed. [1]

Ultrasonic level measurement, capacitance level measurement, floating and transmitter measuring technology, radar-based measurement, and pressure-based measurement are the most widely used measuring techniques. The transmitted pulse is not impaired for ultrasonic measurements, and can be used as a medium in the air. It's not a vacuum. For this the liquid surface will be less turbulent and free from foam, which is similar to the capacitance level calculation.

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Changes in the dielectric can cause errors in capacitance level measurement. The form of measurement of float and transmitter also affects the precision of the measurement. Similarly, the sensor's functionality can be influenced by the sensitivity type, and use of the fluid used can require daily maintenance (e.g., extremely viscous or viscous liquids, corrosive liquids, etc.). Failure to install can lead to errors in radar measurement technology. Additional conductive substances combined with process fluids often cause variations in measurements. [2], [3].

Because of their high precision, pressure sensors have been commonly used to calculate the fluid levels. These are easy to use, mount and work under various conditions and in a variety of applications. [4]. Pressure sensors can be categorized by taking into account the level of pressure they can measure, the level of operating temperature or the amount of pressure they are measuring. It is a kind of indirect, non-contact level measurement with limited range which can be used in open and closed tanks for level measurement. This type of pressure sensor can be used to measure the amount of liquids stored at atmospheric pressure in a tank or container (especially water or aqueous gases: mixed with water) [5], [6].

Resistive level sensors are relatively inexpensive among the level sensors mentioned above, but they carry with them their own problems, mainly investigating corrosion and some measuring conditions. Usually, sensors are invasive multi-probe sensors that use fluid ion material to complete the circuit and measure fluid levels. Tanks / containers made of conductive material are required to restrict the portability of the liquid level sensor to one probe [7].

This paper represents a special although quick addition to the class of resistive liquid level sensors by first using rGO-based nano material as the sensing device. The level sensor employs a basic principle of change in sensing film resistance when exposed to the Specific Cryogenic liquids for level measurement.

2. EXPERIMENTAL

As described in the Figure 2 Graphene nano powder is synthesized and made using modified Hummer's method as a sensing film in the ink. This reduced Graphene Oxide (rGO) ink was used to coat on the substrate (Al_2O_3), which is having the characteristics of chemical inertness, high electrical insulating property and good adhesion to the sensing film. The Substrate is diced to 50mm X 15mm dimension and the above sensing film is screen printed (Figure 1) using a metal mask 1. Curing of this device at 120°C for 3 hours was carried out in an oven. After curing, pre-testing of the device resistance was carried out. Using the silver epoxy, leads were taken out from the sensing film for resistance measurement. The Device was mounted on the PCB board using the adhesive M-bond 200 and leads were soldered to the Teflon coated wires. After testing the sensor resistance, it was coated with Parylene - C for the protection of the sensing film due to moisture, handling, dust/dirt etc., Resistance was measured after the Parylene coating also and the change in the resistance was noted down. Leads of the sensing film were protected using the Cryo epoxy. The level sensor was calibrated using different liquids and the change in resistance was noted down, which was also displayed in a Digital Voltmeter (Agilent 34401A 6 1/2-digit multimeter). An increase change in film resistance proportional to liquid level was observed after immersion in the liquid. Finally, a calibration chart was prepared along with specification and user manual.

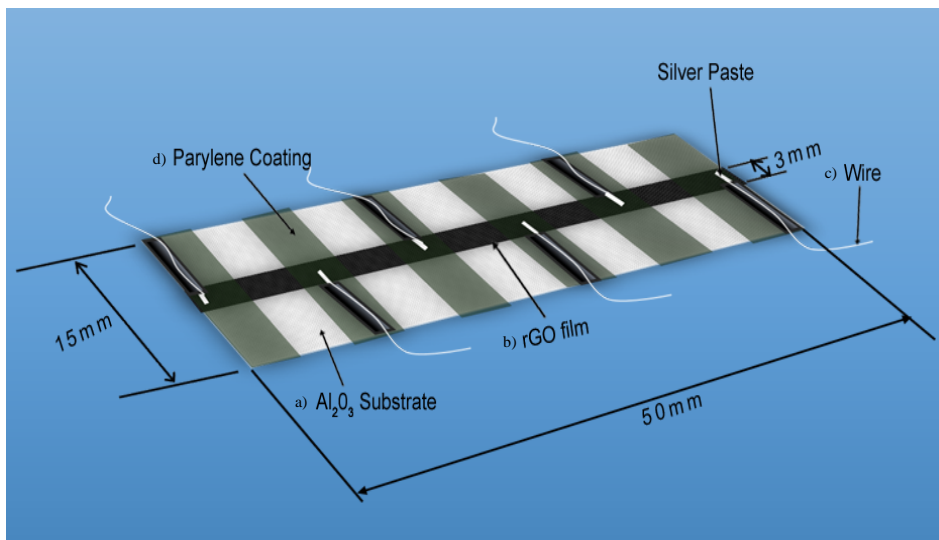


Figure 1. Schematic of the liquid level sensor. a) Al_2O_3 substrate, b) rGO film, c) Enamelled Copper wire contacts using silver paste, d) Parylene-C

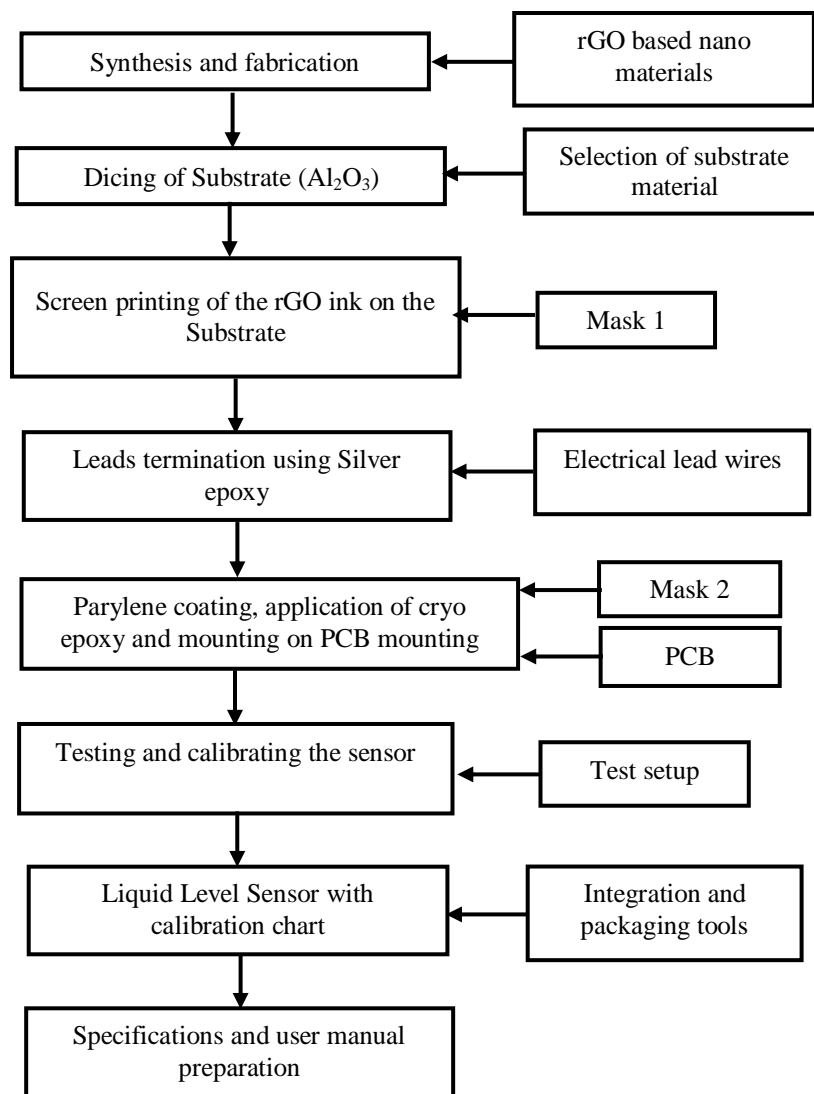


Figure 2. Process flow chart for development, integration and testing of cryogenic liquid level sensor

3. RESULT AND DISCUSSION

3.1. Liquid level measurement

The level sensor was tested with the help of two liquids such as De ionized water and de-ionized Ice water.

3.1.1. Water level measurement

Initial trials were conducted as follows: Sensor was dipped in De-ionized water contained in a beaker, to measure the water level as shown in Figure 3. Sensor wires are connected to a digital multimeter to record the change in the resistance with respect to the liquid level. A graph is plotted for Resistance Vs Water level as shown in Figure 4.

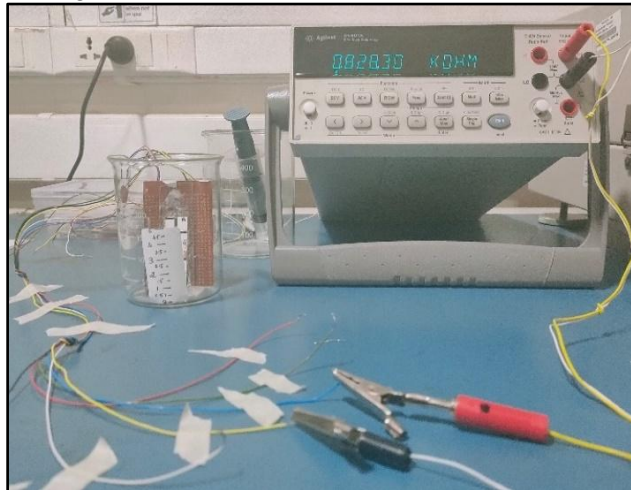


Figure 3. Experimental test setup for measuring the change in resistance of the reduced graphene oxide film with Liquid levels.

It has been found that the sensitivity of Sensors when dipped in de-ionized water is approximately 0.92 /cm. The sensor's nonlinearity value is about 0.064% of full-scale (FSO) output. It should be noted that the Sensor has a linear relation between water level and resistance change.

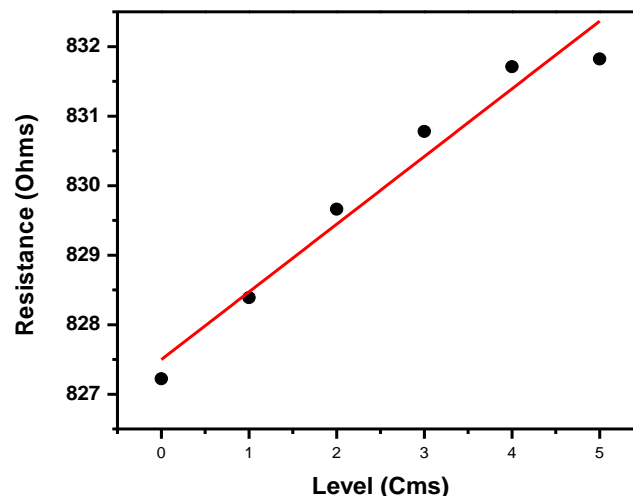


Figure 4. Resistance vs. Water level curve.

3.1.2. Ice water level measurement

Sensor was mounted inside a beaker and de -ionized Ice water (at 0° C) (Figure 3) was gradually poured to measure the level. In each level, change in resistance was noted down using a 61/2 digital multimeter, as shown in Figure 5. A change in ice water level versus resistance was plotted. Plot shows a linear relationship between sensor resistance and level of ice water. Sensitivity of the device is found

to be around $7.144\Omega/\text{cm}$ with a nonlinearity of about 0.621% FSO.

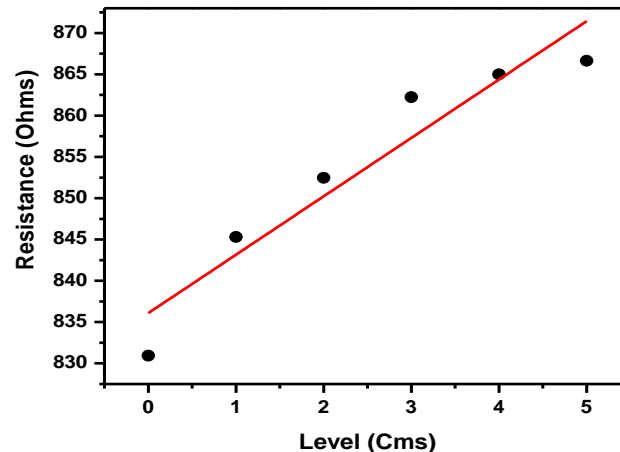


Figure 5. A change in resistance vs ice water level

4. CONCLUSION

A novel cryogenic liquid level sensor using reduced Graphene Oxide was successfully designed, developed, fabricated, assembled, integrated and tested. The device shows $0.92\Omega/\text{cm}$ sensitivity for normal water and $7.144\Omega/\text{cm}$ for ice water with change in liquid level. The surface of rGO film is coated with protective layer of Parylene which is ideal for use in various types of environments and the variety of liquids, such as water, corrosive chemicals and cryogenic liquids. The sensor shows a linear relationship between resistance and level of liquid with a nonlinearity of $< 1\%$. Future research includes improving sensitivity via electronics and testing them for different liquids.

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