The design and experimental verification of broadband absorbing structure combined by Al_2O_{3f}/Al_2O_3 compositesand metamaterials

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Abstract-With the aim to design a particular electromagnetic (EM) wave absorbing structure for broadband frequency used at high temperature, a multi-layerstructurewas proposed by combing the dielectric materials and square patch metamaterial. The absorbing structure was fabricated by precursor infiltration and pyrolysis technique and screen printing process. The computational and experimental results showed that amaximum reflection loss could be lower than −7dB at 2-18GHz with a total thickness of 9mm. This effective enhancement on EM wave absorption property was believed to be a consequence of multi-layerand resonance effect induced by combining the traditional EM absorbing materials with metamaterial structure.

Key Words—Electromagnetic wave absorption properties; Ceramic matrix composites; Computation.

Ⅰ. INTRODUCTION

In the past decades, electromagnetic (EM) wave absorbing materials have attracted considerable attentions in the frequency of GHz owing to their commercial and defense applications [1-2]. Dielectric loss material was the only choice for EM wave absorbing materialsat severe environments, especially for high temperatures, because the magnetic loss material would suffer EM absorption deterioration when the usage temperature exceeded their Curie points [3]. Ceramic matrix composites (CMCs) are good candidates because of their excellent high temperature stability and oxidation resistance. By now, most of researches on dielectric CMCs focus on the frequency range of X-band and Ku-band because of their poor EM wave absorption properties of dielectric loss in C-band and S-band [4-5].

Recent years, metamaterials have attracted much attentions due to their abnormal EM properties. The effective permittivity and effective permeability of metamaterials can be manipulated by designing on sub-wavelength in periodic patterns [6-7]. Meanwhile, metamaterials with high temperature resistance could be fabricated by now. Thus, combining traditional dielectric materials with metamaterials could be an effective method to further improve the EM wave absorption properties for high temperature application and broadband frequency.In this paper, a multi-layer structure was designed to obtain well EM wave absorption properties for high temperature applications with strong absorption at both high and low frequencies.

Ⅱ. DESIGN AND COMPUTATION

The Al_2O_3 fiber reinforced Al_2O_3 composite (Al_2O_{3f}/Al_2O_3) with low dielectric properties had higher temperature resistance than SiO_{2f}/SiO_2. Then, Al_2O_{3f}/Al_2O_3 fabricated via precursor infiltration and pyrolysis technique (PIP) was a good choice for traditional dielectric materials used at severe environment.The metamaterial structure was designed to further improve its absorption properties and guarantee its absorbing capacity stability at high temperatures.A square patch metamaterial was chosen in this study, and numerical simulations were carried out using the standard Frequency Domain Solver method in the CST Microwave Studio software. According to the design principle for two layer square patch metamaterial, the geometry parameters of designed absorbing structure are chosen as: the total thickness was 9.0mm, the dimensions and sheet resistivity of upper square patch metamaterial was 14.8mm and 90Ω/□, the dimensions and sheet resistivity of bottom square patch metamaterial was 19.1mm and 61Ω/□, the thicknesses of the three layer dielectric materials from the top to bottom were 1.88mm, 4.08mm and 3.04mm, the dimensions periodic structures was 20.6mm, as shown in Fig.1.

To conduct the simulation, a waveguide port was set to generate electromagnetic wave perpendicularly to the sample plane, and the S11 (reflectivity) could be calculated by the corresponding ratio of energy. The influence of frequency on

S11 curve of the above absorbing structure was shown in Fig.2. There were three absorbing peaks and the maximum of S11 was lower than -7dB. Then, the absorbing structure based on two layer square patch metamaterial could realize excellent absorbing properties with broadband frequency range of 2-18GHz. The reasons for the enhanced EM wave absorption properties could be ascribed to the following two parts: (1) EM wave loss and destructive interference induced by the dielectric material itself; (2) improved resonance loss induced by the square patch metamaterial.

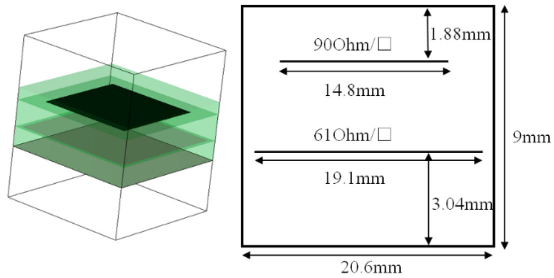

Fig. 1 The structure diagram of multi-layer absorbing structure

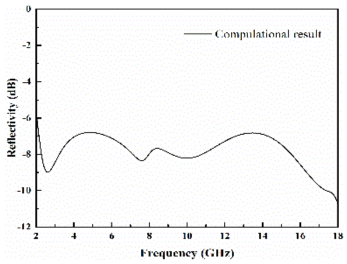

Fig. 2 The S11 curve of the designed multi-layer absorbing structure

III. EXPERIMENTAL VERIFICATION

In order to confirm the accuracy of simulation calculation, the above absorbing structure was fabricated by PIP and screen printing process, as shown in the insert picture of Fig. 3. The preparation process was as follows: (1) prepare the dielectric Al_2O_{3f}/Al_2O_3composite with lower density, (2) prepare the two layer metamaterials on the two faces of the interlayer of Al_2O_{3f}/Al_2O_3, (3) densify the absorbing structure via PIP. The reflectivity of the proposed absorbing structure was measured by compact range facility equipped with the VNA in frequency range of 2~18 GHz.

The comparison of reflectivity between the computational and experimental results was shown in Fig. 3. The computational and experimental results showed the same trend of variability and the positions of the absorbing peaks were very close. Also, the difference value between them was lower than 1 dB. It could be concluded that the computational and experimental absorbing properties had very good consistency, which meant the computation could guide the design of wide-band EM wave absorbing structure.

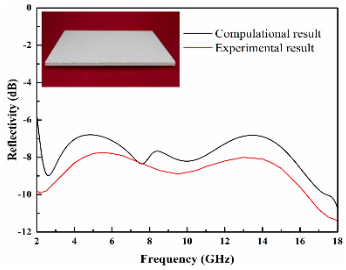

Fig. 3 The comparison of reflectivity between the computational and experimental results

Ⅳ.CONCLUSION

This paper designed a kind of EM wave absorbing structure based on two layer metamaterials. The computational and experimental results matched each other very well and the reflectivity was lower than -7dB under the range from 2GHz to 18GHz. The metamaterials provided an effective solution to EM wave absorption propertiesfor high temperature applications withthe broadband frequencyrange of 2-18GHz.

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