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DETERMINING DIELECTRIC CONSTANTS OF GLASS AND THIN FILM USING A PARALLEL PLATE CAPACITOR

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ABSTRACT

In this paper some experimental lab measurements done, to measure the dielectric constant for glass with thin film, we need to measure the dielectric constant for glass to use it in simulation purposes of frequency selective services, which used to design low pass filter (to pass required frequency) or to design band stop frequency and may type of filters. After using a parallel plate capacitor experimentally determined that the dielectric constant for glass (2mm) with thin film $\varepsilon_r =$ 3.73345 at 100 MHZ.

KEYWORDS: Capacitance, dielectric constant, frequency selective surfaces (FSS), Frequency, Farad (F), relative static permittivity

1. INTRODUCTION

By using parallel plate experimental with relation between capacitance and dielectric constant , can measure and calculate the dielectric constant (relative static permittivity), herein want to measure glass and thin film for some purpose of simulation and studying property for energy saving glass windows to improve the performance and transmission of frequencies by using frequency selective surfaces (FSS) , by determining the accurate relative permittivity (dielectric constant) can be design the accurate frequency selective surfaces in energy saving glass windows to improve required signal inside the buildings.

I. LITERATURE REVIEW

Regarding to relation between capacitance and plate separation for an ideal parallel plate capacitance is very simple, it is common to do experiments to examine this relation, there are many articles relating to capacitors and dielectric materials [1-10]. Frequent purpose of these experiments is to verify the relation between the capacitance and the plate separation based on the parallel plate capacitance equation

$$C = \frac{\varepsilon_r \varepsilon_0 \text{ A}}{\text{d}} \qquad (1)$$

C : is the capacitance, in farads

A is the area of overlap of the two plates, in square meters

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ε_r : is the relative static permittivity (sometimes called the dielectric constant) of the material between the plates (for a vacuum, $\varepsilon_r = 1$)

$\varepsilon_0 = 8.854187817... \times 10^{-12}$ F·m^{-1} (farads per meter) is electric constant
d is the separation between the plates which is the thickness, in meters;

$$\varepsilon_r = \frac{C\,\mathrm{d}}{\varepsilon_0 A} \qquad (2)$$

A dielectric (or dielectric material) is an electrical insulator that can be polarized by an applied electric field. When a dielectric is placed in an electric field, electric charges do not flow through the material as they do in an electrical conductor but only slightly shift from their average equilibrium positions causing dielectric polarization. Because of dielectric polarization, positive charges are displaced in the direction of the field and negative charges shift in the opposite direction. This creates an internal electric field that reduces the overall field within the dielectric itself. If a dielectric is composed of weakly bonded molecules, those molecules not only become polarized, but also reorient so that their symmetry axes align to the field. The study of dielectric properties concerns storage and dissipation of electric and magnetic energy in materials. Dielectrics are important for explaining various phenomena in electronics, optics, solid-state physics, and cell biophysics.

Capacitance is the ratio of the change in an electric charge in a system to the corresponding change in its electric potential. There are two closely related notions of capacitance,(a) self-capacitance and (b) mutual capacitance. Any object that can be electrically charged exhibits self-capacitance. A material with a large self-capacitance holds more electric charge at a given voltage than one with low capacitance. The notion of mutual capacitance is particularly important for understanding the operations of the capacitor, one of the three elementary linear electronic components (along with resistors and inductors).

Fig 1 is the capacitance is a function only of the geometry of the design (e.g. area of the plates and the distance between them) and the permittivity of the dielectric material between the plates of the capacitor. For many dielectric materials, the permittivity and thus the capacitance, is independent of the potential difference between the conductors and the total charge on them.

So as equation (1) and (2) shows that the relation between capacitance and dielectric constant (relative static permittivity).

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The SI unit of capacitance is the farad (symbol: F), named after the English physicist Michael Faraday. A 1 farad capacitor, when charged with 1 coulomb of electrical charge, has a potential difference of 1 volt between its plates [1]. The reciprocal of capacitance is called elastane.

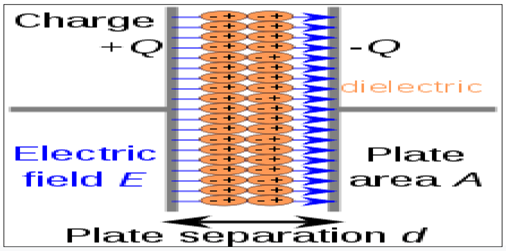

Fig (1): A polarized dielectric material

Experiment

In this experiment we used semiconductor characterization system model (4200-SCS) KITHLEY (Fig 2) instrument, with external test fixture hp16055A (Fig 3),

Fig (2): semiconductor characterization system model (4200-SCS) KITHLEY

Fig (3): test fixture hp16055A

The parallel plate capacitors we construct are simple and extensive. The construction is diagramed in Fig. (4)

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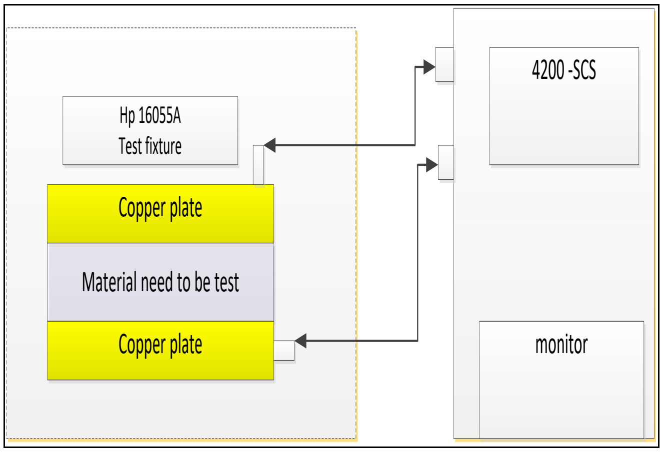

Fig 4: construction diagram

, before starting measure the capacitance, we test one known capacitor with 14 microfarad as Figure (5) for calibration purpose and to satisfy and test the instruments

Fig (5): testing capacitor 14 microfarad.

Capacitance measurements have been used to determine a variety of semiconductor parameters on many different devices and structures. Three measurement techniques are used to derive critical Parameters from a wide range of new materials, processes, devices. Multi-frequency capacitance Provides capacitance vs. voltage (C-V), capacitance vs. frequency (C-f), and capacitance vs. time (C-t) measurements to evaluate at frequencies ranging from 10-MHz down to 1-kHz. Sometimes even lower frequency capacitance measurements are necessary to evaluate test parameters of thin film transistors, MEMS structures, and other high impedance devices. Called very low frequency (VLF) C-V, this newer technique performs C-V measurements in the range of 10-mHz to 10-Hz. To characterize slow trapping and de-trapping phenomenon in some materials, a capacitance measurement technique called quasistatic (or almost DC) measurements can be used.

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Capacitance measurements at the wafer level are often plagued by preventable measurement errors. Ensuring the accuracy of capacitance measurements can be challenging due to parasitic capacitance from cable, switch matrix, and featuring combined with small capacitance values, often in the Pico farad or femto (10-15) farad range. These values are typically far lower than most LCR meters can resolve. Additionally, measuring capacitance on a semiconductor wafer is very different from measuring a packaged device due to the effects of the probe station's chuck.

To ensure measurement integrity, it's important to understand how a capacitance measurement is made. A typical capacitance meter will apply a DC bias voltage across the device under test while measuring the AC signal at a frequency between 1-kHz to 10-MHz. For MOScap structures, the DC voltage is swept, which causes the device under test to pass through accumulation into the depletion region and then into the inversion region. Kiteley's Model 4200-SCS Parameter Analyzer includes an extensive set of sample programs, test libraries, and built-in parameter extraction examples to simplify C-V measurements. after preparing the lab with above instruments, starting taking the measurements as Fig (6).

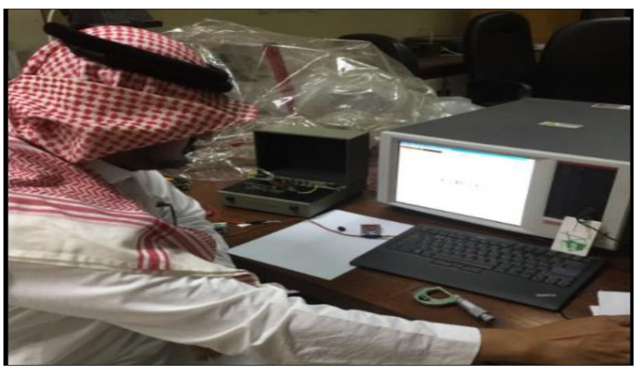

Fig (6): performing test on lab

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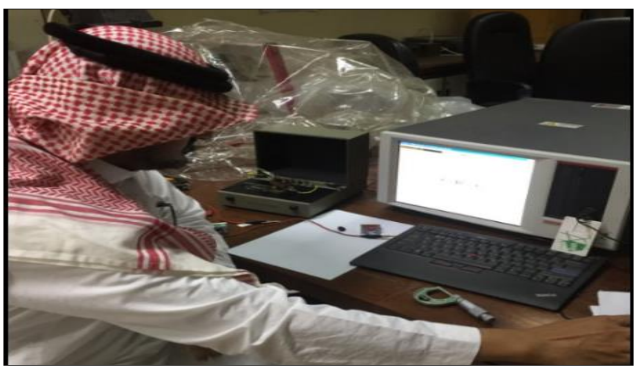

Fig (6): performing test on lab

to measure:

1. Capacitance for glass with thickness = 7.5 mm from 1kHZ up to 10 MHZ
2. Capacitance for glass with thickness = 2 mm from 1kHZ up to 10 MHZ
3. Capacitance for Thin film with thickness = .05 μm from 1kHZ up to 10 MHZ
4. Capacitance for Both glass (thickness = 7.5 mm) with thin film(.05 μm)
5. Capacitance for Both glass (thickness = 2 mm) with thin film(.05 μm)

After performing measurements, collecting data for capacitance in Farad from semiconductor characterization system model (4200-SCS) KITHLEY as Fig (7)

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Fig (7): collecting results and data from KITHLEY model (4200-SCS)

Table (1) shows all results for all cases, dielectric constant (relative static permittivity) in each above case, for glass (both thickness), and glass with thin film

Table (1): Results for dielectric constant (ε_r) for each case

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f(HZ)	glass with 7.5 mm		glass with 2 mm		thin film (.05 micometer)		thin film with glass (7.5mm)		thin film with glass (2mm)	
	C(F)	ε_r	C(F)	ε_r	C(F)	ε_r	C(F)	ε_r	C(F)	ε_r
1.00E+03	2.14E-12	13.682	2.18E-12	3.71381	4.88E-11	2.0785	1.55E-12	9.98417	2.33E-12	4.07518
2.00E+03	1.21E-12	7.7477	1.73E-12	2.94265	5.02E-11	2.1397	2.21E-12	14.2317	2.02E-12	3.52618
3.00E+03	1.54E-12	9.8132	1.66E-12	2.82105	4.99E-11	2.1242	2.37E-12	15.2699	2.03E-12	3.54729
4.00E+03	1.56E-12	9.9948	1.61E-12	2.74458	4.95E-11	2.1079	2.32E-12	14.9458	1.96E-12	3.42984
5.00E+03	1.50E-12	9.5811	1.63E-12	2.77956	4.85E-11	2.065	2.28E-12	14.6778	1.97E-12	3.43139
6.00E+03	1.51E-12	9.6284	1.63E-12	2.778	4.85E-11	2.0644	2.30E-12	14.7875	1.97E-12	3.43246
7.00E+03	1.49E-12	9.5462	1.61E-12	2.73559	4.87E-11	2.0735	2.26E-12	14.5581	1.95E-12	3.40028
8.00E+03	1.49E-12	9.5236	1.60E-12	2.72958	4.86E-11	2.0683	2.26E-12	14.5614	1.93E-12	3.36784
9.00E+03	1.47E-12	9.398	1.58E-12	2.69507	4.83E-11	2.0554	2.24E-12	14.4254	1.93E-12	3.36902
1.00E+04	1.48E-12	9.4365	1.59E-12	2.70838	4.82E-11	2.0536	2.24E-12	14.3877	1.91E-12	3.34318
2.00E+04	1.44E-12	9.212	1.56E-12	2.65443	4.74E-11	2.0196	2.19E-12	14.0705	1.88E-12	3.28639
3.00E+04	1.43E-12	9.1151	1.54E-12	2.6295	4.72E-11	2.0093	2.16E-12	13.9098	1.87E-12	3.26235
4.00E+04	1.42E-12	9.0423	1.53E-12	2.61353	4.69E-11	1.9993	2.15E-12	13.8413	1.86E-12	3.24091
5.00E+04	1.41E-12	9.0009	1.52E-12	2.59371	4.67E-11	1.9907	2.14E-12	13.7699	1.85E-12	3.22757
6.00E+04	1.40E-12	8.9695	1.52E-12	2.59397	4.66E-11	1.9862	2.13E-12	13.7094	1.84E-12	3.21144
7.00E+04	1.40E-12	8.929	1.51E-12	2.58024	4.66E-11	1.9843	2.12E-12	13.663	1.84E-12	3.20524
8.00E+04	1.39E-12	8.8888	1.51E-12	2.56971	4.64E-11	1.9744	2.11E-12	13.5929	1.82E-12	3.18327
9.00E+04	1.40E-12	8.9668	1.52E-12	2.5907	4.59E-11	1.9556	2.13E-12	13.7157	1.83E-12	3.20093
1.00E+05	1.38E-12	8.8434	1.51E-12	2.56756	4.73E-11	2.0157	2.11E-12	13.5571	1.84E-12	3.21696
2.00E+05	1.38E-12	8.7994	1.50E-12	2.55127	4.60E-11	1.9599	2.09E-12	13.469	1.82E-12	3.16956
3.00E+05	1.37E-12	8.7593	1.49E-12	2.53869	4.58E-11	1.9516	2.09E-12	13.4203	1.81E-12	3.15424
4.00E+05	1.37E-12	8.729	1.49E-12	2.53063	4.57E-11	1.946	2.08E-12	13.3702	1.80E-12	3.14456
5.00E+05	1.36E-12	8.7079	1.48E-12	2.52441	4.56E-11	1.942	2.07E-12	13.339	1.80E-12	3.13797
6.00E+05	1.36E-12	8.6927	1.48E-12	2.51952	4.55E-11	1.9389	2.07E-12	13.3164	1.79E-12	3.13358
7.00E+05	1.36E-12	8.6819	1.48E-12	2.51584	4.55E-11	1.9367	2.07E-12	13.2946	1.79E-12	3.12985
8.00E+05	1.36E-12	8.672	1.48E-12	2.51289	4.54E-11	1.9346	2.06E-12	13.2761	1.79E-12	3.12628
9.00E+05	1.36E-12	8.6666	1.47E-12	2.50985	4.54E-11	1.9328	2.06E-12	13.2597	1.79E-12	3.12403
1.00E+06	1.36E-12	8.6598	1.47E-12	2.50747	4.53E-11	1.9312	2.06E-12	13.2455	1.79E-12	3.12216
2.00E+06	1.35E-12	8.647	1.46E-12	2.48867	4.52E-11	1.9239	2.04E-12	13.1474	1.78E-12	3.11619
3.00E+06	1.36E-12	8.6923	1.45E-12	2.47307	4.52E-11	1.9247	2.03E-12	13.078	1.79E-12	3.1278
4.00E+06	1.37E-12	8.7771	1.44E-12	2.45676	4.53E-11	1.9304	2.02E-12	13.0162	1.80E-12	3.15052
5.00E+06	1.40E-12	8.9287	1.44E-12	2.44614	4.58E-11	1.9485	2.02E-12	12.9987	1.83E-12	3.19643
6.00E+06	1.43E-12	9.1307	1.43E-12	2.4319	4.64E-11	1.9765	2.02E-12	12.9777	1.87E-12	3.25743
7.00E+06	1.47E-12	9.4017	1.42E-12	2.41734	4.72E-11	2.0117	2.01E-12	12.9551	1.91E-12	3.34
8.00E+06	1.52E-12	9.7368	1.41E-12	2.39602	4.83E-11	2.056	2.01E-12	12.9103	1.97E-12	3.44359
9.00E+06	1.59E-12	10.161	1.39E-12	2.36325	4.96E-11	2.111	2.00E-12	12.8492	2.05E-12	3.5751
1.00E+07	1.68E-12	10.701	1.37E-12	2.3279	5.12E-11	2.1792	1.98E-12	12.7461	2.14E-12	3.73345

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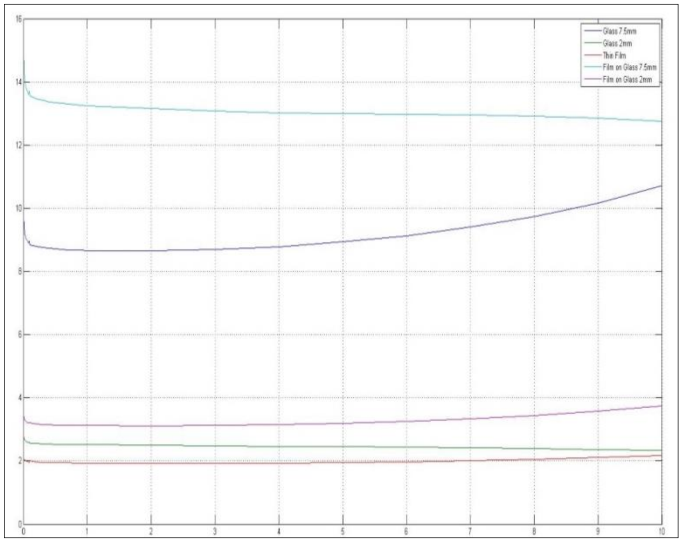

Fig (8): chart curves for different dielectric constant with frequency.

Table (2) shows that some research using parallel plate capacitor to determine dielectric constant for some materials.

Table 2: some research using parallel plate capacitor to determine dielectric constant for some materials

References	Material
[13]	Paper , wood and Teflon
[14]	Liquids and powder
[15]	Polyaniline& epoxy
[16]	Spin-coated
[17]	liquid sample
[18]	thin-film
[19]	Thin-Film
[20]	Liquids

III. CONCLUSION

Small plate separations are required for appreciable capacitances which require to determine the dielectric constant (relative static permittivity), the results for glass was matched the results in [11 – 12], It is clear that when the thickness decrease the capacitance is increase., and when increase the frequency the relative static permittivity is decrease, but the relative static permittivity is constant for same material until changing the thickness , the change only occurs when changing the frequency, for future work need to test measure the dielectric constant by another technique to compare the results.

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REFERENCES

[1] G. W. Parker, ‘‘Electric field outside a parallel plate capacitor,’’ Am. J.Phys. 70, 502–507 (2002).

[2] Yaakov Kraftmakher, ‘‘Measurement of dielectric constant of gases,’’ Am.J. Phys. 64, 1209–1210 (1996).

[3] John J. Meyer and Anthony F. Behof, ‘‘Experiment on the motion of a dielectric in a parallel plate capacitor,’’ Am. J. Phys. 62, 931 (1994).

[4] G. T. Carlson and B. L. Illman, ‘‘The circular disk parallel plate capacitor, ’’Am. J.Phys. 62, 1099–1105 (1994).

[5] F. N. Yan and H. K. Wong, ‘‘Force between the plates of a parallel-plate capacitor,’’ Am. J. Phys. 61, 1153 (1993)

[6] David E. Wilson, ‘‘A direct laboratory approach to the study of capacitors, ’’Am. J. Phys. 57, 630–632 (1989).

[7] Constantino A. Utreras-Diaz, ‘‘Dielectric slab in a parallel plate capacitor, ’’Am. J. Phys. 56, 700–701 (1988).

[8] Ricky Joe Harwood and Donald E. Kinkaid, ‘‘Use of a Mettler balance and a parallel plate capacitor to measure the permittivity of free space,’’Am. J.Phys. 43, 924–925 (1975).

[9] Edwin A. Karlow, ‘‘Let’s measure the dielectric constant of a piece of paper,’’ Phys. Teach. 29, 23–25(1991).

[10] S. K. Foong and C. H. Lim, ‘‘On the capacitance of a rolled capacitor, “Phys. Educ. 37, 429–430 (2002).

[11] Ghaffer I. Kiani, Anders Karlsson, Lars Olsson, and Karu P. Esselle, “Transmission Analysis of Energy Saving Glass Windows for the Purpose of Providing FSS Solutions at Microwave Frequencies", IEEE Antennas and Propagation Society International Symposium, San Diego, California, USA, 5-11 July 2008, Page(s): 1-4.

[12] Ghaffer I. Kiani, Anders Karlsson, Lars Olsson, and Karu P. Esselle,” Glass Characterization for Designing Frequency Selective Surfaces to improve transmission through energy saving glass windows", Asia Pacific Microwave Conference (APMC), Bangkok, December, 2007.

[13] T. T. Grove, M. F. Masters, and R. E. Miers, “Determining dielectric constants using a parallel plate capacitor”, American Association of Physics Teachers,2005.

[14] ATEFEH KORDZADEH, NICOLA DE ZANCHE, “Permittivity Measurement of Liquids, Powders, and Suspensions Using a Parallel-Plate Cell”, Wiley Periodicals, Inc.,2016.

ISSN: 2582-6271

Vol.1 No.4; 2020

[15] Jiongxin Lu a, Kyoung-Sik Moon a, Byung-Kook Kim b, C.P. Wong, "High dielectric constant polyaniline/epoxy composites via in situ polymerization for embedded capacitor applications", Elsevier Ltd,2007.

[16] A. N. AL-Omari and K. L. Lear, "Dielectric Characteristics of Spin-coated Dielectric Films Using On-wafer Parallel-plate Capacitors at Microwave Frequencies", IEEE Transactions on Dielectrics and Electrical Insulation,2005.

[17] V. Hartwig, G. Giovannetti, N. Vanello, M. Costantino, L. Landini, A. Benassi, "An electrodeless system for measurement of liquid sample dielectric properties in Radio Frequency band", EMBS Annual International Conference,2006

[18] Svitlana Kondovych and Igor Luk'yanchuk, "Nondestructive method of thin-film dielectric constant measurements by two-wire capacitor", WILEY-VCH Verlag GmbH & Co. KGaA, Weinheim,2016.

[19] Ge Song, Stephane Follonier, Andre Knoesen, "Characterization of Thin-Film Low-Dielectric Constant Materials in the Microwave Range Using On-Wafer Parallel-Plate Transmission Lines", IEEE MICROWAVE AND GUIDED WAVE LETTERS, VOL. 10, NO. 5, MAY 2000.

[20] Huseyin Canbolat, "A Novel Level Measurement Technique Using Three Capacitive Sensors for Liquids", IEEE TRANSACTIONS ON INSTRUMENTATION AND MEASUREMENT, VOL. 58, NO. 10, OCTOBER 2009.