Penerbit Akademia Baru

Journal of Advanced Research Design
ISSN (online): 2289-7984 | Vol. 8, No.1. Pages 22-28, 2015

A Study on Resistivity Behaviour of Conductive Rubber Sheet (CRS) and Quantum Tunnelling Composites (QTC) Pills for Tactile Sensor Application

A. Aqilah[*,a], *C. Y. Low*[b] *and N. Muthmainnah*[c]

Center of Excellence for Humanoid Robotics and BioSensing (HuRoBs), Faculty of Mechanical Engineering, Universiti Teknologi MARA (UiTM), 40000 Shah Alam, Malaysia
[a,*]*ahsanaaqilah@gmail.com*, [b]*low.uitm@gmail.com*, [c]*nurul.muth@gmail.com*

Abstract – *This paper presents the work of investigating and comparing the uses of CRS and QTC Pills as a tactile sensor material for Robotic Hand application. The materials were tested for their resistivity characteristics to determine the data reproducibility of the materials. The experiments were conducted based on three parameters; the supply voltage, the separation gap, and the sensor construction against the force/ load that had been exerted onto the materials. The results showed that CRS could cover the lower loading range when compared to QTC Pills. However, the data reproducibility of QTC Pills was better compared to those of CRS, thus making it more suitable to be used as a material for tactile sensing application. Therefore, this paper highlights the potential of these two materials as a tactile sensing transducer, and later, can be used as a useful guideline when designing a tactile sensor with these materials.*

Keywords: Conductive Rubber Sheet (CRS), Quantum Tunnelling Composites (QTC) pills, Resistivity behaviour

1.0 INTRODUCTION

In the era of intelligent robots, such as humanoid robot, the evolution of intelligent tactile sensor should also come hand in hand with the development of intelligent robots. Intelligent sensors should have the capabilities of monitoring variations in temperature, force, torque, weight, position, and other parameters. One of the emerging sensors is tactile sensor. According to Dario [1], tactile sensing can be defined as the detection of the wide range of local and distributed force parameters. Lee and Nicholls [2], on the other hand, interpreted tactile sensing as the process of determining the various properties and situations with respect to the contacted object. The definition given by Lee and Nicholls is more accurate and appropriate as the sensor should be able to measure every parameter prior to contact with an object, such as texture, shape, slip, feedback from contact surface, and the correct grasp suitable for the object. As high technological robotic system, such as humanoid, robotic arms, and prosthetic hand, has emerged, the demand for high definition and intelligent tactile sensor that goes beyond force detection is a must. Hence, it is essential to study a new alternative material that could be applied as a tactile sensor.

Journal of Advanced Research Design
ISSN (online): 2289-7984 | Vol. 8, No.1. Pages 22-28, 2015

The Conductive Rubber Sheet (CRS) and the Quantum Tunnelling Composite (QTC) Pills are the new alternative material selections for tactile sensor, which require more exploration and investigation in order to discover their potential as a tactile sensor for robotic hand, as well as other fields. With that, this research discovered the advantages of CRS and QTC Pills in tactile sensing applications in terms of their resistivity characteristics so that they can be applied to a more "human like" sense of touch in the robot application. Lastly, it is hoped that this work can help amputees to improve their quality of life.

1.1 Problems with the Current Sensor

A previous study had shown the application of various types of transduction principles for tactile sensor [3]. There are mainly 6 classifications of tactile sensor transduction methods. They are piezoelectric, optical, magnetic, ultrasonic, capacitive, and resistive. Each sensor has its own advantages and disadvantages. The first four transduction methods are capable in obtaining extremely high sensitivity sensor. However, these devices require a large payload, expensive, difficult to fabricate, and low in material flexibility. These drawbacks limit their application for integration on a robot hand or body [4, 5].

On the other hand, major issues that constitute the capacitive and resistive transduction methods are lack of sensitivity and repeatability; mainly due to the phenomenon of hysteresis or cross-talk between the sensors. However, they are widely used by the majority of the commercial tactile sensor as they are low in cost, easy to fabricate, and possess mechanical stability. In contrast with the first four transduction methods, capacitive and resistive approaches employ simpler read-out electronics, and thus, they are easier for integration with the robotic hand [5].

On top of that, most of the existing sensors use rigid material as the sensor construction [6] e.g. ceramic and quartz. This rigidity limits the sensor in dynamic application, but recently, it has been discovered that softer materials, such as rubber, fluids, and powder, have more preferable characteristics for contact sensor [7]. Since CRS and QTC Pills can be considered as soft and flexible materials, they have the potential of becoming superior materials for new generation sensors. Thus, it is important to investigate the working principle possessed by the materials, and hence, optimized usage of CRS and QTC Pills in tactile sensing can be achieved. Besides, the data repeatability and reproducibility of the materials were also investigated in this research.

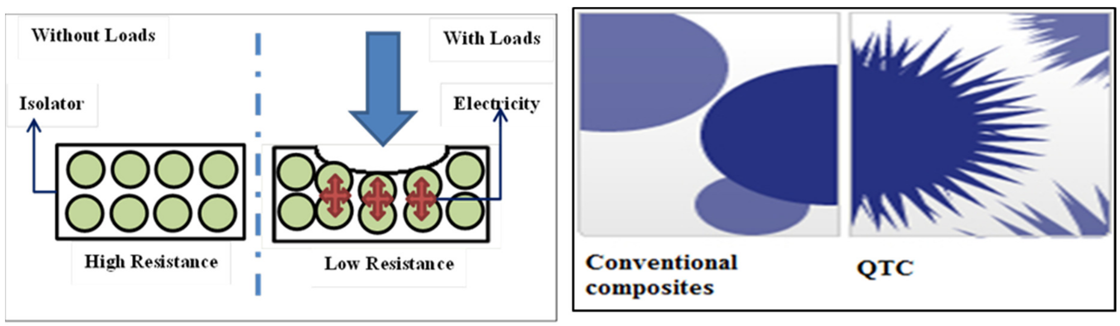
1.2 The Materials

Two materials chosen for this research were Conductive Rubber Sheet (CRS) and Quantum Tunnelling Composites (QTC) Pills. They exhibit piezoresistive like behaviour, where the resistance changes with the change in force/pressure, which is a good point in any application of tactile sensor. The physical properties of these materials, such as flexible, stretchable, lightweight, inexpensive, and conductive, when pressure is applied make it more outstanding among its competitors. Therefore, this research was carried out to explore the potential use of these materials in the sensory field, especially for tactile applications in robotic hand.

ISSN (online): 2289-7984 | Vol. 8, No.1. Pages 22-28, 2015

1.2.1 Conductive Rubber Sheet (CRS)

The first material, called Pressure Sensitive Conductive Rubber ZL 45.1, was purchased and manufactured at ZOFLEX® with Shore A with a hardness of 45 [8]. As the name implies, it is a conductive material when pressure is applied. This material exhibits a feature that is resistant to changes with force/pressure. The resistance comes from the conductive carbon pills that are used to manufacture this material. When there is no presence of force/ pressure, the particles are apart from each other and the resistance is infinitely large (>30MΩ). Meanwhile, with the existence of pressure, the thickness of the material decreases and the conductive carbon particles get into contact with each other, thus creating electrical path/flow that drops the resistance value at the pressure region (Figure 1). Once the pressure is cancelled, the elastic material returns to its original thickness, and so the resistance.



(a) (b)

Figure 1: (a) Working principle of CRS [9] (b) Comparison of working principle between CRS and QTC Pills [10]

1.2.2 Quantum Tunnelling Composites (QTC) Pills

The second material chosen was Quantum Tunnelling Composite (QTC) Pills (Figure 2). It is commercially available from Peratech. It shares some similarities in behaviour with CRS. Without loads exerted to the material, it is a good isolator. However, with loads, it can be a good conductor. The only difference is that, to turn CRS into conductive, there is a need for contact between the carbon particles to create the electrical paths. Nevertheless, with QTC Pills, there is no contact with the individual metal/ carbon particles, but rather the quantum tunnelling effect takes place. The QTC Pills composite surface has an irregular wetted spiked shape. The wetted surface allows the electron concentration to build up. The ability of the QTC Pills to change from insulator to conductor is influenced by the value of the external force applied to the materials. The more it is compressed, the more particles are brought closer together to reduce the potential barrier, as well as increases the tunnelling effects, and thus, exponentially reduces the electrical resistance. Moreover, the spiked surface increases the electron concentration, which helps in the tunnelling process [10].

2.0 METHODOLOGY

While both CRS and QTC have been reported as feasible tactile sensing materials; their characteristics have not been compared in terms of their resistance output data reproducibility. The resistance had been via two different measuring setups. This measuring setup comprises

Journal of Advanced Research Design
ISSN (online): 2289-7984 | Vol. 8, No.1. Pages 22-28, 2015

of three different parameters; different voltage supply, different separation gaps, and sensor construction. The results of the experiments highlighted an important key to fabricate the tactile sensor, as well as to ascertain the most suitable material that could be used as a sensor.

With that, two measuring setups that tested all the parameters were designed. These setups measured the resistivity characteristics of CRS and QTC Pills with respect to the parameters. The dimension of CRS that had been used was $100mm^2$ with a thickness of 0.5mm, while the QTC Pills was $9mm^2$ with a thickness of 1mm. All the setups were measured under a range between 100g and 1000g. Besides, the resistance changes across the contact surfaces were recorded by using a multimeter for the different loads applied. All the resistance results were converted into a logarithmic scale. The use of the logarithms of the resistance values rather than the actual values was to reduce the wide range of resistance to a more manageable size. The log values were then plotted into graphs to represent the result. The measuring setups are depicted in Table 1.

Table 1: Measuring Setups for the Experiments

No	Measuring setup	Sensor Construction	Parameter
1	Measuring setup 1	Side-by-side	Load applied to CRS and QTC Pills via contact join with 0.5mm separation between contact surfaces with voltage supply of 25V for CRS and 5V for QTC Pills
2	Measuring setup 2	Side-by-side	Load applied to CRS and QTC Pills via contact join with 0.25mm separation between contact surfaces with voltage supply of 25V for CRS and 5V for QTC Pills

3.0 RESULTS AND DISCUSSION

From Figures 3 and 4, the values of resistance established for the CRS with 0.25mm and 0.5mm separation gap had not been reproducible. The data did not coincide with each other with the value of resistance reproducibility. Besides, the standard deviation was 4.86Ω log resistance for 0.25mm separation gap, and 5.05Ω log resistance for 0.5mm separation gap. On the other hand, resistance measurements for the QTC pills showed stable and reproducible values.

Journal of Advanced Research Design
ISSN (online): 2289-7984 I Vol. 8, No.1. Pages 22-28, 2015

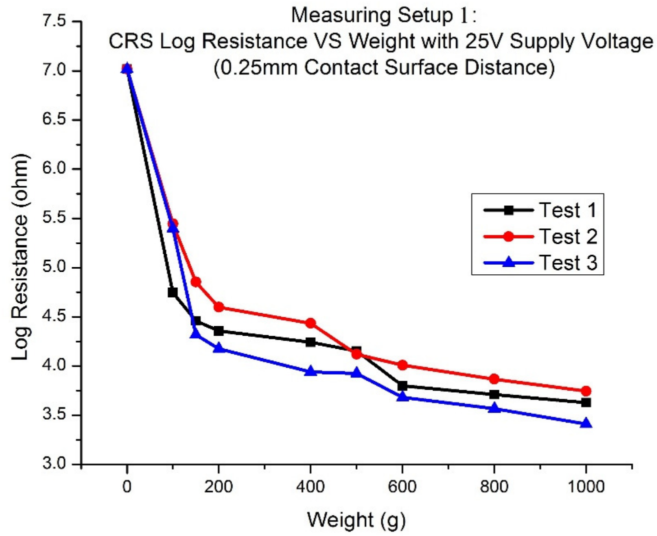


Figure 3: CRS change in log resistance over various weights with 25V supply voltage at 0.25mm contact distance

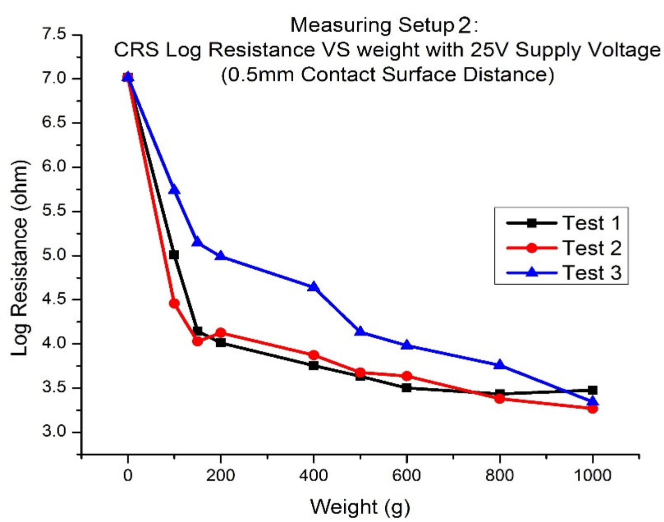


Figure 4: CRS change in log resistance over various weights with 25V supply voltage at 0.5mm contact distance

Meanwhile, resistance measurements of the QTC pills showed stable and reproducible values. The plots in Figure 5 show a high degree of coincidence for the QTC Pills on a separation gap of 0.25mm. Figure 6 shows the highest coincidence between the plots for the QTC Pills on a separation gap of 0.5mm. The values of reproducibility of data in Figures 5 and 6 had been 3.04Ω log resistance and 2.11Ω log resistance.

Journal of Advanced Research Design
ISSN (online): 2289-7984 | Vol. 8, No.1. Pages 22-28, 2015

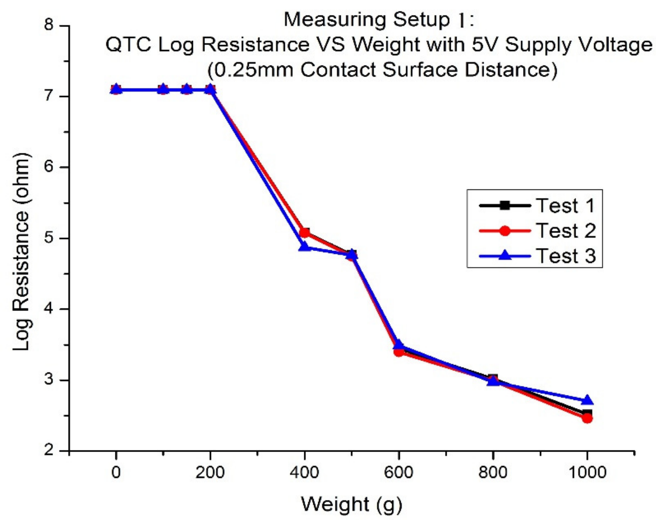


Figure 5: QTC Pills change in log resistance over various weights with 5V supply voltage at 0.25mm contact distance

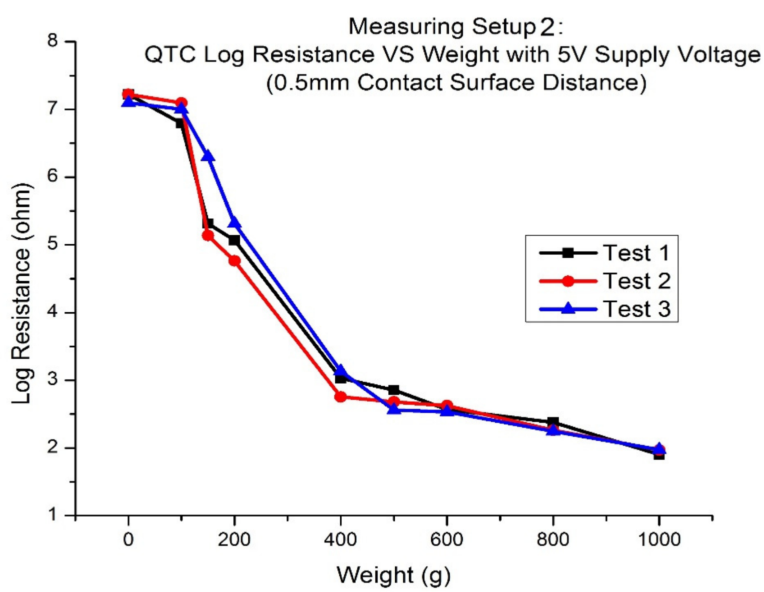


Figure 6: QTC Pills change in log resistance over various weights with 5V supply voltage at 0. 5mm contact distance

4.0 CONCLUSSION

It can be concluded from the results that the QTC Pills had been more suitable to be used as a material for tactile sensing, as compared to CRS. For further development of the project, the

Journal of Advanced Research Design
ISSN (online): 2289-7984 | Vol. 8, No.1. Pages 22-28, 2015

QTC Pills should be used for tactile sensor development because the data reproducibility had been far better than CRS. As for the sensor design with QTC pills, the distance of the tactile array between the conducting paths should be 0.5mm to achieve higher sensitivity of tactile sensor.

ACKNOWLEDGEMENT

The authors would like to acknowledge and thank the grant, RAGS/1/2014/TK01/UITM//5, the Malaysian Ministry of Education (MOE), and Universiti Teknologi MARA (UiTM) Shah Alam, Malaysia for their support.

REFERENCES

[1] P. Dario, Tactile sensing: Technology and applications, Sensors and Actuators A: Physical 26 (1991) 251-256.

[2] M.H. Lee, H.R Nicholls, Tactile sensing for mechatronics - A state of the art survey, Mechatronics 9 (1999) 1-31.

[3] A. Kimoto, Y. Matsue. A new multifunctional tactile sensor for detection of material hardness, IEEE Transactions on Instrumentation and Measurement 60 (2011) 1334-1339.

[4] J.S. Heo, J.H. Chung, J.J. Lee, Tactile sensor arrays using fiber bragg grating, Sensors and Actuators A: Physical 126 (2005) 312-327.

[5] S. Stassi,V. Cauda, G. Canavese, C.F. Pirri, Flexible tactile sensing based on piezoresistive composites: A review, Sensors 14 (2014) 5296-5332.

[6] R.S. Dahiya, G. Metta, G. Sandini. Tactile sensing - From humans to humanoids, IEEE Transactions on Robotics 26 (2010) 1-20.

[7] K.B. Shimoga, A.A. Goldenberg, Soft materials for robot fingers, in Proc. IEEE International Conference on Robotics and Automation, Nice, 1992, pp. 1300-1305.

[8] ZOFLEX®, Pressure-Activated Conductive Rubber Sheets ZL45.1. Internet: http://www.rfmicrolink.com/products.html, Sept 2010, [Jan 2011].

[9] A. Aqilah, Resistivity characteristics of conductive rubber sheet and quantum tunnelling composite pills for robotic hand tactile sensing application, MSc. Thesis, Universiti Teknologi MARA., Shah Alam, Malaysia, 2013.

[10] Peratech Ltd., QTC Material Technology, Interrnet: http://www.peratech.co.uk, 2012, [23 March 2011].