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Simulations and Modeling of Dielectric Paper Material with Selected Electrical Properties under Constant Conductive Plate Distance and DC Voltage.

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Abstract: *Dielectric materials can be solids, liquids, gases, and vacuum. Solid dielectrics material like paper has a tremendous applications in electrical/electronic engineering. Meanwhile, the effects (simulations) of the direct current voltage of 1.5v, free space permittivity of 0.89, constant conductive plate distance of 10mm with 3.50 paper dielectric constant were modeled against the varying surface area in mm^2. Properties such as capacitance ($y=32.24x + 0.0906$; $R^2=1.000$), charge magnitude ($y=21.512x + 0.0038$; $R^2= 1.0000$), stored energy ($y= 28.727x – 0.1985$; $R^2= 1.0000$), dielectricity ($y= 37.514In(x) + 41.135$; $R^2= 0.8351$), dipole moment ($y= 2.1512x + 0.0038$; $R^2= 1.0000$) and polarizability ($y= 64.115In(x) – 270.11$; $R^2= 0.9953$) were clearly modeled.*

Keywords: Dielectric material, paper, electrical properties, modeling, and PhET simulations**.**

1.0 INTRODUCTION

Fundamentally, dielectric materials are electrical insulators that are capable of being polarized with an electrical field. If dielectric materials encounter electric field, charges tend not to flow through such physical material unlike in the cases of the electrical conductor but with a slight change from their stable positions triggering polarized dielectricity [1]. Positive charges are relocated along the orientations of the applied field due to dielectric polarization, as the negative charges migrate through the opposite direction to the field. In other words, the field progresses along the x-axis in a positive direction while the negative charges at the x-axis in the negative direction will shift. This, therefore, induces an internal electric field, which decreases the total dielectric field [2]. When a dielectric consists of weakly bound molecules, they are not only polarized but as well reoriented to match their symmetrical axes with the surface of the field. The research on dielectric properties addresses the conservation and dissipation of magnetic and electrical energies [3] [4]. Dielectrics remain crucial to the understanding of the various concept in solid-state physics, electronics, optics, and cell biophysics [5]. The term insulator means low electrical conductivity as dielectric technically suggests materials with a high polarizability. Generally, the term insulator implies electrical resistance, as the term dielectric describes the material's energy storage potential by polarization. The natural insulators amongst the metallic points of a capacitor device is a classic example of a dielectric. The dielectric polarization by the applied electric field increases with the surface charge of the capacitor at the given electric field intensity [4]. Ideal dielectric materials are characterized with zero electrical conductivity and therefore experiences a distortion current as it retains and generates electrical energy [6]. A substance is composed of atoms in the classical perspective to the dielectric model as it entails a cluster of negatively charged electrons attached and surrounded with a positive charge point at the center. The cloud of charge is skewed in the presence of an electric field [7]. Applying the principle of superposition can be based on a simple dipole that is defined by its vector quantity. It is the interaction between the electrical charges with the moment of the dipole that naturally leads to dielectric behavior [7]. Additionally, in a large simplification, the dipole moment heading in a similar bearing with the electrical charge is often not the case. However, it is valid for some dielectric materials [11]. The removal of the electric field practically returns the atom to its natural state as the time necessary for this process of exponential decay is termed time of relaxation [7]. The dielectric's action now hinges on the circumstances as the complexity of the situation enhances the inputs of the model that will describe the behavior adequately. The association between the dipole moment and the electrical field is the functions of the properties for a given material. Where both the size and size of the electric field for information, then with the identification of the relatively simple functionality that correctly predicts the phenomena of interest. Specifically, electronic paper devices show fascinating technological, environmental, and cultural benefits that will introduces unique recyclable electronic devices such as paper displays, smart packaging, smart labels, disposable electrochemical sensors bio-and medical applications, solar cells, PoC (Point of care) diagnostic devices, RFID tags(Radio-frequency identification), among others[8].

Paper-based electronics are valuable substitutes for electronic industries that introduce modern technology capable of communicating with end-users, classic paper publishing industry that faces challenges from electronic books, and the healthcare industry that intensifies the production of quantitative bio-sensing, Microfluidic and lab-on-chip apparatus[8].PhET Integrated Dielectric models is a fraction of the projects by the Association of American Universities at the University of Colorado Boulder. Nobel laureate Carl Wieman developed it in 2002. With Wieman's dream, PhET started to transform the way science is learned and taught. The mission is to advance and promote science and mathematics literacy globally through free interactivity [9].

2.0 RESULTS AND DISCUSSION

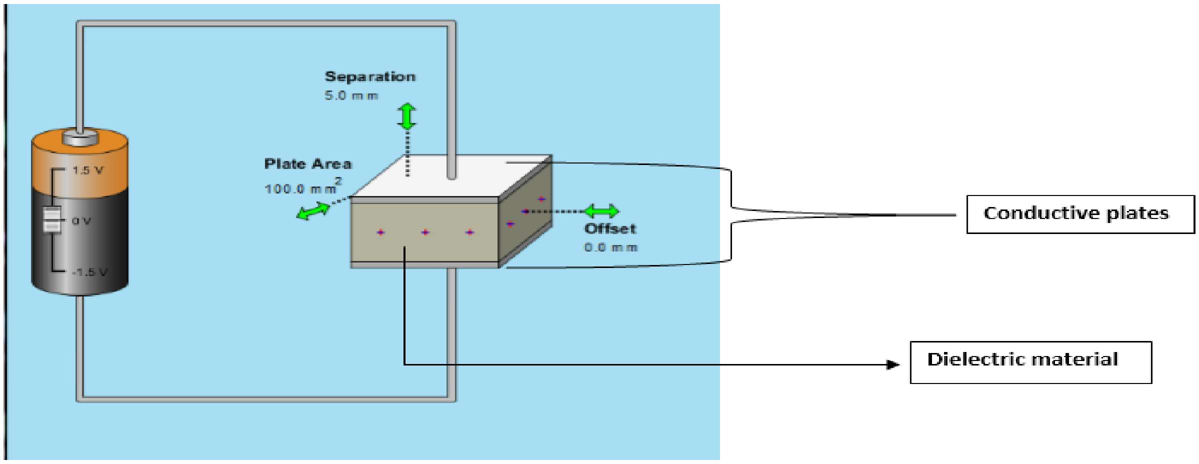


Figure 1. Simulated interface

Permittivity of free space=0.89
DC Voltage=1.5V
Conductive plate distance=10mm
Dielectric constant of paper=3.50

Table 1. Simulated outputs with dielectric activity of the specified paper surface areas under the above stated conditions

Paper surface Area(mm^2)	Capacitance X 10^{-13} (F)	Charge X10^{-13} (C)	Stored Energy X10^{-13} (J)	Conductive plate distance(mm)	Permittivity Constant (X10^{-13})(F/m)	Dipole moment (Cm)	Polarisability (Cm^2V^{-1})
100.0	3.10	4.65	3.49	10	0.310	46.50	310.000
102.7	3.18	4.77	3.58	10	0.318	47.70	326.586
105.4	3.27	4.90	3.68	10	0.327	49.00	344.658
108.2	3.35	5.03	3.77	10	0.335	50.30	362.470
111.0	3.44	5.16	3.87	10	0.344	51.60	381.840
113.8	3.53	5.29	3.97	10	0.353	52.90	401.714
116.7	3.62	5.42	4.07	10	0.362	54.20	422.454
119.6	3.71	5.56	4.17	10	0.371	55.60	443.716
122.6	3.80	5.70	4.27	10	0.380	57.00	465.880
125.5	3.89	5.84	4.38	10	0.389	58.40	488.195
128.6	3.98	5.98	4.48	10	0.398	59.80	511.828
131.6	4.08	6.12	4.59	10	0.408	61.20	536.928
134.7	4.17	6.26	4.70	10	0.417	62.60	561.699
137.8	4.27	6.41	4.80	10	0.427	64.10	588.406
141.0	4.37	6.55	4.91	10	0.437	65.50	616.170

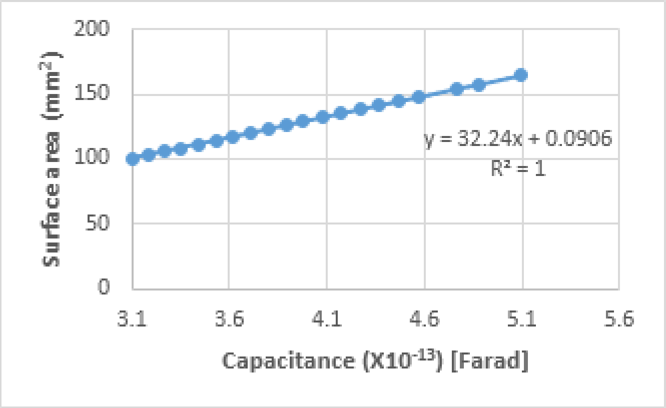


Figure 1. Surface areas against the induced capacitance

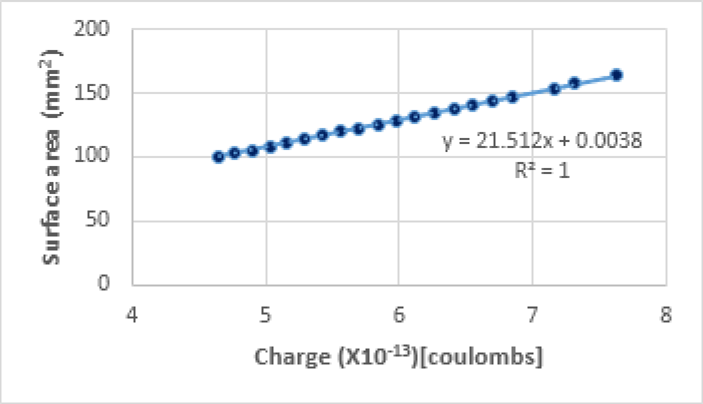


Figure 2. Surface areas against the developed charges.

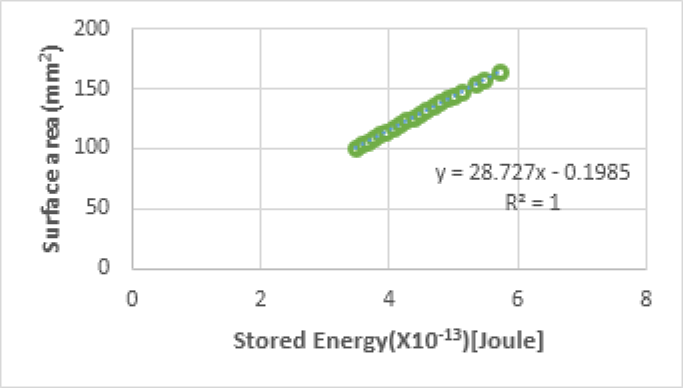


Figure 3. Surface areas against the generated energies.

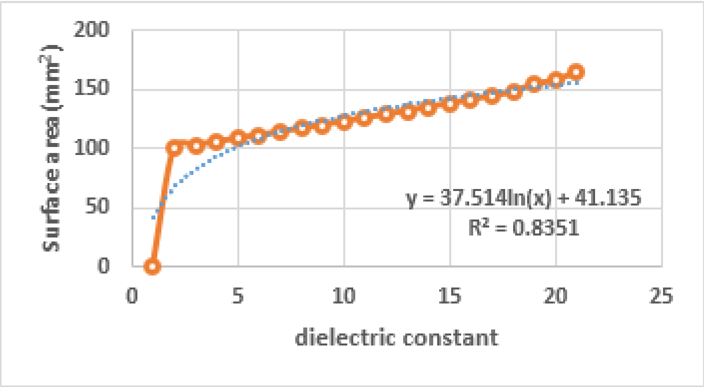


Figure 4. Surface areas against the produced dielectric constants.

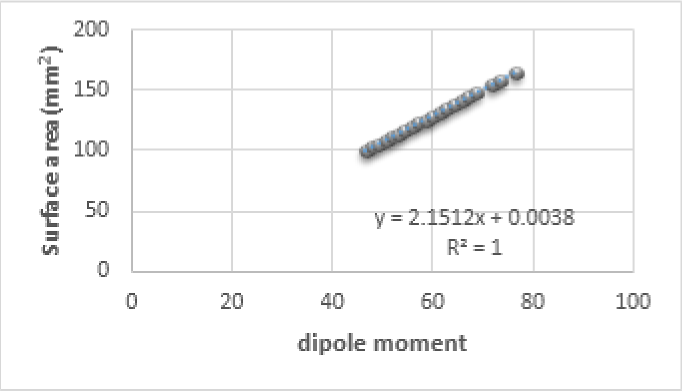


Table 5. Surface areas against the dipole moments.

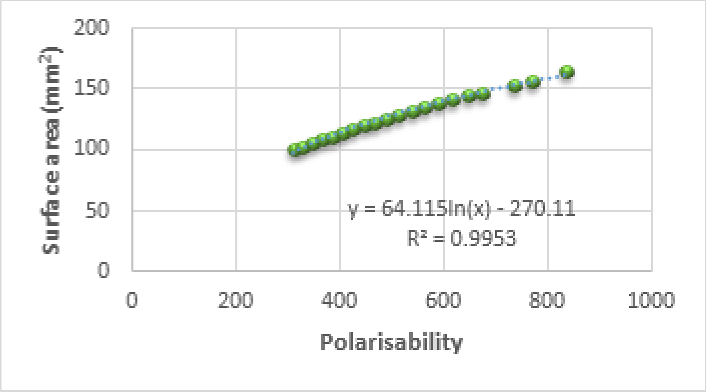
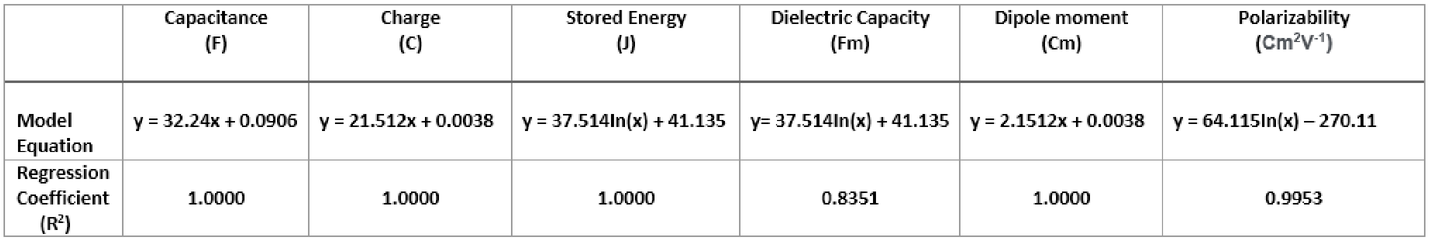


Table 6. Surface areas against the polarisabilities.

Table 2. Modeling expression and regression coefficients with dielectric paper surface areas



	Capacitance (F)	Charge (C)	Stored Energy (J)	Dielectric Capacity (Fm)	Dipole moment (Cm)	Polarizability (Cm^2V^{-1})
Model Equation	y = 32.24x + 0.0906	y = 21.512x + 0.0038	y = 37.514ln(x) + 41.135	y= 37.514ln(x) + 41.135	y = 2.1512x + 0.0038	y = 64.115ln(x) – 270.11
Regression Coefficient (R^2)	1.0000	1.0000	1.0000	0.8351	1.0000	0.9953

PhET dielectric simulations were applied in the active modeling of paper dielectric properties at 0.89 free space permittivity, DC voltage of 1.5 volts, conductive plate distance of 10mm and dielectric constant of 3.50. Table 1 declares the outputs of the simulations with respect to the paper's definite surface areas against the capacitance, the induced charges, generated energies, constant plate distance, estimated paper permittivity, dipole moments and polarizabilities. Figure 1, 2, 3, 4, 5 and 6 established the relationship between the dielectric paper materials against the selected parameters. In addition, table 2 discloses the modeled relationships with each of the selected properties. Obviously, the relationship between the surface area of the paper dielectric material with the capacitance in farad, charges in coulomb, stored energies in joule and the dipole moments in coulomb meter suggest a positive and strong correlation, while the dielectric capacities and the abilities to polarize are as well correlated relatively.

3.0 CONCLUSION

Simulations and modellings with modern electronics applications is gaining attention especially in areas of energy storage in capacitors, specially designed dielectric materials called electrets, modifications of semiconductor devices and mineral oils in the operations of transformer. Hence, this modeling can practically be engaged in the designs and processing of paper dielectric material for relevant applications under standard conditions.

4.0 ACKNOWLEDGEMENT

The authors acknowledge the creativity of Nobel laureate Carl Wieman (2002) of University of Colorado Boulder.

5.0 REFERENCE

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