# Microwave Absorption Properties of Polyurethane Foam Nano Composite Filled Aceh Natural Bentonite for Microwave-Absorptive Materials

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***Abstract*— Microwave-absorptive polymeric nanocomposite materials are becoming important to protect devices from radar detection in military application. The lightweight and elastic materials beside excellent microwave absorption were the purposes of polyurethane foam nanocomposite materials. Nanostructured microwave absorbing materials (RAMs) have received steadily growing interest because of its fascinating properties and various applications compared with the bulk or microsized counterparts. The increased surface area, number of atoms bond and unsaturated coordination on surface lead to interface polarization, multiple scatter and absorbing more microwave. This work, first of all, prepares radar-absorptive polyurethane foam nanocomposites using bentonite as fillers. Aceh natural nanobentonite were prepared using ball milling technique and characterizing their particle size distributions. The nanocomposites, prepared using in-situ reaction of polyethylene glycol and toluene diisocyanate, were then characterized for its morphological properties using scanning electron microscopy and microwave-absorption properties of the composites were characterized on radar frequency 8–12 GHz. The radar absorption properties, which investigated by vector network analyzer, of the nanobentonite filled in polyurethane foam with the ratio of polyurethane foam to nanobentonite was 80% wt : 20% wt shows reflection loss of – 20.16 dB, this condition was observed at 8.92 GHz**

***Keywords*— Polyurethane Foam, Nanobentonite, Microwave-Absorption***

## I. INTRODUCTION

The electromagnetic interference, a specific type of interference environmental pollution, is worsening due to the rapid development and utilization of wireless communications circuit devices and military applications. In the past decades, electromagnetic attenuation materials which comprise dielectric or magnetic fillers and polymer, have been commonly used to minimize the electromagnetic interference [1, 10].

The absorbing characteristics of materials depend on the frequency, layer thickness, complex permittivity ($\varepsilon_r$) and complex permeability ($\mu_r$). All the parameters ε', ε'', μ' and μ'' are found to increase with the increased of ferrite contents and it is found that the absorption properties in the composites are greatly improved with the increasing of ferrite contents in the polymer matrix [7]. But in other side, it will increase the mass of the absorbing materials. Conducting polymer composites with microstructured have attracted a significant academic and technological attention because of their unique physical properties and potential applications [4].

Bentonite mineral is type of rock and a compound of aluminium silicate hydrate with alkali metal which is group of several types of minerals. Bentonite is aluminosilicate with a framework structure enclosing cavities occupied by a large ions and water molecules, both of which have considerable freedom of movement, permitting ion-exchange and reversible dehydration. Natural bentonite is natural mineral that composed of crystalline silica ($SiO_2$) and alumina ($Al_2O_3$), with cavities of metal ions, which is usually alkali and alkaline or earth metals, and water molecules. Unique characteristic, include very stable with very high adsorption capacity and selectivity and have large active pore structure (microporous) and has a high specific surface area. Natural resources have the potential to be further processed into products that can be used for broad applications, among others, as supporting the catalyst or catalysts, and slow release substances. Bentonite crystal structure of alumina silicate shaped frame (framework) three-dimensional, having cavities and channels as well as containing metal ions such as Na, K, Mg, Ca and Fe as well as water molecules. Natural bentonite used in this research taken from Bener Meriah, Aceh Province in Indonesia.

Aceh natural bentonite chemical composition analysis using XRF showed the dominant chemical compounds are $SiO_2$ and $Al_2O_3$ as showed in Table 1.

Table 1. Aceh natural bentonite main chemical compositions

| Compound | % wt |
|---|---|
| $Na_2O$ | 4.13 |
| MgO | 0.71 |
| $Al_2O_3$ | 13.83 |
| $SiO_2$ | 66.55 |
| $K_2O$ | 5.81 |
| CrO | 2.34 |
| $TiO_2$ | 0.25 |
| Chlorine | 6.38 |

## II. EXPERIMENTAL

The fillers used for nanocomposite fabrication was Aceh natural bentonite. The polyurethane foam matrix used was a commercial type which contains two-part urethane monomers i.e. 60% wt polyethylene glycol and 40% wt toluene diisocyanate. The polyurethane foam nanocomposites reinforced with natural bentonite were fabricated with in-situ reaction. The activated natural bentonite prepared using planetary ball mill for 28 hours to complete nanobentonite with average particle size distribution < 100 nm. The nanobentonite divided into the same ratio and mixed with PPG and TDI for 1 minute. Polyethylene glycol and toluene diisocyanate with nanofillers of bentonite are using in-situ reaction. Polyurethane foam nanocomposites filled with nanobentonite is hold and pressed for 30 minutes with the sample thickness of 5 mm,

## III. RESULT AND DISCUSSIONS

Figure 1. shows the X-Ray Diffraction spectrum of Aceh natural bentonite. Observed from the XRD spectrum shows dominant intensity at 2θ = 19.79; 26.59 and 34,.91. Maximum peak occur at 26.59 with FWHM 0.124 which is at the quartz phase.

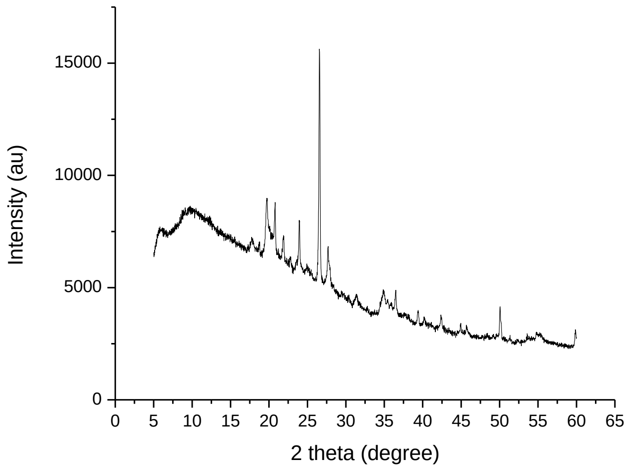


Figure 1. X-Ray diffraction of Aceh natural bentonite

Montmorillonit JCPDS standard have a high intensity at 2θ = 20; 26.75 and 35.01. Crystallites size was calculated based on analysis of Scherrer method. Based on the the calculation, with Scherrer constant (0.9) and wavelength (1.5406 Ǻ), natural bentonite crystallite size was 49.80 nm.

Compare with Aceh bentonite, it shows that natural bentonite is montmorillonit, but another peak at natural bentonite shows that crystaline at Aceh natural bentonite is not only montmorillonit but also mixed with other crystalline and other impurities. Variation of polyurethane foam and nanofiller varied with ratio (90%:10%); (80%:20%) and (70%:30%) by weight.

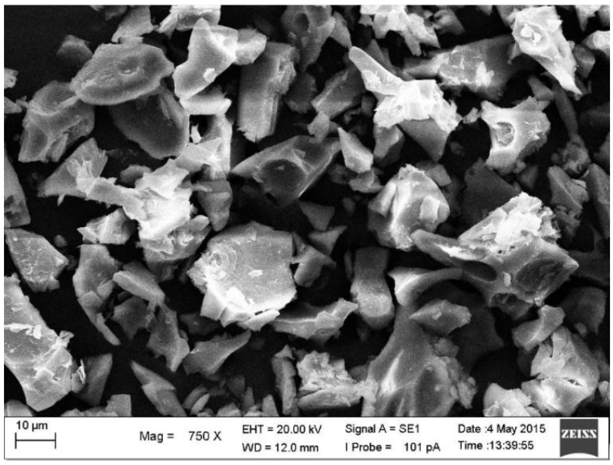


Figure 2. Aceh natural bentonite SEM micrograph

Figure 3.a. above shows the surface of the bentonite have a crystal lattice in the form of pores of the bentonite surface , this is in-line with the report stating that bentonite microporous crystalline solid is hollow and grooved and has a pore size of 3Ǻ to 10Ǻ called as molecular sieves.

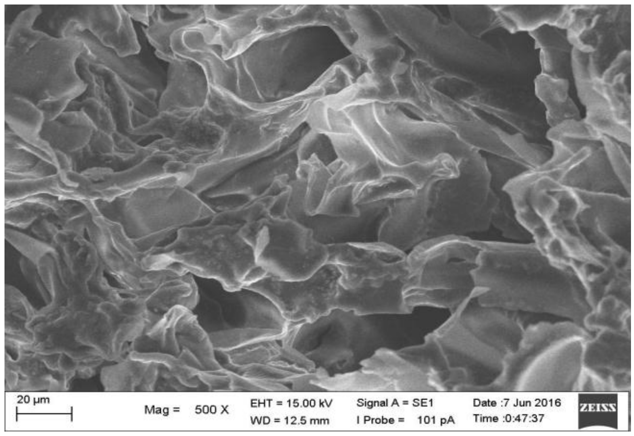


Figure 3. Polyurethane foam nanocomposite SEM micrograph

Figure 3 show SEM photograph shows that dark colors are pores or cavities and a bright color is Polyurethane foam matrices.

Results of other studies suggest that the materials properties will be compatible with the polymer matrices and influenced by several factors such as filler particle size. The particle size will affect the bond of the filler and the matrix. The amount of surface area will be increased by the presence of a surface porous on the filler's surface as well as with the addition of natural nanobentonite.

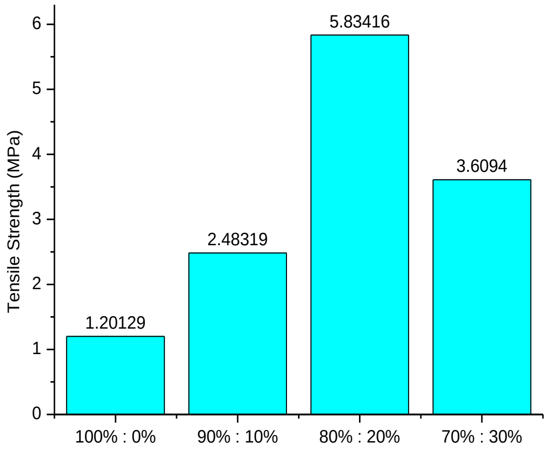


Figure 4. Polyurethane foam nanocomposite tensile strength

From Figure 4. the tensile strength properties show that (80%:20%) wt have the best tensile strength properties. This is because the nanobentonite silicate layers was homogenous distributed in the materials. The silicate layers itself have large contact surfaces that can bind strongly to the PU foam matrix which further give effect the tensile strength properties. In other side by the (70%:30%) wt addition of nanobentonite will affect nanoparticle agglomeration. The nanobentonite agglomeration believe as the stress concentration and will cause the main cracking.

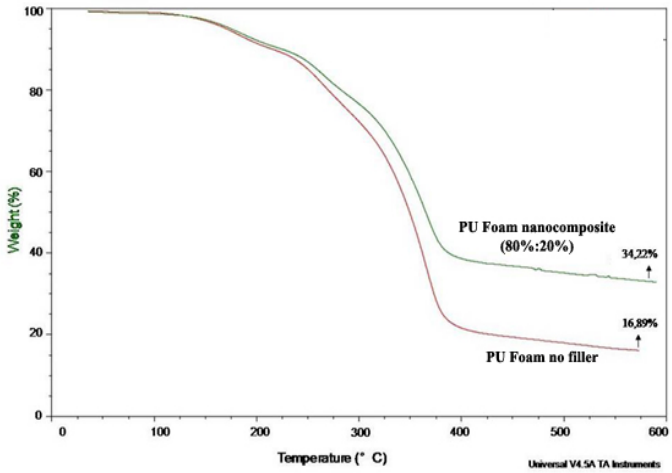


Figure 5. TGA curve of polyurethane foam with no filler and polyurethane foma filled with nanobentonite

According to the TGA curve both of the sample have lost its weight when the temperature increased, all the sample will release the water in the compounds at 200ºC. Decomposition of polyurethane without filler at 316.63ºC and 376.43ºC will loss its weight 19.3% and 50.45%. Decomposition of polyurethane foam filled with nanobentonite at 336.51ºC and 379.35ºC will loss its weight 15.62% and 37.84 %. After heated for 580ºC polyurethane foam will have 16.89 % residue and polyurethane nanocomposite have 34.22 % residue. Thermal stability will increase according the increase of nanocomposite.

Reflection loss measurement using Vector Network Analyzer for polyurethane foam nanocomposites reinforcement with 20% wt of natural bentonite as a function of frequency in X-band (8-12 GHz) shows in Figure 6.

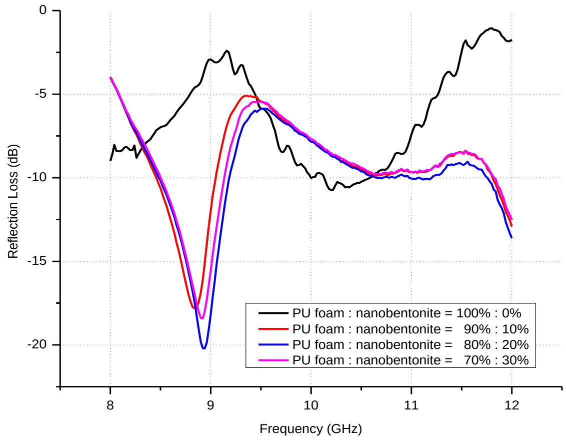


Figure 6. Reflection loss measurement of polyurethane foam nanocomposite

Reflection loss measurement using Vector Network Analyzer for polyurethane foam nanocomposites reinforcement with ratio of polyurethane foam : nanobentonite = (100% : 0%); (90% : 10%); (80%:20%) and (70% : 30) by weight as a function of frequency in X-band (8-12 GHz) shows in Figure 5. Polyurethane foam nanocomposites with ratio (80% : 20%) have the optimum reflection loss of -20.16 dB at 8.92 GHz. The reflection loss of less than -20 dB means the microwave absorption more than 99%. The microwave absorption being dependent on the ratio of $SiO_2$ and $Al_2O_3$ which is to dominant compounds of natural bentonite, the content of natural bentonite will modify the reflection loss and microwave absorption of the nanocomposite and will affect the complex permittivity and complex permeability of the nanocomposite [9]. To satisfy the zero-reflection condition where maximum absorption would occur. Minimum loss occurs when the thickness is about an odd multiple of one quarter of the wavelength of the incident frequency [4].

## IV. CONCLUSION

Polyurethane foam filled nanobentonite has prepared using in-situ reaction. Natural bentonite as a filler in polyurethane foam matrices will cause a different effect in electromagnetic properties and microwave absorption due to material reflection loss. The nanocomposite absorb microwave at X band frequency for > 99 % absorption. This is due to the effect of aluminum silicate binding with polar – polar reaction between filler and matrices. The binding will make effect to the molecul rotation and these reaction cause difference in input impedance and this will make a difference in the resonance at high frequency. The unique properties of nanobentonite and polyurethane foam will provide an important foundation for developing the materials with strong microwave absorption in wide applications prospects.

## REFERENCES

[1] Kong I, Ahmad S, Abdullah M, David, Yusoff, Puryanti, 2010, Magnetic and Microwave Absorbing Properties Of Magnetite-Thermoplastic Natural Rubber Nanocomposites J Magnetism Magnetic Mat **322**: 3401-3409

[2] Guo Z, Lee SE, Kim H, Park S, Hah HT, 2009, Characterization And Microwave Properties Of Polyurethane Nanocomposites Reinforced With Iron Oxide And Barium Titanate Nanoparticles Acta Materialia 2009 **57** : 267-277

[3] Kato Y, Sugimoto S, Shinohara K, Tezuka N, Kagotani T, Inomata K, 2002, Magnetic Properties and Microwave Absorption Properties of Polymer-Protected Cobalt Nanoparticles Materials Transactions M 2002 **43**: 406-409

[4] Hosseini H, Asadnia A, 2012, Synthesis, Characterization, and Microwave-Absorbing Properties of Polypyrrole/MnFe2O4 Nanocomposite J. Nanomater : 1-6

[5] Abbas SM, Dixit AK, Chatterjee R, Goel TC, 2007, Complex Permittivity, Complex Permeability and Microwave Absorption Properties of Ferrite-Polymer Composites J Magnetism and Magnetic Mater

[6] Saptari SA, Manaf A, Kurniawan, 2014, Microwave Absorbing Properties of $La_{0.67}Ba_{0.33}Mn_{1-x}Ti_xO_3$ in The Frequency Range 8-12 GHz, Int J Basic Appl Sci, **14** IJBAS-IJENS

[7] Jamal E.M, Joy, Kurian, Anantharaman, 2009, Synthesis Of Nickel-Rubber Nanocomposites and Evaluation of their Dielectric Properties, Mater Sci and Eng: B, **156**, 24-31

[8] Peng C.H, Wang H.W, Kan S W, Shen M.Z, Wei Y.M, Chen Y, 2004, Microwave absorbing materials using Ag-NiZn ferrite core-shell nanopowders as filler, Journal of Magnetic Materials, J Magn Mater, **284**; 113-119

[9] G Gultom, B Wirjosentono, K Sebayang and M Ginting, 2016, Preparation and Characterization of Microwave-absorption of Sarulla North Sumatra Zeolite and Ferric Oxide-filled Polyurethane Nanocomposites, Procedia Chemistry 19, 441-446

[10] Pawar R.P., Velhal N.B, Puri R.V Electromagnetic characterization of microwave sintered Sr1-xCaxMnO3 (0.0 ≤x≤0.4) thick film Processing and Application of Ceramics, Proc and Appl Ceramics 7 [1] 2013: 1-7