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SOME MICROWAVE PROPERTIES OF LITHIUM-NICKEL-ZINC (LNZ) FERRITES - THERMOPLASTIC NATURAL RUBBER (TPNR) COMPOSITES.

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ABSTRACT

A microwave $(Li_{0.5}Fe_{0.5})_{0.4}Ni_{0.3}Zn_{0.3}Fe_2O_4$ (LNZ) ferrite was prepared by a conventional sintering method in air. A thermoplastic natural rubber (TPNR) was prepared from polypropylene (PP), natural rubber (NR) and liquid natural rubber (LNR) in the ratio of 70: 20: 10 by melt blending technique. LNZ ferrite -TPNR magnetic composites with 0 – 30 weight percent of ferrite filler were prepared via a Brabender plasticorder internal mixer. The microwave complex scattering parameters due to reflection (S_{11}) and transmission (S_{21}*) were measured using a microwave vector analyzer (MVNA). The microwave reflection, transmission and absorption characteristics of the pure LNZ, pure TPNR and their composites in the frequency range of 0.3 – 13.5 GHz were evaluated and discussed.*

The results indicate that the composites having higher filler loading can be used for some microwave application.

Keywords : *Scattering parameters ; reflected power ; transmitted power ; absorbed power.*

INTRODUCTION

Recent developments in absorber technology have resulted in materials with lower production cost that can effectively reduce electromagnetic interferences (EMI) (Cho et al. 1996 ; Hari et al 1999). There are variety of absorber materials for suppressing electromagnetic interferences within a specific range of frequency.

Microwave absorbers are also utilized in transmission lines to absorb unwanted waves that reflected from the loads in order to eliminate undesirable degradation of the microwave generator properties. An ideal absorber is a reflection free one port where incident power is completely absorbed and dissipated as heat. Ferrites are one of the best absorbing material that have been extensively used for that purpose (Kim et al.1991; Kwon et al 1994).

This paper discussed the behaviour of the microwave reflection, transmission and absorption characteristics of a pure LNZ, TPNR and their composites. The effect of incorporating ferrite material into the matrix of the TPNR on the microwave properties are examined and discussed.

MATERIALS AND METHODS

A polycrystalline $(Li_{0.5}Fe_{0.5})_{0.4}Ni_{0.3}Zn_{0.3}Fe_2O_4$ (LNZ) ferrite was prepared by a conventional double-stage sintering technique from high purity powders of Li_2O, NiO, ZnO, Fe_2O_3 (99.99%) and 0.5 wt % of Bi_2O_3. The powders were sintered in air at 800 °C and 1050 °C for 6 h and 15 h respectively. The addition of Bi_2O_3 and the use of lower calcining and sintering temperatures have been previously suggested (Kishan et al. 1985; Mitra et al. 1992) for lithium and lithium-based ferrites in order to avoid excessive vaporization of lithium and zinc as well as to increase the density and homogeneity of the ferrites. A toroid of 1.6 mm inner diameter, 3.4 mm outer diameter and about 4 mm thick was machined for microwave measurement.

A thermoplastic natural rubber (TPNR) was prepared from polypropylene (PP, Mobil), natural rubber (NR, Guthrie (M) Sdn. Bhd) and liquid natural rubber (LNR) as a compatibilizer in the ratio of 70: 20: 10 (Ahmad et al. 1994, 1995). The LNR was prepared by photosensitized degradation of NR in visible light. The materials were melt-blended in a laboratory cam mixer (Brabender Plasticorder Model PL 200 and Mixer Model W 50E/2) at 170 °C and rotor speed of 50 r.p.m .The LNR was added into the mixer 1 min after introducing NR. NR and LNR were allowed to mix for about 2 min before PP was charged into the mixer. Once homogeneous mixing was assumed after about 12 min, the blend was removed from the mixer. The matrix of TPNR was ground by a granulator (Granulator Model Ph 400 SS).

Samples of TPNR – LNZ ferrite composites were prepared by melt-blending of the materials in a laboratory cam mixer at 170 °C and rotor speed of 50 r.p.m. The content of ferrite was varied from 0 to 30 weight percent. The ferrite powder was added into the mixer 2 min after introducing TPNR. The materials were allowed to mix for about 12 min. Once homogeneous mixing was assumed, the blend was removed and subsequently compressed at about 175 °C and 7 kN pressure for about 2 min using a hot press (Carver Laboratory Press) into a thin sheet of about 3 mm thickness from which test specimens were cut. Samples in the shape of toroids were prepared to fit closely into a coaxial measurement cell (outer diameter ~3.5mm, inner diameter ~ 1.6mm).

The complex scattering parameters (S_{11}^* and S_{21}^*) were measured using a Hewlett Packard HP8719D network analyzer in the frequency range of 0.3 - 13.5 GHz. The reflection, transmission and absorption properties of the composites with respect to the microwave propagation were evaluated and discussed.

RESULTS AND DISCUSSION

The microwave vector analyzer measures the response (magnitude and phase) of a material under test by comparing the input and output signals going into and coming out from the material. The reflection and insertion losses which are the characteristic properties of the material can be described by four complex scattering parameters, namely S_{11}^*, S_{12}^*, S_{21}^* and S_{22}^*. The notation used for the S parameter is $S_{\text{out-in}}$. The first number (out) refers to the terminal where the signal leaves the material and the second number (in) refers to the terminal where the signal enters the material. For example, $S_{11}^* = b_1^*/a_1^*$, is electric field leaving terminal 1 (b_1^*) divided by the electric field entering terminal 1 (a_1^*) under the condition that no signal enters the terminal 2 ($a_2^*=0$). This quantity is also known as the reflection coefficient. $S_{21}^* = b_2^*/a_1^*$ is the transmission coefficient, which is the ratio of the electric field leaving terminal 2 (b_2^*) to electric field entering terminal 1 (a_1^*) under the condition that no signal enters terminal 2 ($a_2^*=0$). S_{21}^* is also known as the insertion loss or gain of the system. The other two parameters, S_{12}^* and S_{22}^* are due to the signal propagating in the opposite direction (Yusoff and Abdullah 1999).

The frequency dependence of the reflection coefficient (S_{11}^*) of the samples is depicted in Figure 1. The dependability of S_{11}^* on the frequency is almost the same for all samples. S_{11}^* is seen to increase gradually with increasing frequency before showing a marked drop at about 12.5 GHz for LNZ and 9.5GHz for composites and TPNR. LNZ shows the highest value of the reflection coefficient followed by the composites and TPNR. At a fixed frequency, S_{11}^* increases with increasing ferrite content.

In contrast, the transmission coefficient (S_{21}^*) for LNZ shows a minimum in between 5.0 and 11.0 GHz, which is shown in Figure 2. The values however, increase at both ends of the frequency range used in this study. The S_{21}^* values for the TPNR and the composites slowly decrease with increasing frequency up to about 9.5 GHz, but slightly increase towards the high frequency end. TPNR shows the highest value for S_{21}^*, while LNZ is the lowest. It can be seen that at a fixed frequency, the transmission coefficient decreases with increasing filler concentration for all composites.

Due to the reciprocity behavior shown by the ferrite, the reflected (P_r), transmitted (p_t) and absorbed (P_a) powers can be averagely calculated using the relation $P_r = [0.5(S_{11}^* + S_{22}^*)]^2 \times P_i$, $P_t = [0.5(S_{21}^* + S_{12}^*)]^2 \times P_i$ and $P_a = P_i - (P_r + P_t)$, where $P_i = 3$ mW (or 5 dBm) is the incident microwave power used in this study (Yusoff et al. 2000). Figure 3, 4 and 5 illustrate the percentage of the reflected, transmitted and absorbed powers for all samples.

Almost 65% of the microwave power is transmitted with P_t showing a linearly decreasing trend towards the higher frequency for the composites and TPNR. For LNZ, a broad minimum in P_t is observed from 7 to 11 GHz. P_r for the TPNR and composites are small at lower frequencies but slowly increase as the frequency increases. The microwave power seems to be reflected less than 15% throughout the whole frequency range. The increase of P_r with increasing frequency for LNZ is more prominent up to a maximum at about 12.5 GHz then decrease as the frequency is further increased. The microwave power absorbed by the TPNR and composites is about 20%. It is lower than the transmitted power, but is higher than the reflected power throughout the whole frequency range. A broadband absorption by the LNZ occurs in the frequency range of 2.5 to 10.5 GHz. At a fixed frequency, the power transmission decreases with the increasing filler content.

It can be seen that, the composite with 30 wt % filler content shows a sudden change in P_r, P_t and P_a. At this concentration, a conducting network of fillers is formed in the polymer matrix. This is due to the formation of a mesh among the conducting fillers within the polymer matrix. It seems that the connectivity of the ferrite particles in the matrix affects the microwave propagating properties in the composites.

CONCLUSIONS

The composites and the pure TPNR transmit more and reflect less microwave energy than the pure LNZ in frequency range used in this study. At a fixed frequency, the power reflection and absorption increase but the power transmission decreases with increasing filler content. A sudden change in microwave properties for the composite with 30 wt % filler concentration is due to the formation of a mesh among the conducting fillers within the polymer matrix.

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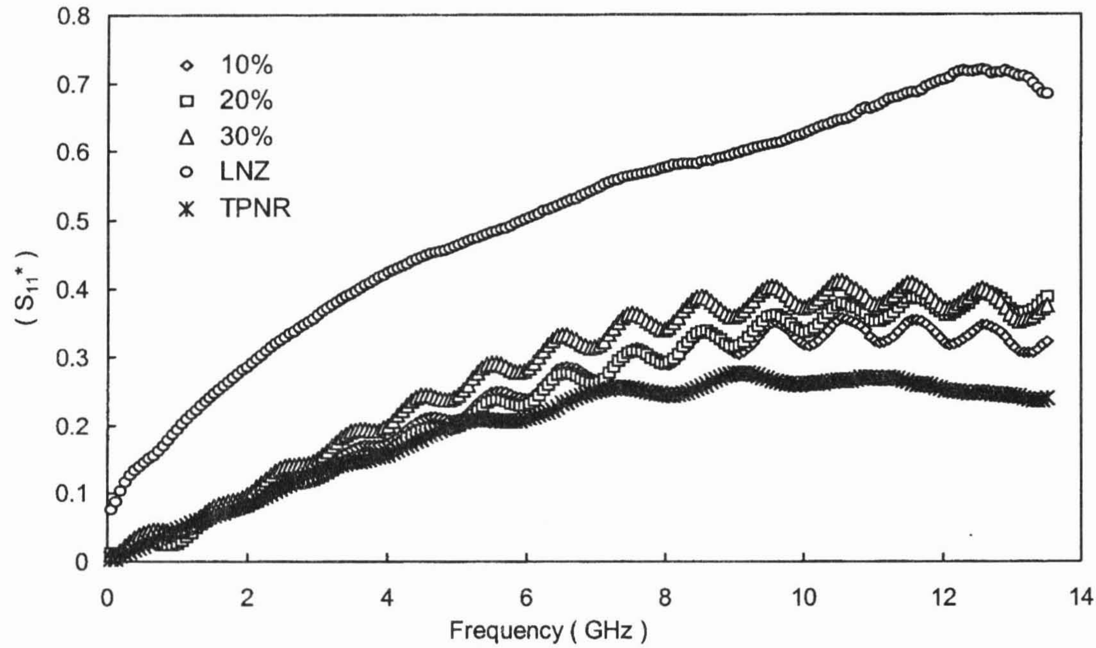

Figure 1 Reflection coefficient (S_{11}*) as a function of frequency.

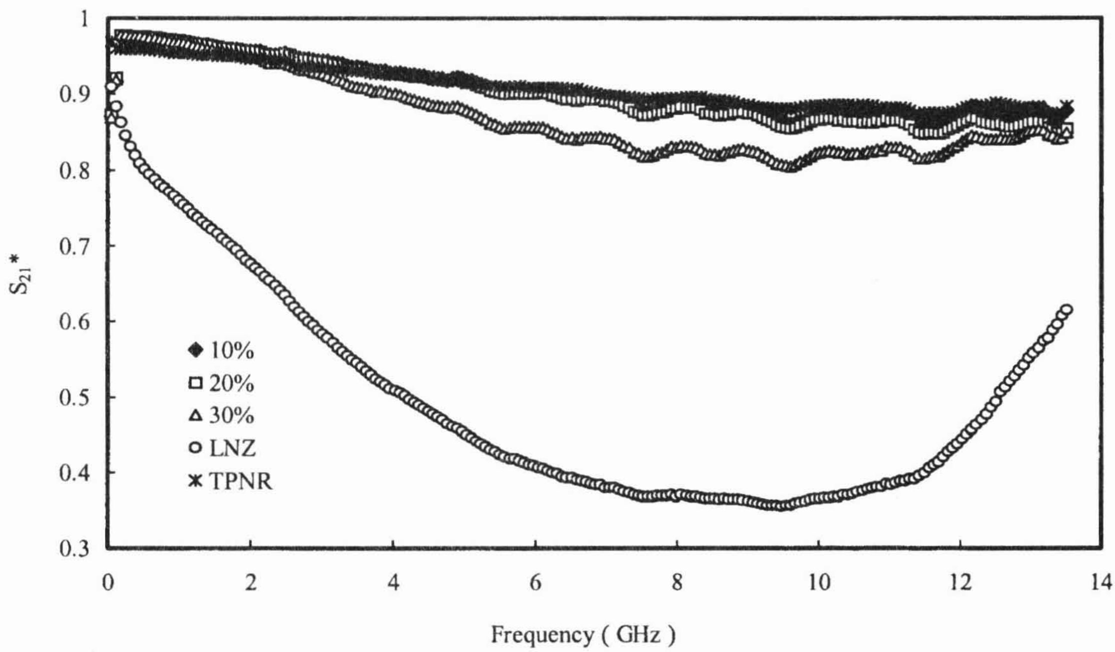

Figure 2 Transmission coefficient S_{21}* as a function of frequency

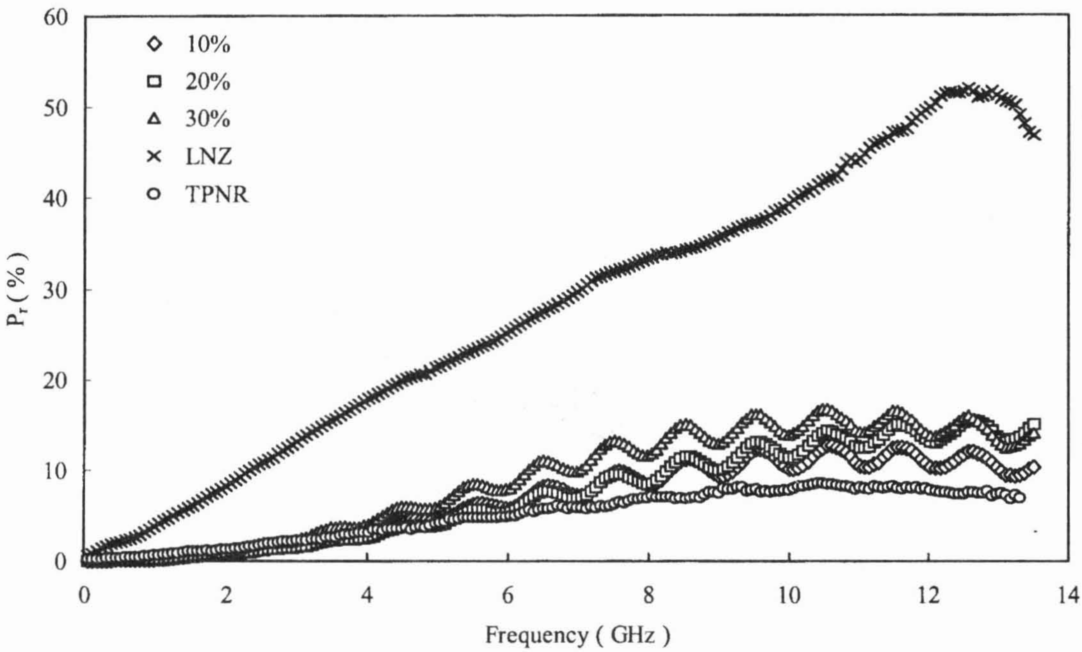

Figure 3 Power reflection (P_r) as a function of frequency.

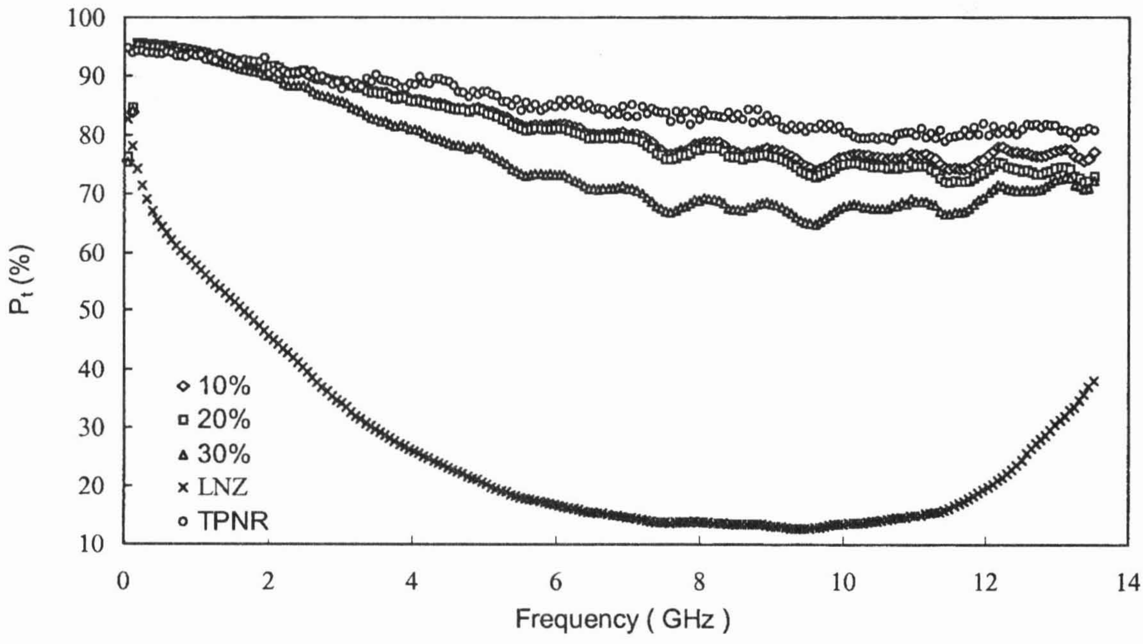

Figure 4 Power transmission (P_t) as a function of frequency

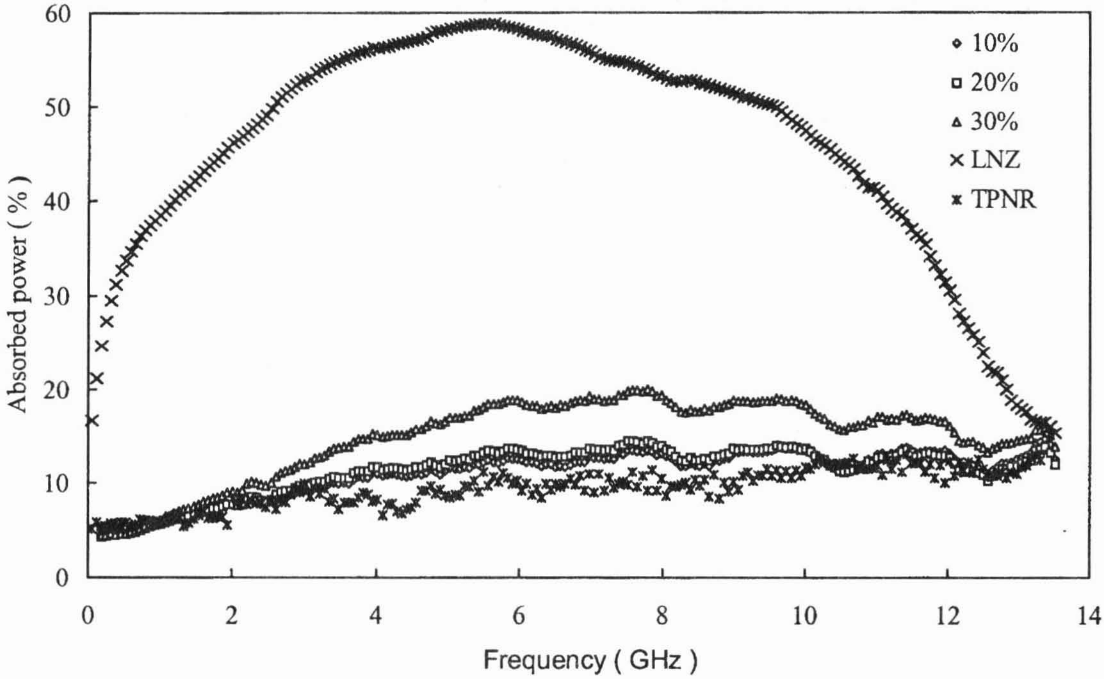

Figure 5 Power absorption (P_a) as a function of frequency