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# The Influence of Dielectric Space on Materials Capacitance of Capacitor

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**Abstract-**This study examines the effect of dielectric space of various types of materials on capacitor capacitance using a theoretical study approach from various relevant literature. Relevant and valid literature is carried out by searching for keywords that are in accordance with the topic being discussed. The discovery of relevant articles uses various online media that provide various trusted journals. The number of articles used is 12 articles. The 12 articles obtained are then summarized for each article found by reviewing the results of the research obtained. In the articles found, the results of research are obtained regarding the capacitance value of capacitors which are influenced by various dielectric material tests. Testing of materials studied from articles found aims to determine materials that are efficient in increasing the capacitance value directly to a capacitor or energy storage. The influence of this selection has an impact on the magnitude of the capacitor capacitance value. The selection of materials makes the dielectric space or constant of different materials which causes different capacitor capacitances. The capacitance of the capacitor increases when the thickness of the type of material used is thinner. The selection of the type of capacitor dielectric material also affects the value of the dielectric space of the material caused by polarization between the dipoles which indirectly causes an increase in the capacitance value of the capacitor

**Keywords:** *Dielectric space, Dielectric Materials, capacitance.*

## 1 Introduction

The need for electronic devices increases every year with the development of technological capabilities that can answer various challenges to make human work easier (Ilhami et al., 2019). To support the performance of an electronic device, software and hardware are needed. The hardware components consist of various types of electronic components, one of which is a capacitor.

Capacitors are electronic components that have the ability to store electrical charges and electrical energy. The storage capacity of capacitors is known as capacitance. In addition, capacitors play an important role in power converter systems as power balancers, suppress voltage ripples, and store short-term energy.

Capacitors have positive and negative charges attached to each plate. The charge contained in the capacitor is temporary, because the function of the capacitor is to make the flowing current stable. Inside the capacitor there is a separator between the two charges which functions to avoid contact between unlike charges, the separator of the two plates is known as a dielectric. A dielectric is a material that has a very small current conductivity or even no current. Dielectric materials do not have conduction electrons that are free to move throughout the material by the influence of an electric field. An electric field will not cause movement of charge in the dielectric material. This property is what makes the dielectric material a good insulator. In dielectric materials all electrons are tightly bound to the core so that a strain structure is formed.

Capacitors are dimensionally composed of two conductor plates of the same size and there is an empty space between the two plates that can be filled with dielectric or insulating material. Technologically, capacitors can be made using 3D printed technology in the form of sheets and can be rolled to increase the

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ability to store electrical charges and electrical energy. In addition, increasing the capacitance of the capacitor can be done by modifying the composition and structure of the dielectric material.
Dielectric materials play a very important role in increasing the capacitance of capacitors. Several studies have examined materials and synthesis methods to create dielectric materials that can be used in supercapacitors.
Dielectric is a material that has very little or almost no current conductivity. All dielectric materials have a resistance level called "dielectric strength", defined as the highest electrical pressure that can be withstood by the dielectric without changing its properties to be conductive. If a dielectric changes its properties to be conductive, then the dielectric has undergone electrical breakdown.
Based on the measurement data for the comparison of capacitance values with the boundary material or dielectric space, there are differences in values. where there are various types of boundary materials, namely fiberglass, sponge and law density polyethylene. The boundary material with the highest value is fiberglass with a capacitance value of 28.81 nF, the boundary material with the second highest value is sponge with a capacitance value of 28.36 nF and the boundary material with the lowest value is the type of polyethylene boundary material with a capacitance value of 26.54 nF. In this study, what affects the size of the capacitance in the capacitor is its dielectric constant. The dielectric constant of the fiberglass boundary material is 6.3, sponge 3 and polyethylene 2.3. The capacitance value is directly proportional to the dielectric value. The higher the capacitance value, the higher the value of the dielectric material. So the purpose of this study is to examine the effect of the dielectric space of the material on the Capacitance of the Capacitor theoretically with references from various relevant related articles.

## 2 Research methodology

This study uses a literature review approach or library study by analyzing various theories and previous research findings related to the effect of the dielectric space of materials on capacitor capacitance. This article does not involve direct experiments, but will discuss and synthesize the basic concepts and results found in previous studies.
The main data sources in this study are relevant journal articles, books, and academic publications published in the period 2017 to 2023. These articles will be analyzed to find the relationship between the dielectric materials used in capacitors and the resulting capacitance values.
Data collection was carried out by conducting a literature search on various scientific databases such as Google Scholar, IEEE Xplore, ScienceDirect, and JSTOR to search for articles that discuss the theory of capacitors and capacitance, the effect of dielectric materials on capacitance, physical characteristics of dielectric materials commonly used in capacitors (such as dielectric constant, polarity, and conductivity), experimental results related to the use of dielectric materials in capacitors.
After the data is collected, this study will analyze the theoretical relationship between dielectric materials and capacitor capacitance, Synthesize the results of previous studies related to the influence of dielectric space, and discuss the variations of dielectric materials and how the properties of these materials affect the capacitance value of the capacitor. Review the differences in dielectric materials that are often used in capacitors, such as air, paper, polyethylene, silicon, and composite materials, and their relationship to increasing charge storage capacity. Evaluate the role of dielectric constant in determining capacitance and explain how external factors, such as temperature and voltage, can affect capacitance in the context of certain dielectric materials.

Table 1. Review Article

| No. | Author | Year | Article Title |
|---|---|---|---|
| 1 | **Elisa, E., Anas, M., Takda, A.** | 2023 | Efek Jenis Bahan Pembatas Terhadap Kapasitansi Capacitive Deionization (Cdi) Dari Arang Aktif |
| 2 | **Jaya, G. W., Aponno, S.V., Barus, C. S. A.** | 2024 | Kajian Teoritis Pengaruh Jenis Material Dieletrik Terhadap Penurunan Tegangan Listrik Kapasitor |
| 3 | **Siagian, M., Gede Jaya, W., Nurhidayati, I.** | 2021 | Analisis Jumlah Muatan Listrik Serta Energi Pada Kapasitor Berdasarkan Konstanta Dielektrik Suatu Material |
| 4 | **Umami, R.** | 2018 | Karakteristik Konstanta Dielektrik Serbuk Lada Putih Menggunakan Sensor Kapasitor Pelat Sejajar |

| | | | |
|---|---|---|---|
| **5** | **Agus, A,** | 2014 | Superkapasitor Sebagai Piranti Penyimpan Energi Listrik Masa Depan |
| **6** | **Didik, L. A.** | 2016 | Pengaruh Pemberian Medan Magnet Terhadap Konstanta Dielektrik Material Agcro2 |
| **7** | **Fauzah, Mastin. (2014).** | 2014 | Pengaruh Lama Penyimpanan Terhadap Nilai Kapasitansi Dan Konstanta Dielektrik Daging Sapi Dengan Metode Dielektrik Pada Frekuensi Rendah |
| **8** | **Jaya, G. W., Aponno, S.V., Barus, C. S. A.** | 2024 | Kajian Teoritis Pengaruh Jenis Material Dieletrik Terhadap Penurunan Tegangan Listrik Kapasitor |
| **9** | **Jumingin dan Setiawati, S.** | 2016 | Kajian Ketebalan Tanah Liat Sebagai Bahan Dielektrik Kapasitor Plat Sejajar |
| **10** | **Suhendar, Herudin, dan Lase, D.S.** | 2022 | Rancang Bangun Kapasitor Tegangan Tinggi Berbahan Polyvinyl Chloride dan Polyethylene Sebagai Perangkat Uji Simulasi Tegangan Tinggi DC |
| **11** | **Siagian, S., M, Jaya, G., W., Nurhidayati, I.** | 2021 | Kajian Teoritis Pengaruh Jenis Material Dieletrik Terhadap Penurunan Tegangan Listrik Kapasitor |
| **12** | **Taufik, Sammi Rizki and Surtono, Arif and AlHuda, Mahfudz** | 2016 | Karakterisasi Porositas Batuan Shalegas Terhadap Nilai Kapasitansi Dengan Menggunakan Sensor Kapasitansi |


## 3 Results and Discussion

In this study, various relevant literature on the effect of dielectric space on capacitor capacitance is reviewed starting from the basic concept of dielectric space of materials and capacitor capacitance and the relationship between the two.

Based on the type of capacitor dielectric material against the electric charge and energy of the capacitor with various variations of DC voltage. The DC voltage used is 20, 40, 60, 80, and 100 volts as independent variables and the area of the capacitor plate used is 10 cm2 and the distance between the capacitor plates is 10 cm as the dependent variable. The schematic image of the capacitor can be seen in the following figure.

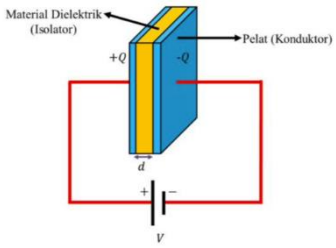


**Figure 1.** Capacitor with dielectric space

Capacitors with dielectric material (Figure 1) have a capacitor capacitance value ($C$) which is different from capacitors without dielectric material. The equation for the capacitance value of a capacitor with dielectric material can be written with equation 1:

$$C = K\varepsilon_o \frac{A}{d} \quad \ldots\ldots\ldots\ldots\ldots\ldots(1)$$

**with$C$is the capacitance of the capacitor (F),$K$is the dielectric constant of the material inserted in the capacitor,$\varepsilon O$is the permittivity of a vacuum with a value of 8.85 x 10-12 F/m,$A$is the cross-sectional area capacitor (m2), and$d$ is the distance between the capacitor plates (m). The amount of electric charge that can be stored by a capacitor using dielectric material can be written in the form of equation 2:**

$$Q = \left(K\varepsilon_o \frac{A}{d}\right)V \quad \text{.....(2)}$$

with$Q$is the amount of electric charge (C), and$V$DC voltage (V) (Abdullah, 2017).
Based on the research results of Elisa, et al. (2023) who studied the Effect of the Type of Boundary Material on the Capacitive Deionization (Cdi) Capacitance of Activated Carbon, it was found that the dielectric material value of the type of boundary material or dielectric space affects the capacitance of the capacitor with the type of material, namely fiberglass, sponge and low density polyethylene. The results of this study are based on capacitance measurements determined by measuring the input voltage (Vin) and output voltage (Vout).) with a signal generator as a frequency source and an oscilloscope to see the input and output waveforms. The input and output frequencies were varied from 100 Hz to 1000 Hz and using a 10 kΩ resistor, measurement data were obtained by varying the type of activated carbon separator material of candlenut shells. The graph of the relationship between frequency and capacitance is shown in the following graph 1:

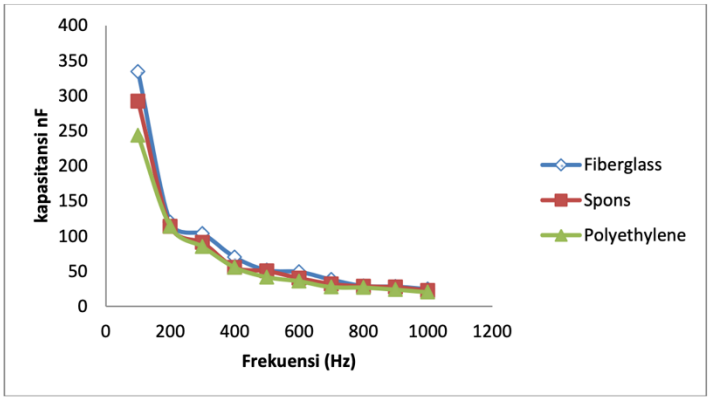


**Figure 2.** Relationship between Frequency and Capacitance in Various Types of Activated Carbon Separator Materials from Candlenut Shells

Based on the graph in Figure 3.2, it shows that the capacitance value decreases along with the increasing frequency used in various types of separator materials. Based on graph 1, the best frequency is obtained based on the analysis of graph 2, that for the entire 600-1000 area, there is a very small frequency change when compared to other values in the frequency area, apart from that the graph looks constant. So the frequency used is 800 Hz.
The results of the study conducted by Umami (2018) obtained experimental research results with the title Characteristics of Dielectric Constant of White Pepper Powder Using Parallel Plate Capacitor Sensors obtained the results of the relationship between the addition of mixing materials and the dielectric constant value of white pepper powder showing an increasing dielectric constant value, along with the increasing concentration of mixing materials (dry rice powder) added to the white pepper powder. This is because the dielectric constant of pure white pepper powder is smaller than the dielectric constant of pure dry rice powder. So that the addition of the concentration of dry rice powder causes a large increase in capacitance in the white pepper powder, which causes the dielectric constant of the white pepper powder to also increase.
Other research results related to the dielectric space of materials were also carried out by Siagian, M., Gede Jaya, W., Nurhidayati, I. (2021) using the theoretical study method, the results of mathematical calculations showed that glass has a greater amount of charge compared to other materials. When connected in series

and parallel, it was found that the amount of charge of the capacitor connected in parallel is much greater than the series, the energy stored in the capacitor connected in parallel also has a greater value than the capacitor connected in series.

Research conducted by Jumingin and Susi in 2016 with the research title Study of clay thickness as a dielectric material for parallel plate capacitors found that the dielectric material replaces the vacuum between the two conducting plates resulting in a polarization mechanism in the dielectric field, which has an impact on increasing the electric charge stored in the capacitor. This is due to the contribution of electric dipoles due to the polarization mechanism and the amount of charge stored in the capacitor, which affects the permittivity of the material (behaving as a dielectric material). The permittivity of this material will affect the capacitance of a capacitor.

Other research that applies the concept of dielectric space to the capacitance of capacitors is also found in research conducted by Agus Rianto in 2014 entitled Super Capacitors as Future Electrical Energy Storage Devices. The research found that Supercapacitors follow the same basic principles as conventional capacitors. However, in supercapacitors the surface area of the electrodes is made larger and the thickness of the dielectric material is made much thinner, thus reducing the distance between the electrodes. Thus, it can cause an increase in both capacitance and energy in the capacitor.

The concept of using dielectric space materials is also applied in several related studies conducted by Suhendar Suhendar in his research on Design and Construction of High Voltage Capacitors Made of Polyvinyl Chloride and Polyethylene as High Voltage DC Simulation Test Devices in 2022. The design uses Polyethylene material with different thicknesses. The material thickness of 0.0012 m has a capacitance of 207 pF and 190 pF better than high voltage made of PVC which requires a thickness of 0.003 m with a capacity of 197 pF and 186 pF. This shows one of the effects of the dielectric space of the material on the capacitance of the capacitor.

The increase in capacitor capacitance in Didik's research in 2016 through his research title entitled The Effect of Magnetic Field on the Dielectric Constant of Agcro2 Material, it was found that the dielectric constant is proportional to the increase in magnetic field strength. The increase in dielectric constant is caused by the compound used experiencing magnetization which results in a decrease in the effective electric field between the plates. As a result, the capacitance will increase and the dielectric constant will also increase. This shows that the dielectric space of the material also has an effect on capacitance.

Measurement in knowing the capacitance value produced by the dielectric material space can also be seen from the results of research conducted by Fauzah, Mastin in 2014, through experiments on the Effect of Storage Time on the Capacitance Value and Dielectric Constant of Beef with the Dielectric Method at Low Frequency. In the results of his research, the Capacitance value was obtained from measurements with the dielectric method at low frequency using parallel capacitor plates measuring 20 x 10 mm2 with a distance between plates of 5 mm connected to the LCR meter GW-instek series 816 with dual probes L and H. The dielectric constant was obtained through calculations from the capacitance results, plate area and distance between plates. The frequency range used was 100 Hz - 2000 Hz. The beef samples consisted of 4 samples with storage for 1 to 4 days in the refrigerator and 1 sample without storage (storage 0 days). The results showed that the capacitance value generally increased with the longer storage, as did the dielectric constant value. In this study it can be assumed that when the capacitance increases the dielectric constant also increases.

The increase in capacitance by the dielectric space of the material was also obtained from the results of research conducted by Rizki Taufik, Arif Surtono & Mahfudz Al-Huda in 2016 in his research on the Characterization of Shalegas Rock Porosity Against Capacitance Values Using Capacitance Sensors. The results obtained that the capacitance sensor is able to measure the difference in capacitance in each rock sample with different rock characteristics (porosity). From the results of the CV-converter circuit measurements, the maximum capacitance frequency was obtained at low frequencies between 500kHz–1MHz and from the results of capacito meter measurements, the relationship between porosity and capacitance was inversely proportional for sandstone rocks but in shalegas samples it was directly proportional.

## 4 Conclusion

Based on the results of literature studies sourced from various articles that have been published in various journals, the dielectric space or dielectric constant of the material used has an effect on the capacitance value of the test carried out. The measured capacitance value is used in determining the

selection of more efficient materials to improve the performance of a device, especially in storing electrical energy. The storage of electrical energy can be stored in an electronic device called a capacitor. Capacitors can be categorized by the type of material used. Through literature studies, it was obtained that the dielectric space of the material affects its capacitance value both directly and indirectly used in the system circuit.

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