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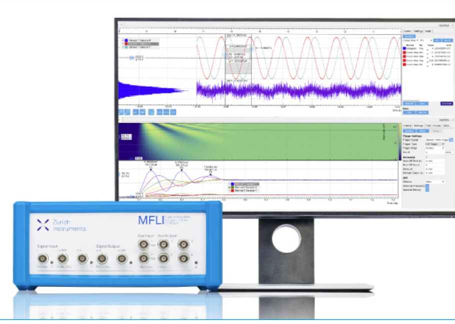

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Microwave Absorption Properties of Flexible Zinc Oxide Sheet

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Abstract. This paper presents the fabrication and microwave absorption properties of low-cost flexible light-weight zinc oxide (ZnO) sheet. The elastomers, films and foams used as microwave absorbers are made of lossy materials impregnated on low density matrixes which are thicker, heavier and expensive in wide frequency ranges. The prepared ZnO sheet in polytetrafluoroethylene (PTFE) matrix and isopropyl alcohol (IPA) as binder is characterized using XRD which showed the crystalline structure of ZnO in the sample. The microwave characterization is done using waveguide method by placing the sheet samples of different thickness (1 mm and 2 mm) perpendicular to the direction of propagation of power inside the rectangular wave-guides with operating frequency ranges of 5 - 7 GHz and 7 - 9 GHz connected to a Vector Network Analyzer (VNA). Transmission (S_{21}) and reflection (S_{11}) coefficients are analyzed in the above frequency ranges. The reflection coefficients show no remarkable variation throughout the measured frequency range whereas the transmission coefficients exhibit noticeable drop in the transmitted power around 5 - 15 dB at certain frequencies. As the thickness of the sample increases, the absorption level also increases. The absorption of microwave power is observed to be maximum at 8 - 9 GHz frequency range. Absorption properties of conducting ZnO sheet may find applications in the design of novel type of microwave absorbers.

INTRODUCTION

Research and development of microwave absorbers are of great importance in various electromagnetic gadgets and applications which may have immense industrial and technological prospects. The relevance and the importance of these absorbers have renewed the interest in the selection and fabrication of materials for the realization of these frequency selective surfaces of high quality. The health related hazards associated with the tremendous increase of electromagnetic (EM) machineries in various ISM (industrial, scientific, and medical) applications have led to a greater demands of advanced technologies. So high quality microwave absorbers with advances in device processing methods can address the above issues related to state-of-the-art microwave technology.

The conductivity and electric/magnetic losses owing to the hysteresis nature of the absorbing material is mainly used to characterize the quality of microwave absorbers. Proper tailoring of electromagnetic parameters like permittivity (ε) and permeability (μ) can fuel and fan the boundary mismatch, which is a major concern in connection with any type of microwave absorber [1]. Carbonyl ions, ferrites and conductive polymers are now-a-days used as reliable absorbent materials for sheet type microwave absorbers [2, 3, 4, 5, 6, 7]. The use of agricultural wastes and rice husk in pyramidal and sheet forms respectively had also been proposed by researchers, but they are rigid and require complicated synthesis process [8, 9].

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Recently scientific community has considered zinc oxide (ZnO) as a ‘future material’ with potential applications in piezoelectric transducers, varistors, phosphors and transparent conducting films [10]. ZnO also affords superior radiation hardness enhancing the usefulness of this material for space applications [11, 12].

In this paper we present a self-standing, lightweight and flexible zinc oxide based microwave absorber for the first time in the form of a thin sheet. It shows enhanced microwave absorption properties in the specific frequency regions. This sheet is prepared from zinc oxide by embedding it in polytetrafluoroethylene (PTFE) matrix with isopropyl alcohol (IPA) binder. The sheet is characterized using XRD which revealed the crystalline nature of ZnO in the sample. The microwave characterization is done using waveguide method [13] by placing the sheet samples of different thickness (1 mm and 2 mm) parallel to the plane of electric field vector inside rectangular waveguides which is excited with a TE_{10} with operating frequency ranges of 5 - 7 GHz and 7 - 9 GHz connected to a Vector Network Analyzer (VNA). ZnO, which is a transparent conducting oxide, are ideal for situations requiring high degree of microwave absorption levels with added advantages of frequency selective properties.

EXPERIMENTAL

In order to prepare ZnO based microwave absorber sheet, this transparent conducting oxide powder is used as filler in polytetrafluoroethylene (PTFE) matrix [2]. The light weight PTFE adhesive is chosen as matrix to provide flexibility. The ZnO powder (in gm) and de-mineralized water (in ml) is mixed in an ultrasonicator in the ratio of 1:10. PTFE (7 wt. %) in aqueous solution is added to the above mixture which is magnetically stirred for around one hour and is then filtered. The air dried filtrate is then ground to fine powder with help of a mortar. Using a few drops of IPA, the filtrate is made into dough which is then rolled to form ZnO sheets [2]. Two such sheets of thicknesses 1 mm and 2 mm are prepared by the above procedure. Figure 1 shows the photograph of flexible ZnO sheet of thickness 2 mm.

FIGURE 1. Photograph of flexible zinc oxide sheet of thickness 2 mm.

MEASUREMENT TECHNIQUES

The microwave absorption characteristics of the ZnO sheet are analyzed at room temperature by evaluating the transmission and reflection coefficients which are obtained by waveguide method. By calibration the absorption power level is normalized to 0 dB before taking measurements. Here ZnO sheet of thickness 1 mm and 2 mm are

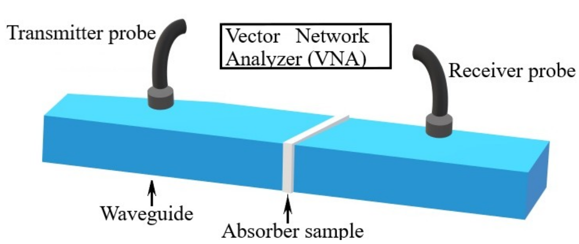

FIGURE 2. Schematic diagram of experimental set up, for the measurement of transmission and reflection coefficients, using waveguide method showing the ZnO sheet specimen.

used. In both cases, the sample is placed inside the waveguide covering the entire cross section with the plane of sheet perpendicular to the direction of propagation. The transmission (S_{21}) and reflection (S_{11}) coefficients of the samples are taken from 5 - 9 GHz frequencies using suitable waveguide to coaxial adapters connected to a Vector Network Analyzer (VNA). Figure 2 represents a schematic diagram of the experimental set up with the absorber sheet sample. Crystalline nature of the ZnO sheet sample is analyzed using XRD equipped with CuK_{α} ($\lambda = 1.54\ A^0$).

RESULTS AND DISCUSSIONS

The crystalline nature of ZnO powder is already established [14]. After the insertion of ZnO in PTFE matrix the XRD is taken and Fig. 3 shows the spectra of the sample. The ZnO sheet maintains the crystalline structure showing the peaks as in ZnO powder. All the distinct peaks observed for ZnO sheet matches with that of ZnO powder (JCPDS #043-0002) except the one at an angle around 18^0 corresponds to PTFE (JCPDS #47-2217) [15, 16].

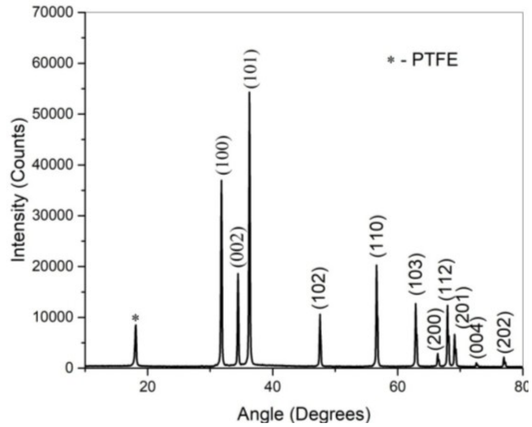

FIGURE 3. X-ray diffraction pattern of zinc oxide sheet with peaks indexed.

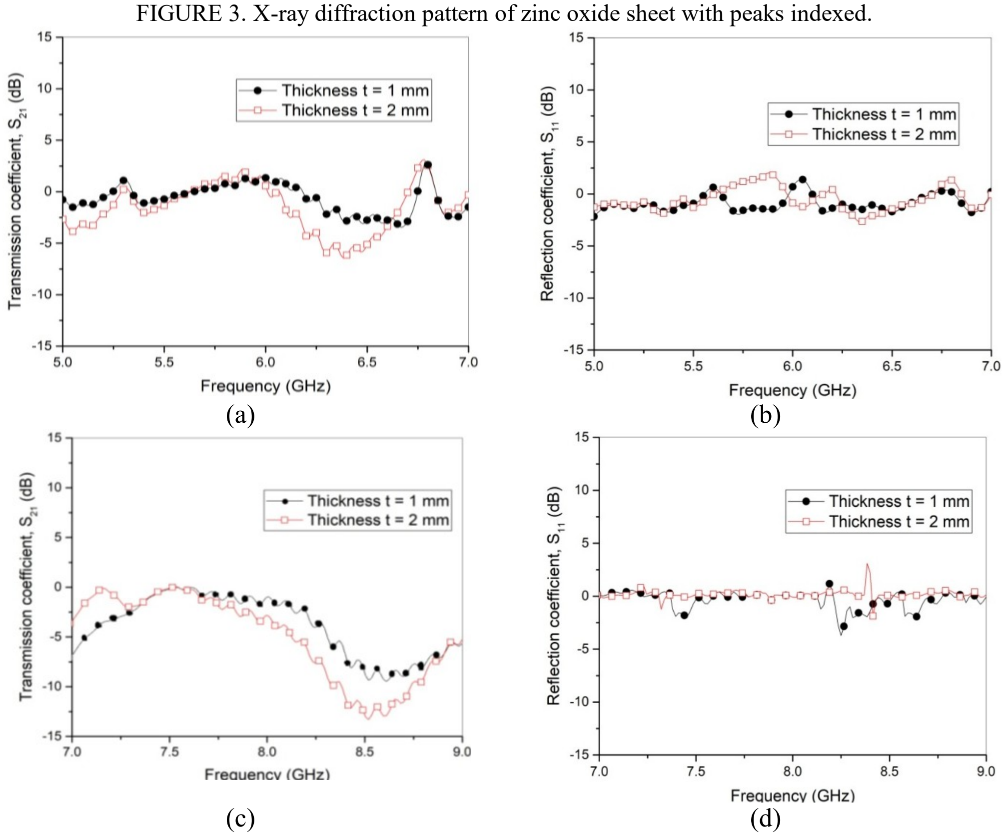

FIGURE 4. Transmission (S_{21}) and reflection coefficients (S_{11}) of ZnO sheets of different thickness at different frequency ranges[(a) & (b) in 5 - 7 GHz and (b) & (d) in 7 – 9 GHz].

CONCLUSION

The proposed zinc oxide (ZnO) sheet is thin, flexible and lightweight which has excellent microwave absorption characteristics. The frequency selective absorption properties of this sheet find applications in band stop filters and for other EMI (electromagnetic interference) applications. The low and high temperature electrical stability of ZnO extend its potentiality to use in any climatic conditions. This suggests that ZnO is an ideal candidate which can be used as an efficient microwave absorbing material.

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