ISSN: 5072-4228
Volume 9, Number 3, 2021
Innovative Journal of Scientific and Advanced Studies

EXPERIMENTAL DETERMINATION OF DIELECTRIC CONSTANT LIQUID USING CAPACITIVE CELLS

Clement Ogbonda and Precious Onuchuku
Department of Physics, Ignatius Ajuru University of Education, Rumuolumeni, Port Harcourt, Rivers State, Nigeria

ABSTRACT

This paper presents a new and simple method of capacitive cell for dielectric constant measurement in liquids. The cell is used for measuring the degradation of overheated edible oil through the evaluation of their dielectric constant and as a proposed device for measuring impedance .

Keywords: Heat sink, Dielectric Constant, Cells, oil, beaker , impedance

Nomenclature

ε_0	dielectric constant of vacuum,
A	plate area
d	distance.
K	dielectric constant

INTRODUCTION

The dielectric constant, also called the relative permittivity, is a fundamental property of the materials as are density, refractive index, viscosity and others. Its proper definition, (David and Reed 1999) is based on the way in which an electric field changes the polarization of a material. At an introductory level, the dielectric constant is defined based on the concept of capacitance and in terms of the change undergone by the electric field between the plates of a capacitor when an insulating material (dielectric) is sandwiched. The amount of molecular polarization in the material determines how the applied electric field changes and in this manner it's capacitance. In a laboratory, the most common way to measure the dielectric constant of a solid dielectric is through the capacitance of a parallel plate when this disc shaped material, is sandwiched between its plates (see figure 1)

Figure 1. Parallel plate capacitor used for the basic experiment to measure dielectric constant

Using a capacitance meter the capacitance ***C*** is measured and the dielectric constant ***k*** deduced using the well known relationship;

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

This is a very limited experiment given that it only can be used to measure solid dielectric materials and it is not possible to measure small changes in their dielectric constant. This parameter can change in a material as a consequence of temperature, pressure, humidity, pollution and other factors. Measuring these changes provides valuable information about the physical and chemical properties of a material. From an educational point of view it would be better to have an experiment in which the student can appreciate these change in properties. As the dielectric constant is a measure of the ability of a material

to store electric energy, it would be very interesting to measure quantitative changes in a material when this capability has been altered by some process. This applies primarily to liquid dielectrics.
An interesting case occurs in certain liquid dielectrics such as cooking oil. In these oils the dielectric constant is permanently altered when exposed to high temperature for long periods, which decreases the amount of unsaturated fatty acids, and some toxic elements are generated (*Nawar 1984*). Therefore, one way to measure this deterioration, and hence determine how safe the oil is after having been heated several times, is through the measurement of their dielectric constant ***k*** *(*Khaled et al 2014*)*. This requires the use of an appropriate capacitive cell for liquid materials and some way to measure this capacitance..

MATERIALS AND METHOD
Materials used for this study are
Heat sink
Capacitance meter
Corn oil
Microprocessor
Oven
Thermometer
Meters

Experimentation
Since a standard capacitance meter can measure a few pico farads, a low capacitive cell is employed for measuring of the oil dielectric constant. A 50 pF capacitor is applied to reduce measurement errors by noise and parasitic capacitances, In fact, the greater the cell capacitance, the better the measurement. The problem is that the greater the capacitance, the greater the amount of sample required for a measurement. The cell size were reduce the cell size measurement accuracy but this is not an easy task. A cell of a suitable size and capacitance using a microprocessor circuit's heat sink from those used in computers was employed. The heat sink is divided into two parts and their fins used as a multiple capacitor plates when interleaved as shown in figure 2.

Figure 2. The heat sink cut into two parts.
.

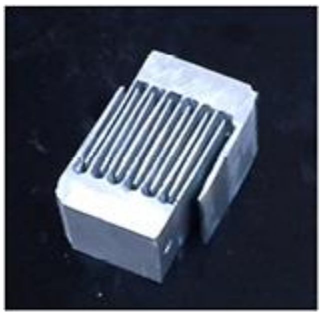

Figure 3 shows the two sides of the heat sink with its fins interlaced in parallel position and centered. The arrangement was set in a rectangular cardboard mold filled with epoxy resin in order to tie up the fins. After the resin has hardened the fins keep their position permanently and wires are attached to each part for the electrical connections to the meter as shown in fig 4.

Figure 4. The two heat sinks placed over the card mold.

The oil samples were prepared using a corn oil from a local brand 200 ml samples where heated in an oven to 175 °C. Four samples were exposed to heating times of 10, 20, 30 and 40 hours. Cell operation in the measurement process is very simple. First the cell capacitance in a vacuum (air) is measured. This value must be greater than 50 picofarads and, very importantly, the dissipation factor '***D***' measured by the instrument at 10 kHz was 0.50; otherwise, it would be an indication that the resin is contaminated and has high electrical losses. The cell capacitance in vacuum was 73 pF and the ***D*** factor was 0.015. The cell was put inside a 200 ml beaker and its electrodes were connected to the meter. A Stanford Research LCR meter model SR715 was used in this experiment. Thereafter, the oil was completely poured into the beaker covering the cell and reading was taken. the vessel is drained of all the oil and filled with a new oil sample. It was obtained from the ratio of the cell capacitances with oil to the cell capacitance in vacuum for each sample. All the measurements were carried out at 10 kHz but other frequencies produces basically the same results.

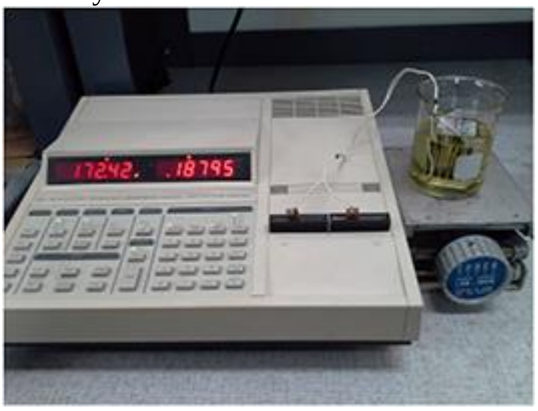

Figure 5. Capacitance measurement of the cell immersed in oil.

RESULTS AND DISCUSSION

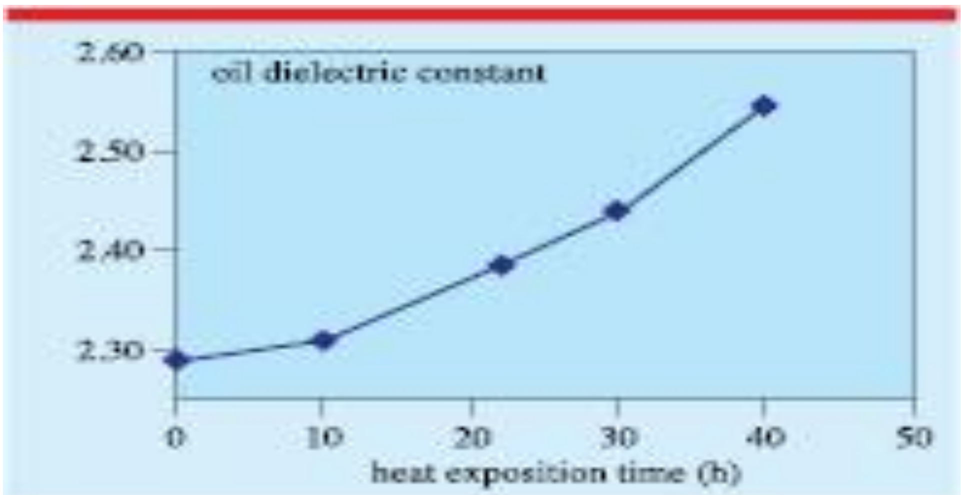

Figure 6. dielectric constant graph.

This graph clearly above shows how the dielectric constant growth as heat time exposure increases. Therefore, the electric constant can be used as an indicator of the oil deterioration. An explanation of why the oil dielectric constant changes is not easy without entering into a detailed description of oil physicochemical (Pecovska-Gjorgjevich et al 2012, Sankarappa and Prashantkumar, 2014) Edible oils are made primarily of fatty acids. The molecules of these acids are long chain molecules made of carbon and hydrogen, called triglycerides. The distribution center of the positive charges does not match the distribution center of the negative charges, but they are displaced. This means they are polar molecules, that is, have an associated electric dipole moment. The sum of all these moments produces the dielectric constant of the material. When the temperature increases, the large molecules chains are modified resulting in shorter ones (free fatty acids, etc) whose added dipole moments (called total polar compounds, TPC) are larger than those of the original string. This entails to an increase in ε value. With regards the dissipation factor D, it must be understood as a measure of the charge 'leakage' occurring between the plates in a capacitor. The lower this value is better. Capacitance meters normally include a dissipation factor measurement but, for our main purpose, this parameter can be overlooked. So, you just have to be careful that the cell built does not present electrical continuity in DC, an issue that can easily be verified with an ohmmeter. More interesting than the above simple experiment is the measurement of the dielectric constant when the measurement frequency is swept over a wide range, with a technique known as impedance spectroscopy. In many materials *(*Pecovska-Gjorgjevich et al *,2011*) their dielectric constant changes with the frequency applied due to the oscillations induced in the electric dipoles of their molecules and atoms and different energy levels are absorbed depending on the frequency used. This technique provides extra information about the material internal structure. The implementation of this kind of measurement requires the use of a more complex instrument called an impedance analyzer, which allows a continuous change in the operating frequency when measuring capacitance.

CONCLUSION

It has been shown the construction of a capacitive cell based on a circuit's heat sink for measurement dielectric constant in liquids. An experiment has been conducted in order to evaluate the dielectric constant in edible oils with different heating times. The dielectric constant changes as length of heat exposure increases—and therefore the health hazard—allowing for a correlation of deterioration with this parameter. This is a more complete experiment than the classic parallel plate capacitor and provides useful information on the samples measured. It is possible to reduce the cell size using a smaller heat sink, but this would involve a very careful measurement process with noise shielding, leakage capacitance reduction and a very sensitive meter.

REFERENCES

(1*)* David G and Reed C (1999) Introduction to Electrodynamics 3rd edn (Upper Saddle River, NJ: Prentice Hall)
(2) Nawar W (1984) Chemical changes in lipids produced by thermal processing J. Chem. Educ. (61) 299–302
(3) Khaled A Y, Aziz S A and Rokhani F Z (2014) Development and evaluation of impedance spectroscopy sensor to assess cooking oil quality Int. J. Environ. Sci. Dev. 5 299–302
(4) Pecovska-Gjorgjevich M, Andonovski A and Velevska J (2012) Dielectric constant and induced dipole moment of edible oils subjected to conventional heating Maced. J. Chem. Chem. Eng. 31 285–94
(5) Sankarappa T and Prashantkumar M (2014) Dielectric properties and AC conductivity in some refined and unrefined edible oils Int. Journal of. Adv. Res. Phys. Sci. 1 1–7
(6) Pecovska-Gjorgjevich M, Andonovski A and Velevska J (2011) Measuring frequency and temperature-dependent permittivities of vegetable oils . journal of Phys. Maced. (59) 77–89