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Simulation of *Aloe vera* Gel as Organic Dielectric Material in Microelectronics Instead of SiO_2 (Silicon Dioxide)

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Abstract: Due to superior mechanical and electrical properties and the cost advantage associated with their processing, organic materials can be viewed as an important technology for an ample range of electronic applications. In this study, authors presented a comparison between silicon dioxide and *Aloe vera* gel with dielectric barrier discharge model and capacitive model in COMSOL Multiphysics. Effect of both AC and DC applied voltage on two dielectric plates with argon gas, dielectric barrier discharge current has been reported. In addition, terminal current between two aluminium electrodes separated by a dielectric material is also examined. It has been demonstrated that *Aloe vera* gel can be used as a dielectric material in microelectronic device.

Key words: COMSOL, *Aloe vera*, dielectric material, silicon dioxide, green electronics

INTRODUCTION

Organic materials have been widely used because of their excellent properties and low production cost for large scale fabrication (Reyes-Reyes *et al*., 2011). Now a days, organic materials have been proved their capability to be used in memory device (Ouyang *et al*., 2005), organic thin film transistor (Bettinger and Bao, 2010), gas sensor (Regaco *et al*., 2005), organic solar cell (Puigdollers *et al*., 2005) and organic light-emitting device (Karzazi, 2014; Yan *et al*., 2005).

Silicon dioxide is used for the manufacture of semiconductors, wire insulation, active gate electrode in MOS device structure and fiber optic cables. With this advantage of silicon dioxide, there are also some disadvantages of it. Silicon irritates the skin and eyes on contact and it may affect the immune system, lung cancer, leading mycobacterial infection (http://www.lenntech.com/periodic/elements/si.htm). Inhalation silicon dioxide will cause irritation to the lungs and mucus membrane.

Because of these disadvantages of silicon dioxide, there is a need of new organic material which can accomplish the same property of silicon dioxide and obviously environmentally safe. Most of the organic dielectrics are based on synthetic polymeric materials. Some of natural organic dielectric material such as chicken albumen (Chang *et al*., 2011), maiza leaf and potato tissues (Nelson, 2005) are reported in previous. After comparing the results of *Aloe vera* gel with silicon dioxide, authors reported that, *Aloe vera* gel can be used as natural organic dielectric material instead of silicon dioxide in the fabrication of electronic device.

MATERIALS AND METHODS

Geometry of the model: Two different types of model have been conducted in COMSOL Multiphysics. Dielectric barrier discharge model has been performed to investigate the dielectric discharge current and capacitive model for the terminal current for both silicon dioxide and *Aloe vera* gel. The detailed geometry of the models is given below.

Dielectric barrier discharge model: Dielectric barrier discharge analysis has been performed in COMSOL 1D plasma module. This model simulates discharge current in an atmospheric pressure argon gas. The dielectric plates are 10 cm in diameter and have 1 mm gap thickness between two dielectric plates. On one of the dielectric plates, different sinusoidal voltage and DC voltage are applied. The other plate is electrically grounded. The frequency of the applied sinusoidal voltage is 50 Hz around of 1-50 sinωt and 1-50 V DC. Relative permittivity of silicon dioxide and aloe vera gel is defined for their

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dielectric properties (Khor and Cheong, 2013). Argon gas is also defined by relative permittivity. The plasma chemistry reaction elastic, excitation, superelastic, ionization and implemented sticking coefficient of argon gas are considered.

Capacitive model: Capacitive model has been performed in COMSOL 3D AC/DC module. Capacitive model is combined with an external electrical circuit, voltage source and a resistor. This model consists of two aluminium electrodes of 20 mm width, 8 mm depth and 2 mm height. The height of dielectric is 0.5 mm. Capacitance of this capacitive model is ≈50 pF and external resistor is 1 KΩ range. To define the dielectric properties of silicon dioxide (Khor and Cheong, 2013) and *Aloe vera* gel, conductivity and relative permittivity are considered. Applied voltage is 1 V DC on aluminium electrodes and then terminal current is computed and compared to the analytic result. Analytic result is measured by Eq. 1:

$$i(t) = \frac{V_o}{R}\exp\left(-\frac{t}{RC}\right) \quad (1)$$

where, V_0 is the applied voltage.

RESULTS AND DISCUSSION

Dielectric barrier discharge: The output discharge current with respect to time and induced electric field surface when applied voltage is 1 V DC on the both silicon dioxide and *Aloe vera* gel are shown in Fig. 1.

The output discharge current with respect to time and induced electric field surface when applied voltage is 20 V DC on the both silicon dioxide and *Aloe vera* gel are shown in Fig. 2.

The output discharge current with respect to time and induced electric field surface when applied voltage is 50 V DC on the both silicon dioxide and *Aloe vera* gel are shown in Fig. 3.

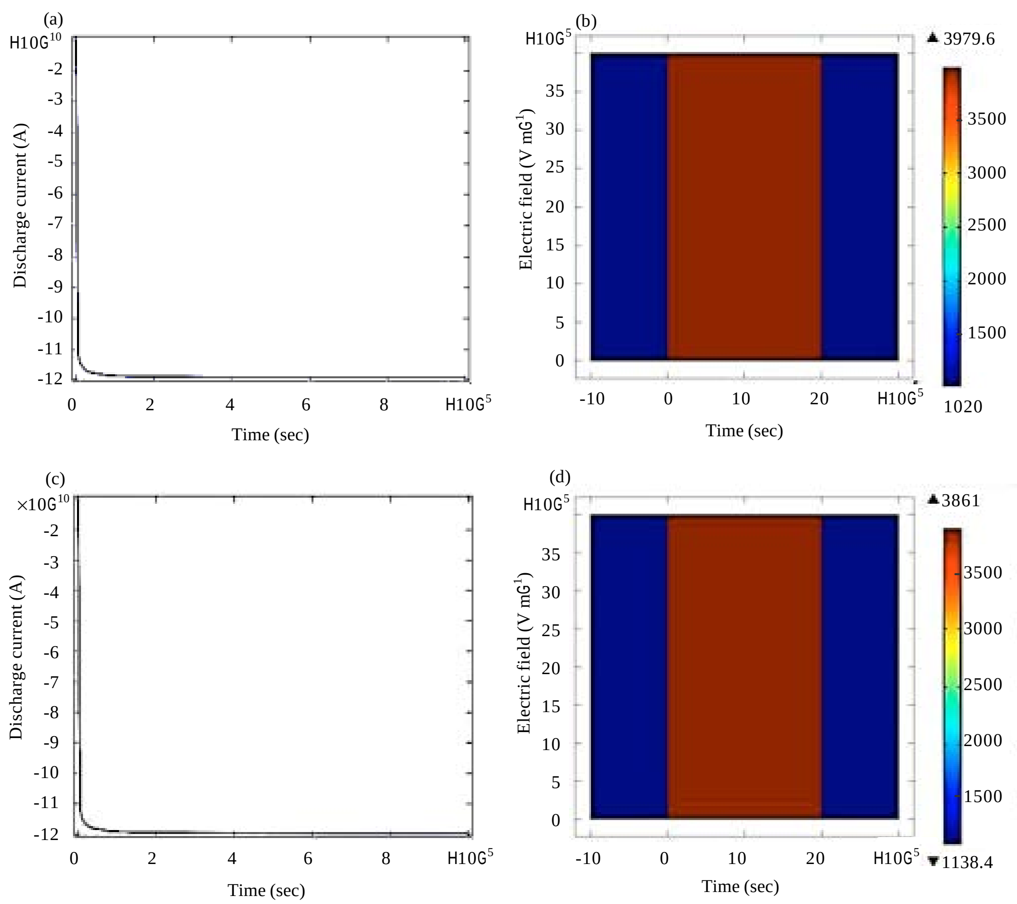

Fig. 1(a-d): Output when applied voltage is 1 V, (a) Discharge current of silicon dioxide, (b) Electric field surface of silicon dioxide, (c) Discharge current of *Aloe vera* gel and (d) Electric field surface of *Aloe vera* gel. All units are in SI range

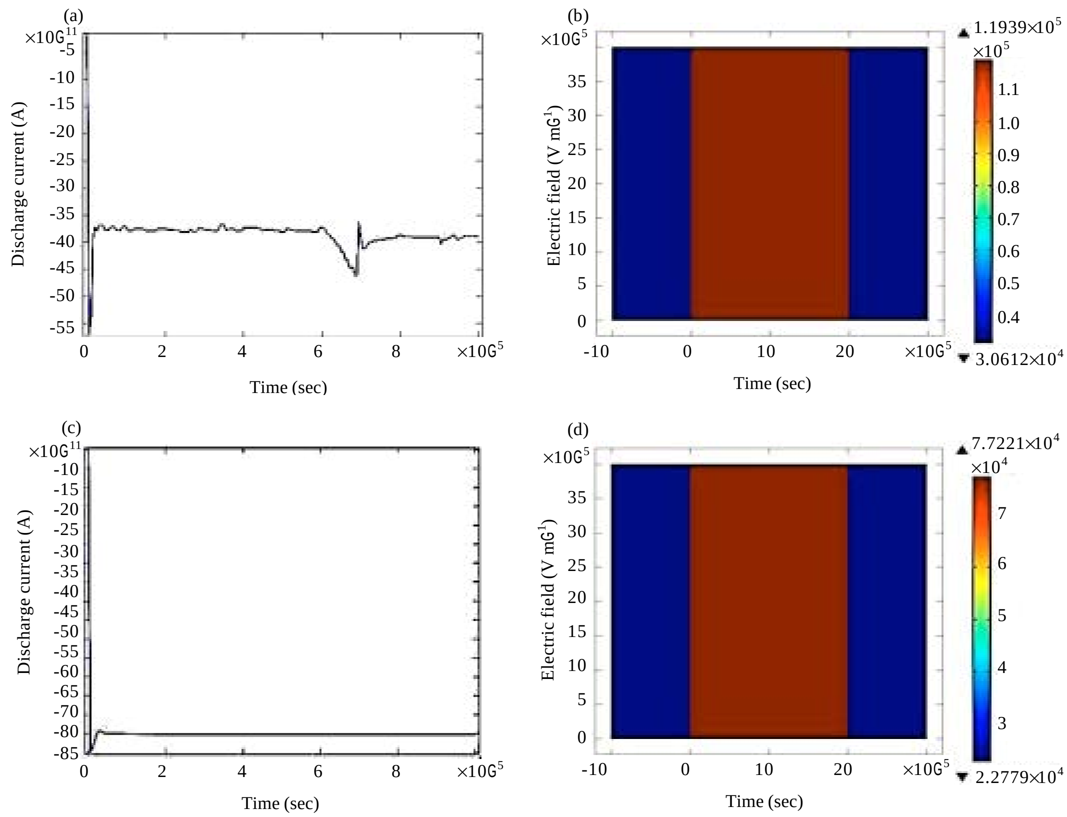

Fig. 2(a-d): Output when applied voltage is 20 V, (a) Discharge current of silicon dioxide, (b) Electric field surface of silicon dioxide, (c) Discharge current of *Aloe vera* gel and (d) Electric field surface of *Aloe vera* gel. All units are in SI range

The output discharge current with respect to time and induced electric field surface when applied sinusoidal voltage is 1 sinωt on the both silicon dioxide and *Aloe vera* gel are shown in Fig. 4.

The output discharge current with respect to time and induced electric field surface when applied sinusoidal voltage is 20 sinωt on the both silicon dioxide and *Aloe vera* gel are shown in Fig. 5.

The output discharge current with respect to time and induced electric field surface when applied sinusoidal voltage is 50 sinωt on the both silicon dioxide and *Aloe vera* gel are shown in Fig. 6.

Khor and Cheong (2013) presented the performance of *Aloe vera* gel with some organic material and now this study presented the performance of *Aloe vera* gel with silicon dioxide. After examined the COMSOL model result, it is illustrated that after various DC and sinusoidal voltage applied on both dielectric plate of silicon dioxide and *Aloe vera* gel, output discharge current and induced electric field for both dielectric material are very close. It seems that, *Aloe vera* gel can be used instead of silicon dioxide in microelectronic device.

Capacitive model: The schematic diagram of capacitive model is shown in Fig. 7.

For capacitive model, applied electric potential surface when applied voltage is 1 V DC is shown on Fig. 8.

The output terminal current of the capacitor for silicon dioxide when applied voltage 1 V DC is shown on Fig. 9.

The output terminal current of the capacitor for *Aloe vera* gel when applied voltage 1 V DC is shown on Fig. 10.

The capacitive model also shows that, the terminal current through both silicon dioxide and *Aloe vera* gel is decreased exponentially with respect to time and the output results of *Aloe vera* gel and silicon dioxide are

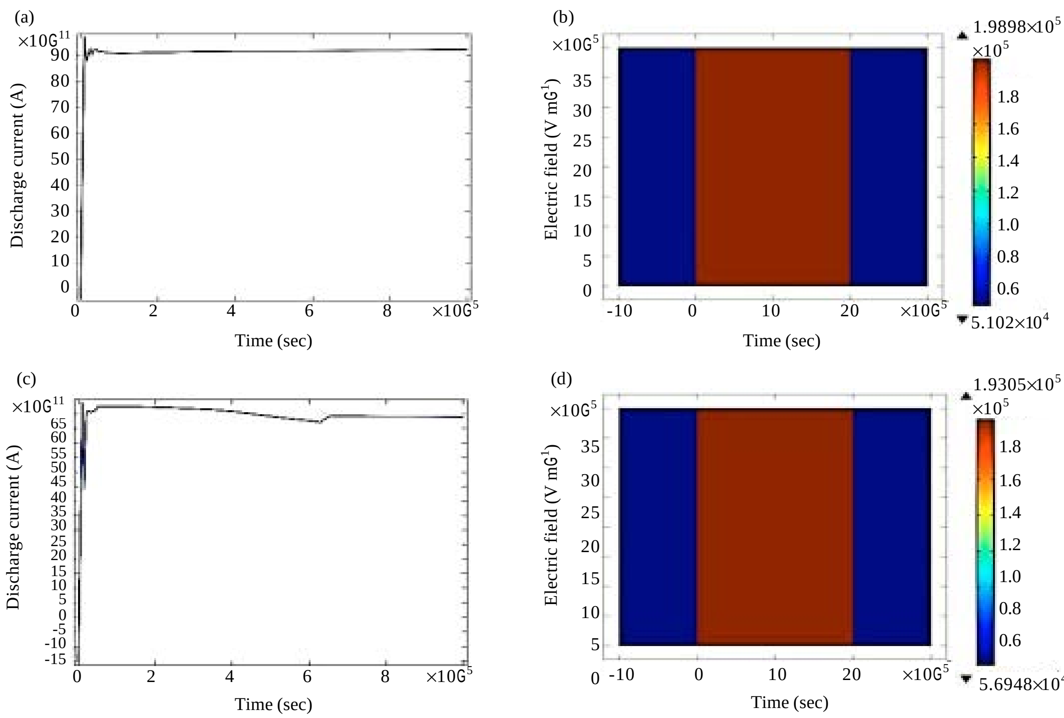

Fig. 3(a-d): Output when applied voltage is 50 V, (a) Discharge current of silicon dioxide, (b) Electric field surface of silicon dioxide, (c) Discharge current of *Aloe vera* gel and (d) Electric field surface of *Aloe vera* gel. All units are in SI range

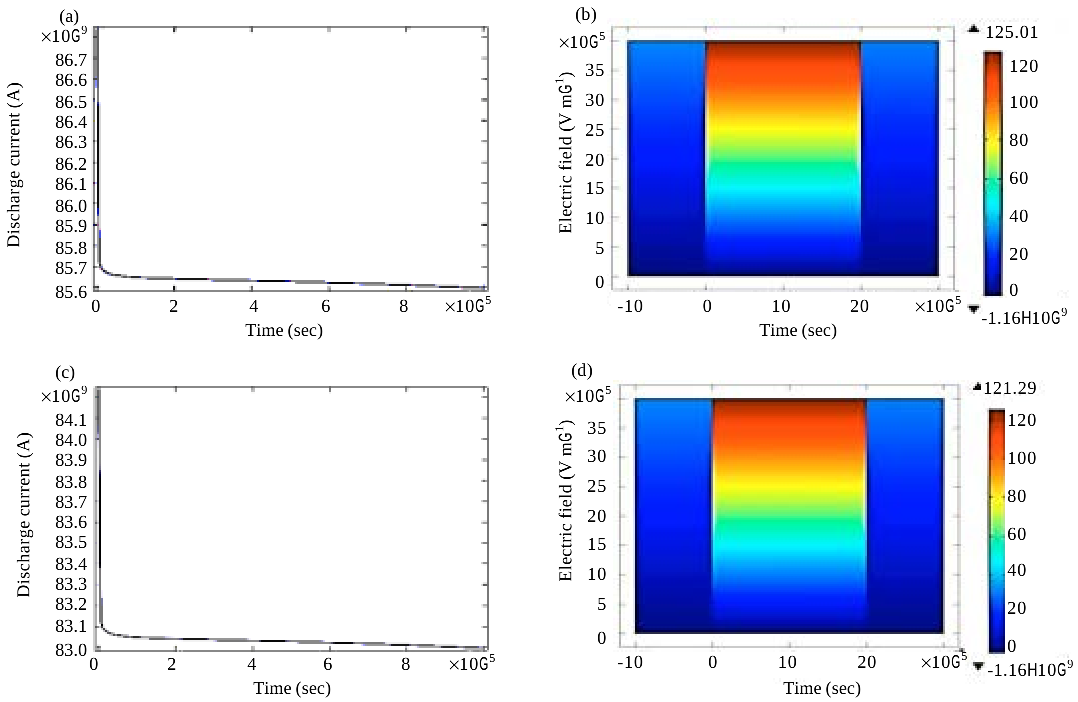

Fig. 4(a-d): Output when applied voltage is 1 sinωt, (a) Discharge current of silicon dioxide, (b) Electric field surface of silicon dioxide, (c) Discharge current of *Aloe vera* gel and (d) Electric field surface of *Aloe vera* gel. All units are in SI range

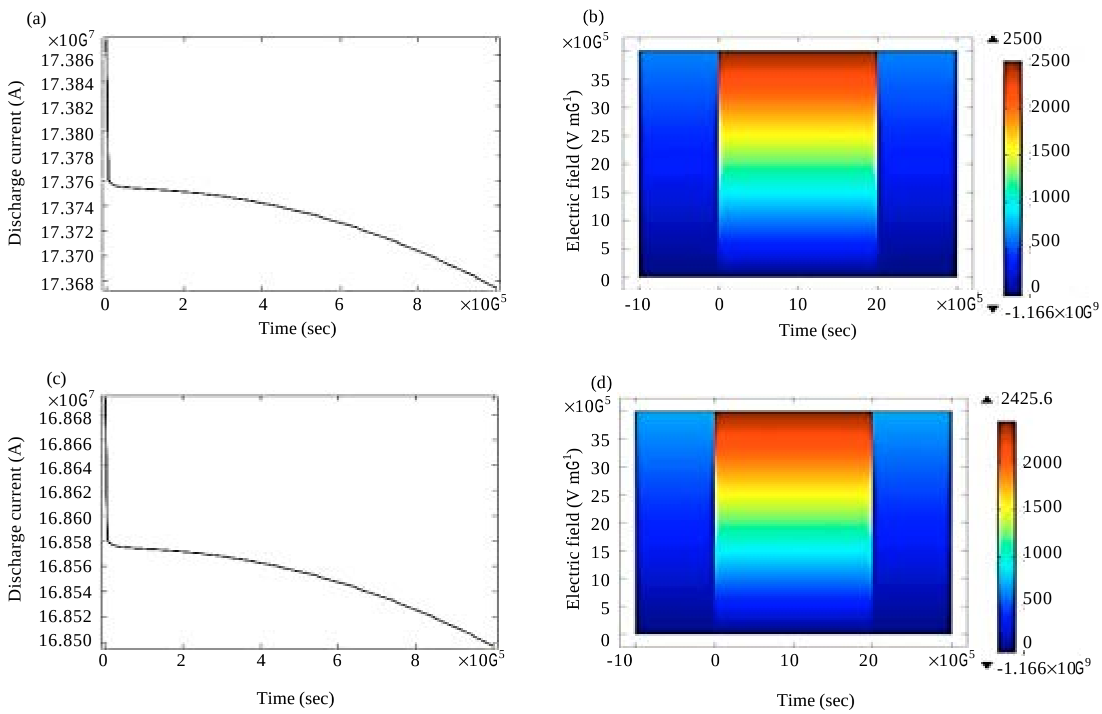

Fig. 5(a-d): Output when applied voltage is 20 sinωt, (a) Discharge current of silicon dioxide, (b) Electric field surface of silicon dioxide, (c) Discharge current of *Aloe vera* gel and (d) Electric field surface of *Aloe vera* gel. All units are in SI range

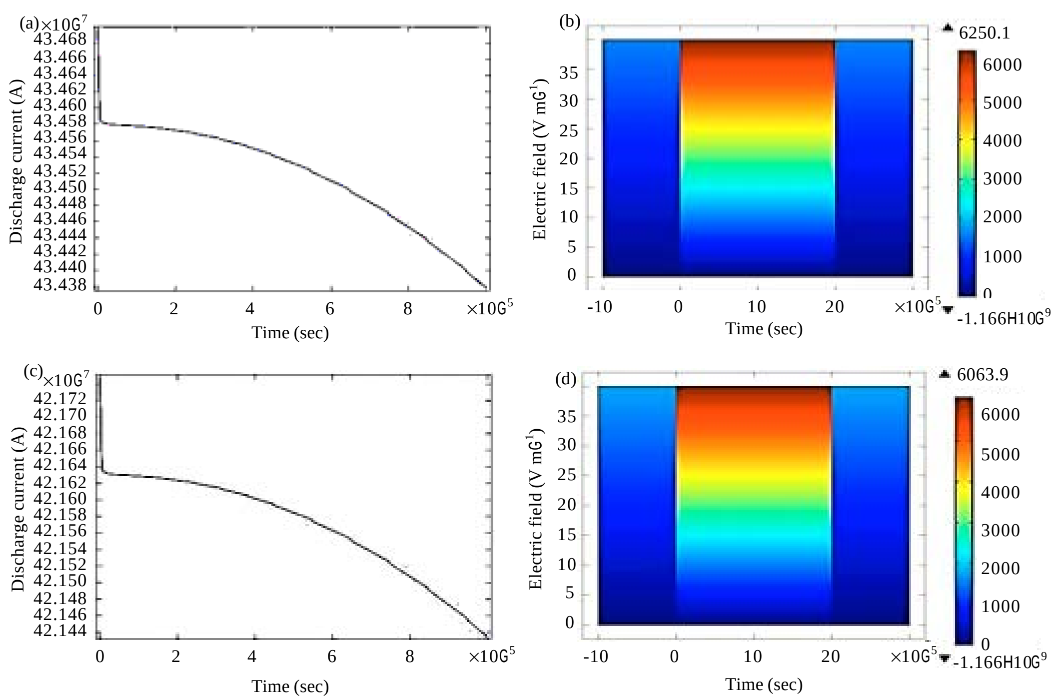

Fig. 6(a-d): Output when applied voltage is 50 sinωt, (a) Discharge current of silicon dioxide, (b) Electric field surface of silicon dioxide, (c) Discharge current of *Aloe vera* gel and (d) Electric field surface of *Aloe vera* gel. All units are in SI range

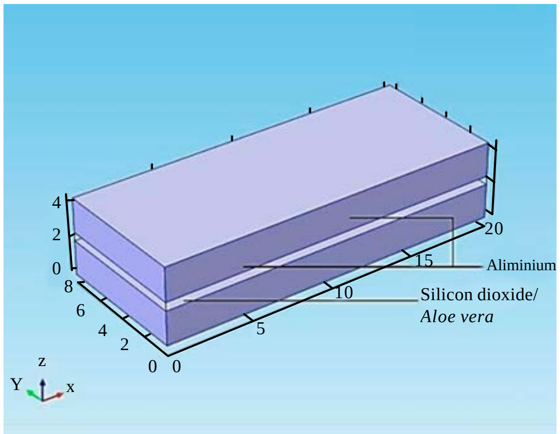

Fig. 7: Schematic diagram of capacitive model

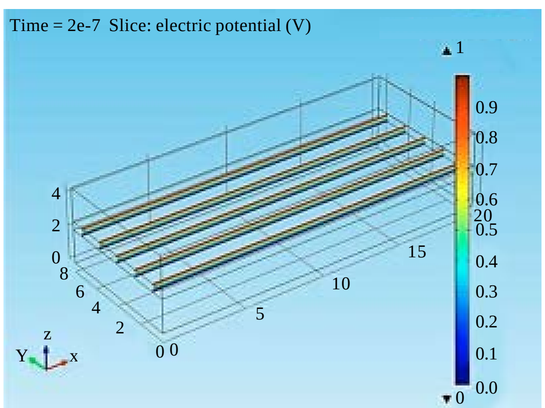

Fig. 8: Electric potential surface

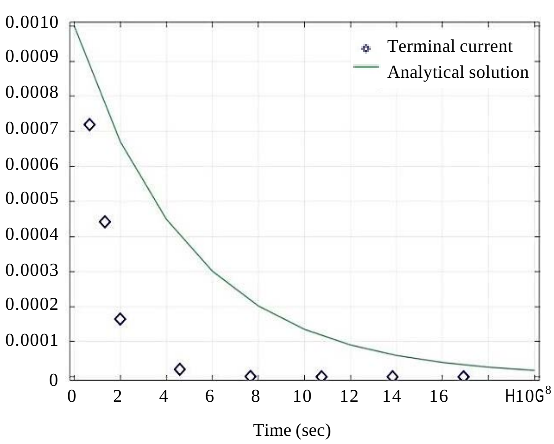

Fig. 9: Terminal current for silicon dioxide when 1 V is applied

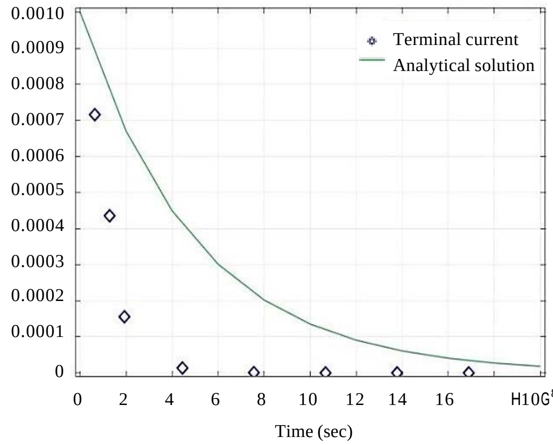

Fig. 10: Terminal current for *Aloe vera* gel when 1 V is applied

very close. So, this COMSOL model also showed that, *Aloe vera* gel can be used instead of silicon dioxide in microelectronic device.

CONCLUSION

This study visualized some electrical characterization for silicon dioxide and *Aloe vera* gel in two different models on COMSOL Multiphysics. After comparing both results of these two materials, it can be authenticated that *Aloe vera* gel can be used instead of silicon dioxide in microelectronics.

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