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MEASUREMENT OF QUANTUM TUNNELING COMPOSITE RESISTIVITY CHARACTERISTICS FOR TACTILE SENSING APPLICATIONS

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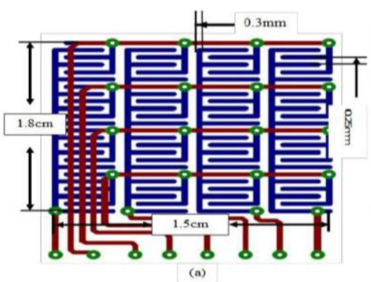
Graphical abstract



Abstract

This paper presents the work of investigating the used of Quantum Tunneling Composites (QTC) Pills as a tactile sensor material. The QTC Pills was tested for their resistivity characteristics to determine the sensor sensitivity, time of response and its allowable working range. The experiments were conducted base on the two parameters; the voltage, and the separation gap against the force/ load that exerted onto the QTC Pills. The results show that with a 5 V supply voltage and 0.5 mm separation gap of a side-by-side sensor construction, the usage of the QTC Pills as a tactile sensor can be optimized. Besides that the resistivity values established from the repeated experiment using QTC Pills produce the similar value and result. This makes the material suitable to be used as a tactile sensor material for the robotic hand.

Keywords: Quantum Tunneling Composites (QTC) Pills, piezoresistivity tactile sensor, resistivity

1.0 INTRODUCTION

Tactile sensor is usually referred to a transducer that is sensitive to touch or sensitive when pressure or load is exerted to it. Previous study had shown there are seven types of tactile sensors based on various transduction principles [1]. They are piezoresistive sensors, tunnel effect tactile sensors, capacitive sensors, optical sensors, ultrasonic bases sensors, magnetism based sensors and piezoelectric sensors. Each sensor has its own advantages and disadvantages. Piezoresistive tactile sensor like microelectromechanical system (MEMS) and silicon based touch sensor are appealing because of high sensitivity and high spatial resolution. However the physical properties of silicon are fragile and brittle in nature that limits its application [2]. Magnetic type transduction usage is limited to nonmagnetic medium and not suitable to be used in harsh environment because of signal instability and complex computation [3].

The advantages include high sensitivity, no hysteresis and robust. Other types of material used in sensor can be very complicated, with excessive wiring, and costly to produce.

Most of the existing sensors use rigid material as the sensor construction [4] e.g. ceramic and quartz. This rigidity limits the sensor in dynamic application useful in grasping. In addition, it is discovered that softer materials such as rubber, fluids and powder have more preferable characteristics for contact sensor [5].

In this paper QTC Pills which is the soft material is used as a sensor material for the UiTM Robotic Hand. Flexibility, affordability and resistivity behavior are the three major factors in choosing Quantum Tunneling Composites (QTC) Pills over the other materials. This report highlights the potential of this material as a tactile sensing transducer and later describes the best design parameters for it to be applied as a tactile sensor.

1.1 Quantum Tunelling Composites (QTC) Pills

The QTC pills refer to Figure 1 is chose among other materials because it's superior characteristics in terms of physical characteristics and working ability. Flexible and small in size make it suitable to be used as a tactile array sensor that can cover all shape and area of the robotic finger.

The material has resistivity characteristics, whereby the value of resistor are changeable with different value of force exerted to the material. Through force placed on the material, it can be a good isolator or a good conductor. The more it is compressed, the more particles are brought closer together to reduce the potential barrier and increases the tunnelling effects thus exponentially reduce the electrical resistance [6].

Figure 1 The actual size of the QTC Pills [7]

The future aim of this work is to design an array sensor board that consists of fanning strip or comb like structure to enrich the information that can be extracted from the sensed environment. This design structure is also to improve the sensitivity of the sensor. Later, the QTC Pills will be laid on this comb like structure and attached to the robotic hand for further used. Figure 2 shows the initial design of the fanning strip like structure of the sensor board.

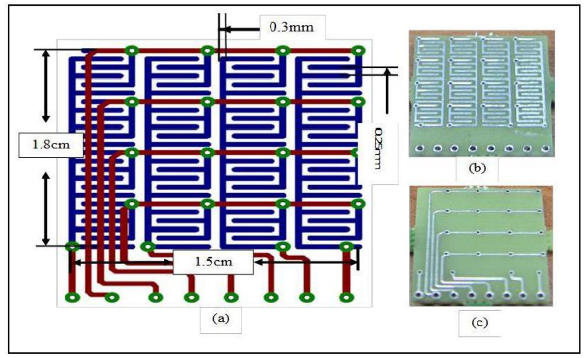


Figure 2 (a) Fanning strip like structure of sensor board consist of 16 sensing elements; (b) first layer, (c) second layer [8]

2.0 QTC PILLS RESISTIVITY CHARACTERISTICS

This paper highlights the potential of using the QTC Pills as a transducer for the development of tactile sensor in robotics hand applications. The aim is to discover the advantages of the QTC Pills in terms of its resistivity characteristics. To test the resistivity characteristics, pressure/ weight is exerted to the QTC Pills and the behavior of the output current or resistance will determine the potential of this material as a tactile sensor.

The test is also to determine the maximum and minimum range of weight that this material can permit. Two parameters were chosen based on the sensor design parameter. First parameter is the voltage value due to the tunnel effect use voltage energy to excite the electron. The second parameter is separation gap between the fanning strips that resembles the design of sensor board as in Figure 2. The separation gap is to determine the sensitivity of the sensor.

Table 1 Measuring setup to test the resistivity of QTC pills

No	Measuring setup	Sensor Construction	Parameter
1	Measuring setup 1	Side-by-side	Load applied to QTC Pills via contact join with 0.5mm separation between contact surfaces with different voltage supply
2	Measuring setup 2	Side-by-side	Load applied to QTC Pills via contact join with 0.25mm separation between contact surfaces with different voltage supply

The dimension of the QTC Pills will be 9 mm^2 with thickness of 1 mm. All setups are measure under constant 0.5 kg weight. Two measuring setup as per listed in Table 1 was constructed. The separation distances between the conducting contact surfaces are set at 0.5 mm and 0.25 mm. Loads of 0.5 kg is applied. Resistance changes across the contact surfaces are recorded using a multimeter for the different resistance yield. All of the resistance results are converted into logarithmic scale.

2.1 Resistance Behavior using Measuring Setup 1

In Measuring Setup 1, the sensor setup is arranged in a side-by-side position with 0.5 mm separation path and 9 mm^2 QTC Pills is laid above the separation. The supply voltages used in the experiment are 0.5 V, 5 V and 25 V. Refer to Figure 3; at an initial value of 25 V, the resistance value is greater than the resistance value of 5 V. However at about 30 s, full equalization is achieved using both supply voltage. On the other hand, 0.5 V supply voltage produce the resistance that is much higher compared to the other voltage. Thus, the use of 0.5 V supply voltage should be ignored.

Figure 4 and Figure 5 shows the individual test series with the supply voltages of 25 V and 5 V. At supply voltages of 25 V or 5 V, constant values result after about 30 s. For 5 V result of test 1 and 2 shows significantly higher in reproducibility of the resistance. Larger resistance values were detected at a supply voltage of 25 V compared to 5 V supply voltage.

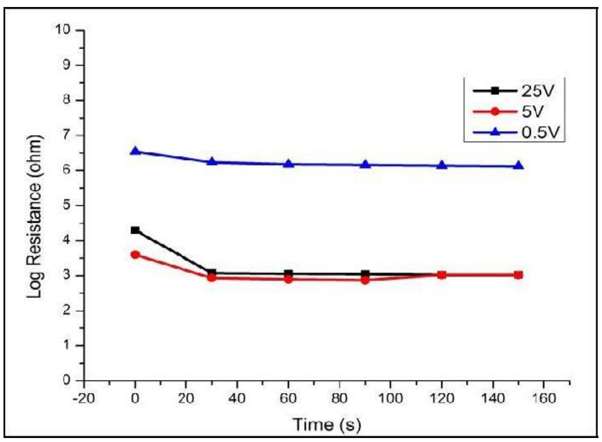


Figure 3 Measuring Setup 1: Log resistance of the QTC Pills over time at different supply voltage

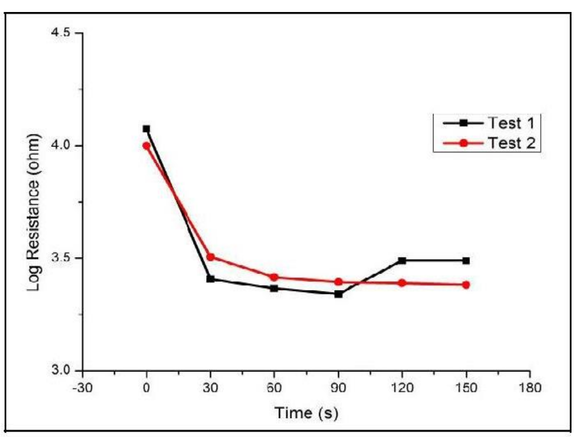


Figure 4 Measuring Setup 1: Log resistance of the QTC Pills over time 25 V supply voltage

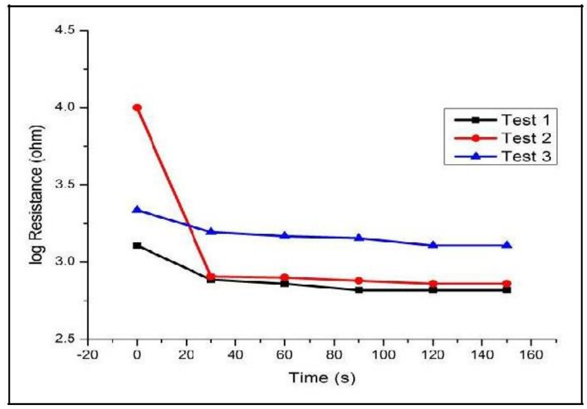


Figure 5 Measuring Setup 1: Log resistance of the QTC Pills over time at 5 V supply voltage

2.2 Resistance Behavior using Measuring Setup 2

Figure 6 shows the test series with the QTC pills for different supply voltages. The resistance values between the individual measurements are closer together than the Measuring Setup 1 with the contact space of 0.5 mm. At about 30 s, all three supply voltages approach constant current or resistance values.

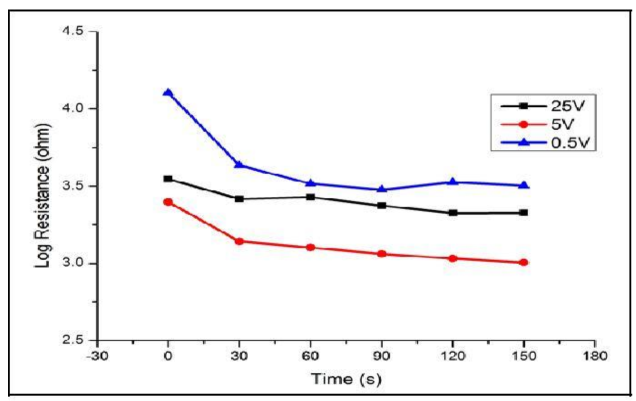


Figure 6 Measuring Setup 2: Log resistance of the QTC Pills over time at different supply voltage

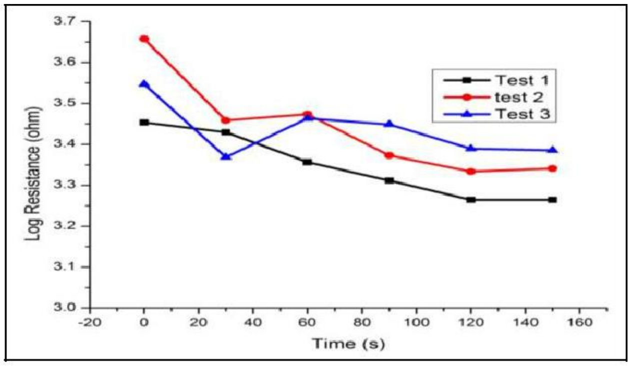


Figure 7 Measuring Setup 1: Log resistance of the QTC Pills over time at 25 V supply voltage

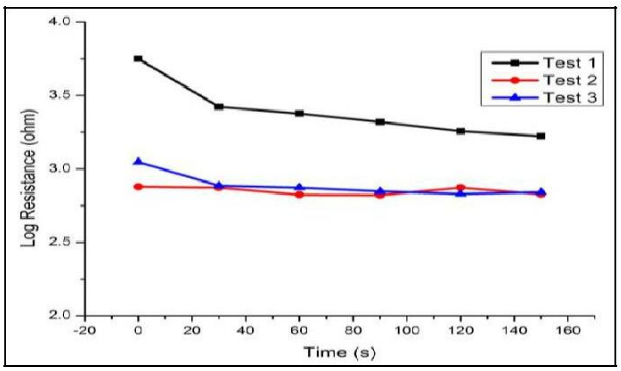


Figure 8 Measuring Setup 1: Log resistance of theQTC Pills over time at 5 V supply voltage

At 25 V as in Figure 7, we can see the resistance values are fluctuating at the beginning of time. Then after 80 s, the curve profiles begin to drop stably and constantly. In the Figure 8, the measurements are more constant with a supply voltage of 5 volts after 30 s, while the test series 2 and 3 are almost identical. The higher resistance values at test series 1 cannot be justified.

2.3 Comparison of Resistance Measurements between Different values of Separation gap

From the above experimental result, it is observed that, The QTC pills function just as good with a voltage supply of 5 V, as with a voltage supply of 25 V. Because of that, Figure 9 and Figure 10 shows the measurement results for the QTC pills using 5 V voltage with different separation gap values against different values of weight range between 0.5 kg to 1 kg. Reproducible results can be generated with the QTC pills. The individual curves are similar, at a contact distance of 0.25 mm. However, at a distance of 0.5 mm the contact area has a better result. From Figure 10, the measuring range for the QTC pills begins to drop stably at the weight value of 0.5 kg and continue until 1 kg before the value of the resistance remain constant.

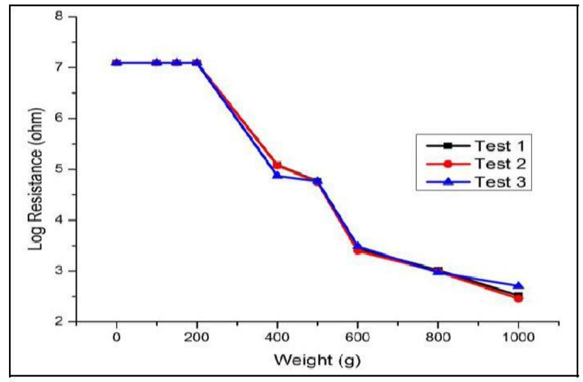


Figure 9 The QTC Pills change in log resistance over various weight with 5 V supply voltage at contact distance of 0.25 m

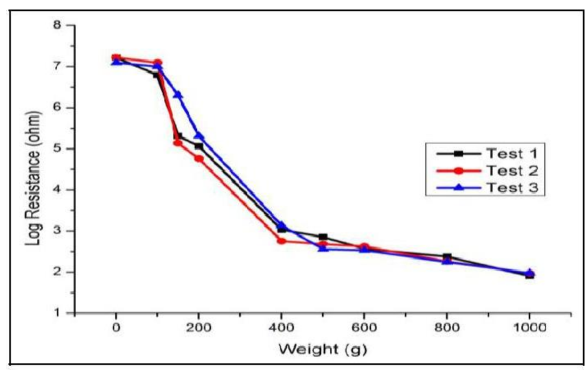


Figure 10 The QTC Pills change in log resistance over various weight with 5 V supply voltage at contact distance of 0.5 mm

The reproducibility value of the QTC pills (for Figure 9 and Figure 10) with respect to different value of weights and separation gap is measured using the standard deviation technique. The results are presented in Table 2. It shows that with 0.5 m separation gap the value of standard deviation is better compared to 0.25 mm separation gap. The reproducibility value of standard deviation is 3.04 Ω for 0.25 mm separation gap and 2.11Ω for 0.50 mm separation gap.

Table 2 Reproducibility value of QTC Pills

Reproducibility value (Ω log^{10} resistance)	QTC Pills with 5V supply voltage
0.25mm	3.04Ω
0.50mm	2.11Ω

3.0 CONCLUSION

As a conclusion, QTC Pills is suitable to be used as a material in tactile sensing application. To design a QTC Pill tactile sensor using the proposed sensor board as in Figure 2, the 5 V supply voltage with 0.5 mm separation gap between the conductive paths should be used.

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