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The Dielectric Characterization of Tapioca Starch – Ha Tissue Scaffold

Nashrul Fazli Mohd Nasir[1],Cheng Ee Meng[1], Nurathirah Jamal[1], Mohd Riza Mohd Roslan[1], Nur Aerina Fitri Mohd Hori[1], Beh Chong You[1], Muzammil Jusoh[2], Mokhzaini Azizan[3], Mohd Zakimi Zakaria[4] and Mohd Farid Abdul Khalid[5]

[1]Biomedical Electronic Engineering, Program, School of Mechatronic Engineering, Universiti Malaysia Perlis, Kampus Pauh Putra, Perlis, Malaysia.
[2]BioElectromagnetics Research Group, School of Computer and Communication Engineering, Universiti Malaysia Perlis, Main Campus Pauh Putra, Perlis, Malaysia.
[3]School of Electrical Engineering, Universiti Malaysia Perlis, Kampus Pauh Putra, Perlis, Malaysia.
[4]School of Manufacturing Engineering, Universiti Malaysia Perlis, Kampus Pauh Putra, Perlis, Malaysia.
[5]Microwave Research Institute (MRI), Universiti Teknologi Mara, Shah Alam, Malaysia

E-mail: nashrul@unimap.edu.my

Abstract. Tapioca starch- hydroxyapatite (HA) composites scaffold was fabricated using solvent casting and particulate leaching. The solvent casting involved the casting of polymer while particulate leaching involved the removal of porogen agent. The percentage of tapioca starch used were 50%, 60%, 70%, 80% and 90%, with the percentages of hydroxyapatite (HA) were set as 50%, 40%, 30%, 20% and 10% respectively. Here, sodium chloride was used as a porogen agent. SEM analysis was conducted to determine the micro structural of the scaffold surface. Based on the results, the pore size of composite scaffold is between ranges of 198 µm to 786 µm. For the dielectric study, the dielectric constants (□') and dielectric loss factor (□") over frequency range from 12.4 GHz to 18.0 GHz were obtained by transmission line method. Based on the result, both dielectric constant (ε') and dielectric loss factor (ε") was declined with the increment of the frequency.

1. Introduction

Tissue engineering scaffold is an initiative to repair, restore and regenerate damaged tissues using biocompatible materials [1]. Hydroxyapatite (HA), $Ca_{10}(PO_4)_6(OH)_2$) which can be derived from synthetic or natural resources such as seashells [2, 3], corals [4] and animal bones [5] offers exquisite biocompatibility, bioactivity, and osteo-conductivity are commonly used in this application [6]. HA alone as a tissue engineering scaffold is not suitable due to its low tensile strength and fracture toughness which may not be compatible for load bearing applications [7].

Starch can be described as a natural polymer, low cost, easily accessible resources, great water holding capacity and can interact with antimicrobial sytems [8, 9]. It has been widely used in biomedical engineering a a bone cement and bone replacement [10, 11]. Other studies had been conducted using corn flour starch and Bario rice starch as a potential biopolymer for tissue engineering scaffold [12, 13].

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Thus, the combination of tapioca starch and HA may assist in increasing the desired properties of tissue scaffolds such as its porosity.

2. Materials and Methods

The tapioca flour and the sodium used chloride were purchased from local market in Sarawak. Hydroxyapatite and 25% glutaraldehyde solution were supplied by Sigma Aldrich.The overall study is summarized in figure 1.

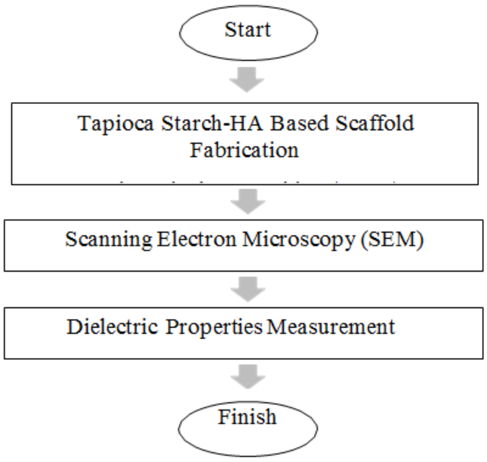

Figure 1. Overall experimental flow chart.

2.1 Scaffold Fabrication

Five different ratio of Tapioca starch-HA scaffolds were prepared using this ratio; 50:50(wt%), 60:40(wt%), 70:30(wt%), 80:20(wt%) and 90:10(wt%). The tapioca flour was mixed with distilled water to form starch solution. The HA solution was prepared separately. Both the tapioca solution and was mixed together and later double boiled until 70^{o}C.Sodium chloride which acted as the porogen was added into the slurry solution and then casted onto the Teflon mold with dimension of 25mm x 15mm x 15mm. The next process was drying the slurry in the mold for 48 hours at 65^{o}C. After the drying process, the scaffolds were soaked in 25% glutaraldehyde for 5 hours to enhance the structure of the scaffold and followed by immersion in distilled water to remove both sodium chloride and the glutaraldehyde. Lastly, the scaffolds were dried again at room temperature before characterizations proceed.

2.2 Scanning Electron Microscopy

The samples ued here were cut symmetrically to observe the scaffold's morphology at the inner part. The sample were coated with platinum. The SEM model used was the HITACHI TM 3000 Tabletop Microscope with the excitation voltage of 15kV which was bombarded upon the samples. The magnifications used were about 50 times magnifications.

2.3 Dielectric Properties Measurement

The measurement of the dielectric constant ε' and dielectric loss ε'' were based on the transmission line method by using Agilent E8362B Performance Network Analyzer (PNA). The samples dimension were 8 mm x 16 mm x 5 mm which was basically based on the dimension of WR62 waveguide dielectric holder. Later, the frequency was set in the range of 12.4GHz to 18.0GHz. Prior to the experiment, the open air condition measurement was taken without the sample. Hence, the sample was placed in the WR62 waveguide holder with the wave guide adapter and the results were taken in triplicate.

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3. Results and Discussions

3.1 Scanning Electron Microscopy

Figure 2 shows the size of pores size of the composites scaffold respectively. The size of pores inclined when the percentage of the tapioca starch increased.

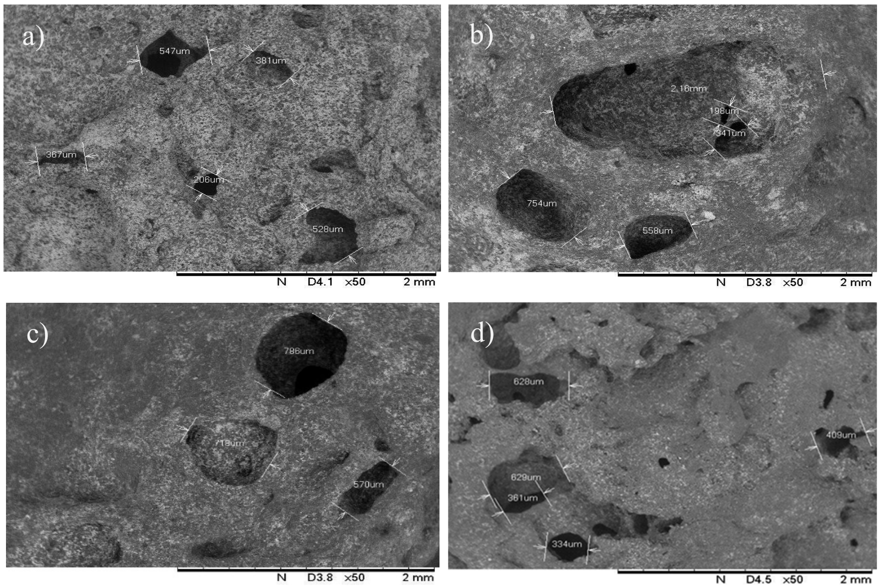

Figure 2. SEM results for a) 50% of tapioca starch b) 60% of tapioca starch c) 70% of tapioca starch and d) 80% of tapioca starch.

Figure 2 a) illustrates the pore size for 50% of tapioca starch which is 206 µm to 547 µm. While figure 2 b) shows the pore size for 60% of tapioca starch which from 198 µm up to 754 µm. Figure 2 c) shows the pore size for 70% of tapioca starch which is 570 µm to 786 µm. Next, figure 2 d) illustrate the pore size for 80% of tapioca starch which is 361 µm to 629 µm. Here, the optimal pore size is in the range of 100-500 µm but others found out that to control the macro porous composite scaffold, the optimal pore size should be 300-400 µm for enhance of the bone formation [14].

The size of the pores are also depended on the size of the porogen [15]. Besides, the pore size is important for the growth of bone and biological fixation with the tissue [10]. The scaffold is more rough and porous due to the surface of micro structural morphological of the composite scaffold influenced by the combination of the tapioca starch.

3.2 Dielectric Properties Measurement

Figure 3 and 4 illustrate the combination of the dielectric constant and the dielectric loss factor with the difference percentage of tapioca starch- HA over the frequency respectively. When the frequency increased, the dielectric constant will decrease. At the same time when the frequency inclined, the dielectric loss factor will decline. But at the beginning all the proportion shows upward trend and continue with decline gradually.

The mechanism of polarization for both dielectric constants and dielectric loss factor decreased across the incline of frequency due to the interaction of dielectric field. Besides, the polarization of material decrease because loss of energy [12]. At high frequency, the alternating field cannot maintain the charges.

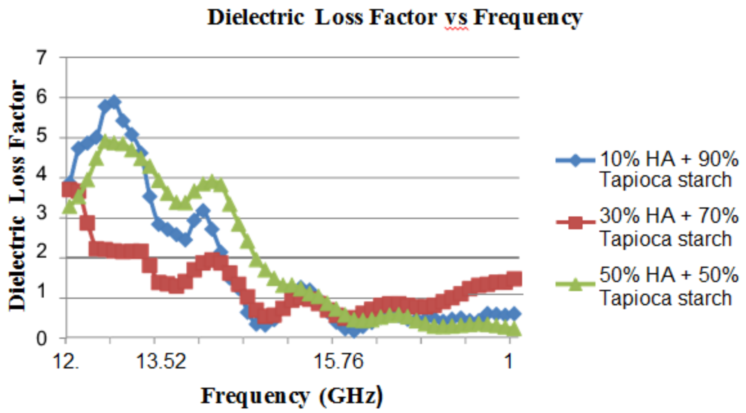

Figure 3. Combination of the dielectric constant with the different percentage of tapioca starch-HA over the frequency.

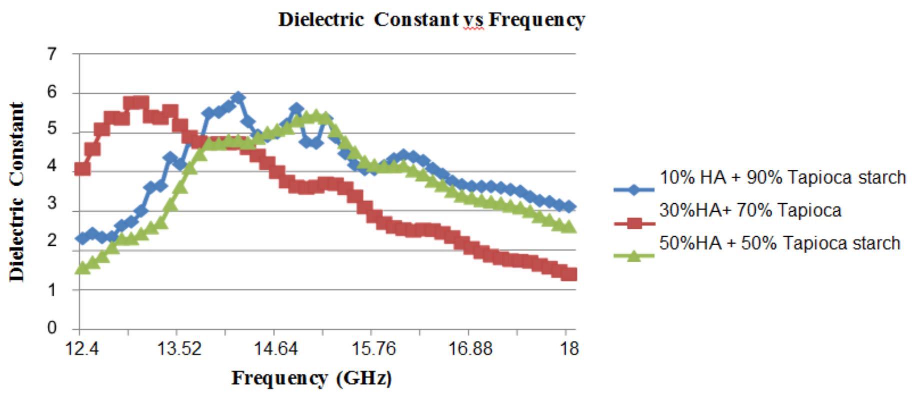

Figure 4. Combination of dielectric loss factor with the different percentage of tapioca starch-HA over the frequency.

4. Conclusion

In this study, the tapioca starch – Hydroxyapatite (HA) scaffolds were able to be fabricated using solvent casting and particulate leaching technique. For the SEM results, it is showed that by increasing the tapioca starch percentage, the porosity distributed on the scaffold will increase. The pore size of the scaffolds that were obtained during the test are between 198 µm to 786 µm. For the dielectric properties measurements, the characterizations of dielectric for porosity analysis shows that the porosity behave as dielectric properties of air matrix whereby, initially the porosity is claimed as the air matrix. If the porosity increases, so thus the dielectric properties.

Thus, the results are different in comparison to Bario rice starch-HA scaffold which did not show a trend of increment due to the increase amount of the starch for both SEM and the dielectric properties measurements [13]. From our observation, the results here are similar to the starch-HA scaffolds made from corn flour starch and future studies are required to investigate and established whether this trend is the normal trait to be observed if a starch-HA composites are to be fabricated.

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