PRELIMINARY ANALYSIS OF NHA BASED TISSUE ENGINEERING SCAFFOLD DIELECTRIC CHARACTERISTICS

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ABSTRACT

Cornstarch/nano Hydroxyapatite (nHA) composites scaffold had been fabricated by the technique of solvent casting and particulate leaching. Different amount of nHA powder and cornstarch were used to produce different compositions of scaffold. Various compositions of nHA are expected to produce different dielectric properties and this can be applied as a basis of reference for the dielectric properties of the scaffold. Thus, this may enable us to quantify probably the porosity and biocompatibility characteristics of the scaffold by indirect measurement using dielectric parameters for our future work. In this study, there were three different proportions of cornstarch/nHA scaffold which had been fabricated. The dielectric constant (ε′), dielectric loss factor (ε″), reflection coefficient (S_{11}) and transmission coefficient (S_{21}) over frequencies ranging from 12.4GHz to 18GHz were obtained by transmission line method. The experimental cost can be reduced within this frequency range because the size of the prepared sample can be miniaturized. Based on the results and analysis, dielectric constant decreases when frequency increases due to Maxwell Wagner dielectric mechanism. Hence, ionic relaxation polarization mechanism is responsible for the changes of both the dielectric constant and dielectric loss factor which declined with increasing frequency. This preliminary experimental results showed that the sample exhibit reflection, transmission and absorption coefficients which are less than 1. It can be summarized that cornstarch/nHA scaffold exhibit low absorbability of electromagnetic wave within the frequency range from 12.4GHz to 18GHz.

Keywords: starch/nano hydroxyapatite, tissue scaffold, dielectric properties.

INTRODUCTION

Tissue Engineering is the combination of knowledge in the field of medicine, biology and material which all apply in engineering area (Narbat *et al*. 2006). It is the study of growth connective tissue and organ from highly porous scaffold biomaterials to produce a completely functional organ for implantation back into the body. Scaffold is a short-term artificial biomaterial constitution used to sustain three dimensional (3D) tissue formations in implantation (Willerth and Sakiyama-Elbert, 2008).

In this study, nHA has been chosen as the biomaterial of interest to produce tissue engineering scaffold. HA is a calcium apatite based mineral with the formula Ca_{10} $(PO_4)_6$ $(OH)_2$ which is a kind of natural bioceramic material. nHA shows excellent osteoconductivity and ability in bone bonding due to its similar constituent like the natural bone (Wei and Ma, 2004). However, the brittleness of HA limits it to further the usage of scaffold which has been aimed in the bone engineering field (Willerth and Sakiyama-Elbert, 2008). A composite scaffold fabricated through the combination of nano Hydroxyapatite (nHA) and cornstarch materials was produced from solvent casting and particulate leaching.

Dielectric can be described as the polarization of electrical insulator by an applied electric field (Popović and Popović, 2000). There are many dielectric materials which are suitable to be used in electronic systems including microstructure and bonding of HA had shown important role in this field (Kaygili *et al*., 2012). The dielectric properties of the scaffold includes dielectric constant (ε′) and dielectric loss factor (ε″) will be measured by using E8362C PNA Microwave Network Analyzer with varying frequency range from 12.4 GHz to 18 GHz. Besides, reflection coefficient (S_{11}) and transmission coefficient (S_{21}) which are known as s-parameters will be measured using Transmission Line Method. Conductivity and polarization measurement in the tissue scaffold was investigated to establish their dielectric properties, which can be used later as a promising way to quantify biocompatibility and other scaffold material properties using inexpensive method in comparison to the established method such as Scanning Electron Microscopy (SEM) and cell viability assessment.

EXPERIMENTAL

Scaffold fabrication

First of all, sodium chloride (NaCl) particulates were introduced into the mixture to form pores in the scaffold. Sodium chloride (NaCl) particulates were then transformed into NaCl solution by dissolving them into distilled water and mixed them together until homogenous. After that, corn starch powder was poured into NaCl solution to make cornstarch/NaCl mixture and the mixture was stirred homogenously for 10 minutes. Then, nano Hydroxyapatite (nHA) powder was added depending on the desired concentration to prepare cornstarch/nHA mixture in the experiment. Next, the beaker that contained cornstarch/nHA/NaCl composite mixture was put into a larger beaker which was filled with distilled water and then placed on a hot plate.

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The temperature of distilled water inside the larger beaker was monitored and maintained at 85°C. If the temperature of distilled water inside the larger beaker exceeded 85°C, distilled water will be added to ensure the temperature remained at 85°C. The composite mixture was stirred and heated continuously with constant speed for 30 minutes before it was poured into the Teflon mold. After the mixture of cornstarch/nHA was poured into the mold, the specimens were oven dried at 80°C and were left for three days to ensure they were fully dried.

Dielectric properties measurement

The samples were prepared according to the dimension of waveguide ready for measurement of dielectric properties which are the dielectric constant (ε′) and the dielectric loss factor (ε″). Measurement system was set up using Performance Network Analyzer (PNA), cable, sample holder, WR62 waveguide adapter and Agilent dielectric measurement software (85071E). Frequency for measurement of dielectric properties was set according to the desired range which is 12.4GHz to 18.0GHz. Calibration and measurement of descriptions were performed before starting the measurement. Small width of waveguide, sample holder length, distance to sample and sample thickness were set. First of all, measurement of the open air was taken. Next, the sample was placed inside the waveguide in contact with two waveguide adaptors and the reading was taken. Lastly, the sample measurement for the same sample was repeated three times to obtain the average reading.

S-parameters measurement

Samples are prepared according to dimensions of waveguide which is ready for measurement for reflection coefficient (S_{11}) and transmission coefficient (S_{21}). After that, measurement system is set up using Performance Network Analyzer (PNA), cable, sample holder, WR62 waveguide adapter, reflector, calibration kit and Network Analyzer software. Frequency for measurement of reflection coefficient (S_{11}) and transmission coefficient (S_{21}) is set according to the desire range which is 12.4GHz to 18.0GHz. Calibration is performed before starting the measurement. Firstly, measurement of the open air which means no sample is taken. Next, sample is placed inside the sample holder in contact with two waveguide adaptors and the reading is taken. Lastly, the sample measurement for the same sample is repeated three times to obtain the best result.

RESULTS AND DISCUSSION

In this study, the dielectric properties of cornstarch/nano Hydroxyapatite (nHA) which include dielectric constant and dielectric loss factor for three different proportions which are 10% nHA mix with 90% cornstarch, 30% nHA mix with 70% cornstarch and 50% nHA mix with 50% cornstarch corresponding to the frequencies were measured. The frequencies were ranging from 12.4GHz to 18GHz. Tables-1 and Table-2 below illustrate the data of dielectric constant and dielectric loss factor of cornstarch/nHA respectively.

Table-1. Dielectric constant of cornstarch/nHA over the frequency range of 12.4 GHz to 18GHz.

Proportion	Frequency (GHz)							
	12.4	13.2	14.0	14.8	15.6	16.4	17.2	18.0
10% nHA+ 90% cornstarch	2.293	3.593	6.659	5.205	4.054	4.070	3.586	3.110
30% nHA+ 70% cornstarch	5.066	5.361	4.882	4.029	3.090	2.497	1.939	1.390
50% nHA+ 50% cornstarch	1.560	2.576	4.797	5.115	4.253	3.762	3.190	2.603

Table-2. Dielectric loss factor of cornstarch/nHA over the frequency range of 12.4GHz to 18GHz.

Proportion	Frequency (GHz)							
	12.4	13.2	14.0	14.8	15.6	16.4	17.2	18.0
10% nHA+ 90% cornstarch	3.851	5.056	3.156	0.326	0.639	0.565	0.344	0.354
30% nHA+ 70% cornstarch	4.082	2.426	1.858	0.673	0.679	0.829	0.980	1.455
50% nHA+ 50% cornstarch	3.265	4.673	3.827	1.936	0.849	0.546	0.275	0.219

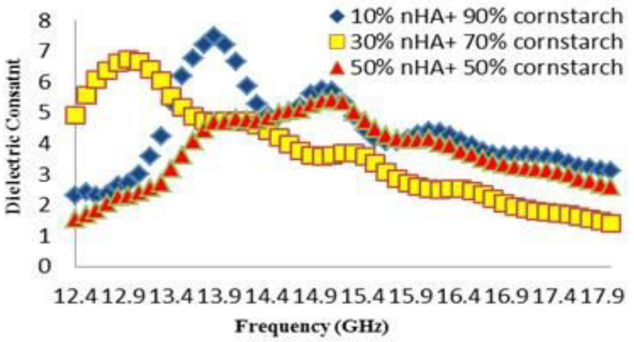

Figure-1. Variation of dielectric constant of cornstarch/ nHA for three different proportions.

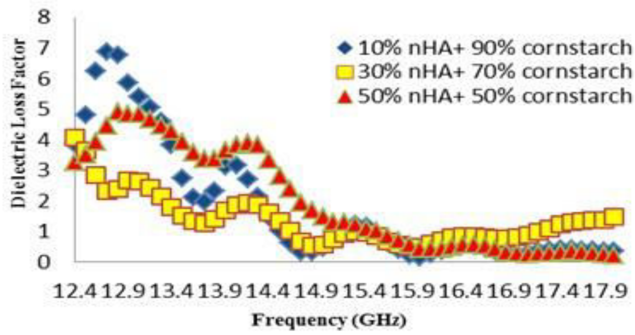

Figure-2. Variation of dielectric loss factor of cornstarch/nHA for three different proportions.

Both of the graphs of dielectric constant and dielectric loss factor of cornstarch/nHA over frequency are shown in Figure-1 and Figure-2 respectively. Most of the graphs show upward trend at the beginning followed by decreasing gradually. Dielectric constant declined when frequency increases due to Maxwell Wagner mechanism (Aal *et al*., 2011). It is usually appeared in composite materials where charges are separated by a boundary due to inhomogeneous medium.

In this study, nHA and cornstarch materials create two different-material interfaces. Maxwell Wagner mechanism is applied on cornstarch/nHA scaffold which can be explained by disarray of the structure and Coulomb force which focus on the charges of particles (Ige *et al*., 2012).The force will repel the particles from each other if they are like charges. On the other hand, unlike charges will attract the particles together (Schnick, 2006).

Besides, polarization mechanism causes both the dielectric constant and dielectric loss factor declined with increasing frequency. Ionic relaxation polarization is the type of polarization mechanism which responsible for the changes (Abuetwirat, 2014). As frequency rises, the polarization of material decreases due to the interaction of dielectric field and its polarization that produces heat which is then cause the energy loss. Also, the charges cannot maintain with the alternating field at higher frequency, thus it cannot keep up alignment with the field (Abuetwirat, 2014). Hence, it will prohibit the polarization mechanism of dielectric.

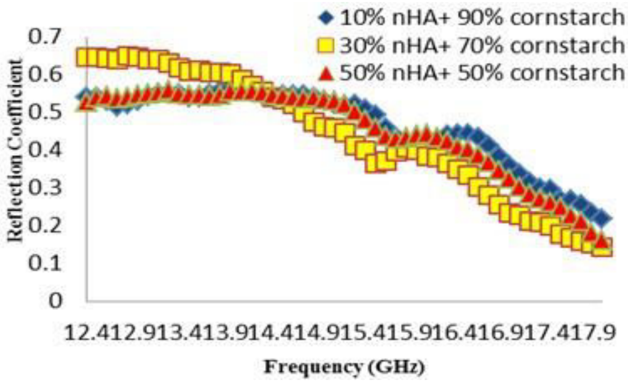

Figure-3. Variation of reflection coefficient of cornstarch/nHA for three different proportions.

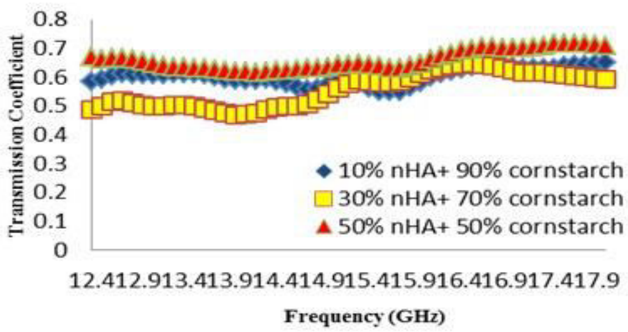

Figure-4. Variation of transmission coefficient of cornstarch/nHA for Three different proportions.

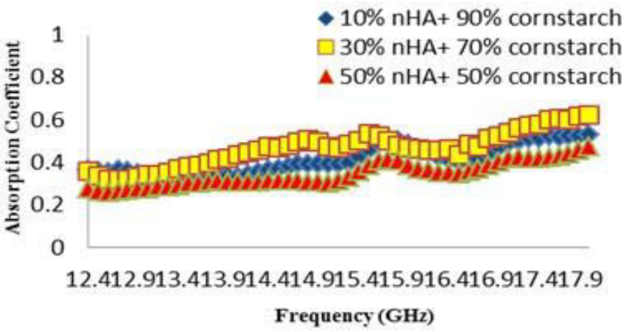

Figure-5. Variation of absorption coefficient of cornstarch/nHA for three different proportions.

Figure-3 shows the variation of reflection coefficient of cornstarch/nHA for three different proportions. At the beginning of experiment, the overall graphs demonstrated level off and then decrease systematically until a lowest trough is reached. After that, it continues to decrease until 18GHz. Initially, all the samples have high reflection coefficients due to high conductivity. This is because high conductivity will cause most of the incident wave to be reflected (Staelin, 2011). However, it can be concluded that as the frequencies increase, the reflection coefficient decreases for the three different proportions of cornstarch/nHA. On the other hand, the variation of transmission coefficient of cornstarch/nHA for three different proportions is illustrated in Figure-4. The graph is fluctuated within the range of transmission coefficient of 0.487 to 0.719.

Figure-5 illustrates the variation of absorption coefficient of cornstarch/nHA for three different proportions. From the Figure 5, most of the absorption coefficients were in the range of 0.272 to 0.620. The maximum absorption coefficient for the three different proportions of cornstarch/nHA occurs at 18GHz. Therefore, it can be inferred that 18GHz is the ideal absorption for the samples in this study. Besides, it can conclude that cornstarch/nHA scaffold is a weak absorbent where it would only able to absorb and dissipate very little amount of energy. In addition, cornstarch/nHA scaffold is not strong enough to minimize reflection and weaken the transmission of microwave. When the electromagnetic wave is passing through the cornstarch/nHA, there is very little signal will be trapped. Thus, transmission loss had been taken place where the receiver is only able to receive low signal (Lee *et al.*, 2013). Occurrence of absorption losses during the interaction process because material heating and ohmic losses produced by current that was induced in the medium.

CONCLUSIONS

A newly developed composite scaffold with NaCl remained in the combination of nHA and cornstarch materials had been fabricated by solvent casting and particulate leaching technique. Based on the results and analysis, dielectric constant decreases when frequency increases due to Maxwell Wagner mechanism. Hence, ionic relaxation polarization mechanism is responsible for the changes of both the dielectric constant and dielectric loss factor which declined with increasing frequency. For the reflection coefficient, all of the samples have high reflection coefficients at the beginning of experiment due to high conductivity. This is because high conductivity will cause most of the incident wave to be reflected. In addition, most of the absorption coefficients were in the range of 0.272 to 0.620. It can be summarized that cornstarch/nHA scaffold exhibits low absorbability of electromagnetic wave within 12.4GHz to 18GHz where it is able to absorb and dissipate very little amount of energy. Thus, it is concluded that cornstarch/nHA scaffold is not strong enough to minimize reflection and weaken the transmission of microwave. These preliminary characteristics might be used later in our future work to quantify biocompatibility and other properties of the tissue scaffold with inexpensive indirect measurement technique.

ACKNOWLEDGEMENTS

This research is funded by the Fundamental Research Grant Scheme (FRGS) (9003-00487) from the Ministry of Education, Malaysia and the conference fees is supported by the Research Management & Innovation Centre (RMIC), Universiti Malaysia Perlis.

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