A Vacuum Window Based on Metamaterial

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Abstract: *This paper presented a vacuum window based on metamaterial. The vacuum window is designed for 94.95 GHz and the dielectric is sapphire piece with thickness of 0.4mm. In the cold-test simulation, the Voltage Standing Wave Ratio (VSWR) is 1.0029 at 94.95GHz and it achieves a 3 GHz bandwidth with VSWR below 1.2.*

Keywords: Vacuum window, metamaterial

Introduction

Output window, which acts as a barrier between the vacuum and external environment, is a critical component of vacuum electron devices (VEDs).[1-3] It should withstand high RF power, mechanical thermal stresses, and be vacuum leak tight as well as lossless to RF transmission.[4] Owing to the good performance in terms of wide bandwidth, high power capacity, and easier realization for brazing, pill-box window system is popular for window designers.[5] However, with the operation frequency increases, the dielectric material of the window piece properties is very difficult to meet the requirement of vacuum windows because that the thickness of the window becomes too small.

Metamaterials (MMs), which exhibit interesting electrodynamic properties that are not found in naturally occurring materials, can be designed to conduct any effective permittivity or permeability.[6] Therefore, MMs may be utilized on the output window to get a thicker window at high frequency potentially.

In this paper, a thick pill-box window, which is composed of a 0.4mm sapphire plate with two structural copper plates separated by it, at 94.95GHz is proposed, and the cold-test simulation results of the window show it has potential application to be the vacuum window.

Design

The structure of the vacuum window with metamaterial is shown in Figure 1(a). The front view of this window structure is shown in figure 1(b), and the lateral view of it is shown in figure 1(c). The front view of metamaterial structure is shown in figure 1(d). Sapphire (ε=9.6, tanδ=0.0008) is selected to be the dielectric material of this window, and copper (σ=5.8e8 S/m) is selected to be the metal material. The structure parameters are a=2.54mm, b=1.27mm, R_cir=1.4199mm, R_die=1.55662mm, L_rec=3mm, L_cir=0.45mm, L_die=0.4mm, L_met=0.035mm, p=0.5mm, len=0.35mm, w=0.05mm.

Results

The VSWR of this window, compared with the same thickness without metal plates, is shown in Figure 2. It can be seen from Figure 2 that VSWR is 1.0029 at 94.95GHz, and between 93.42-96.33GHz, the VSWR<1.2. It can also be figured out that the VSWR of the window with two metal plates is much smaller than that without metamaterials, which demonstrates that MMs can be utilized on the output window to get a thicker window at high frequency.

Conclusion

The design of a window with MMs is proposed. The VSWR is obtained as 1.0029 at 94.95GHz, and the bandwidth of 2.79 GHz is achieved for VSWR<1.2.

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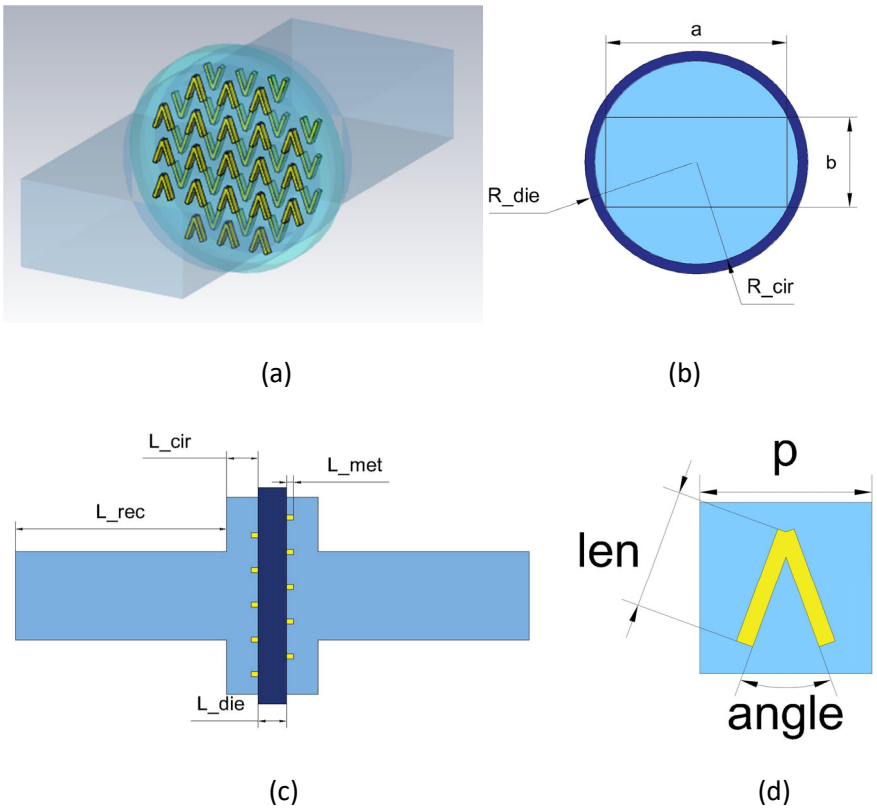

Figure 1 (a)structure of window with metamaterial (b)front view of this window structure (c)lateral view of this window (d)front view of metamaterial structure

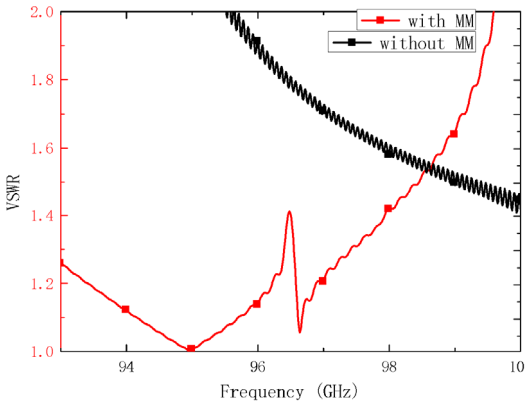

Figure 2 VSWR of window with(red) and without(black) MM