Electromagnetic Study of Ethylene Glycol and FC-75 for an RF Window

Presenter: Anshu Sharan Singh

Authors: Anshu Sharan Singh and S. V. Rao

Center of Research in Microwave Tubes, IIT BHU Varanasi, India

Outline

- Motivation
- Introduction
- Operating principle
- Design and Modelling
- RF propagation study
- Conclusion

Motivation

- From particle accelerators to fusion reactors, vacuum electron devices (VEDs) are needed, which generates watt to Gigawatt of RF power.
- Unlike the Solid-state devices (SSDs), highly relativistic electrons interaction with RF wave renders the vacuum electron devices (VEDs) as a promising RF source for high power generation [1].
- The vacuum for the beam-wave interaction is maintained by RF window as well as it ensures maximum RF output power propagation with minimum reflections[2].
- To support such a high power operation, a cooling mechanism is required for RF window of VEDs.

Introduction

- At desired frequency, high power operation of electromagnetically transparent (Min Reflection & Max Transmission) RF window is feasible through the cooling mechanism.
- For a RF window in High power operation, Surface coolant is the most effective cooling technique; therefore, the electromagnetic compatibility of coolant is needed to investigate.
- Dielectric properties of ethylene glycol in X-band are investigated by R. J. Sengwa in 2003 [3].
- In this paper, we have studied the RF propagation behavior of ethylene glycol to design a 10 GHz RF window, and compared the results with known RF window's coolant Fluoro-carbon 75.

Operating principle

(1).

- To achieve the zero reflectivity, the RF window is designed through the following expression

$$d = n\,\lambda/2\,(\sqrt{\varepsilon_r})$$

Where d is the thickness of window, λ is the wavelength, n is the integer multiple and ε_r is permittivity of dielectric disc.

Figure 1 shows that reflectivity of RF window is function of function of frequency and integer multiple for a thickness and a dielectric constant of RF window.

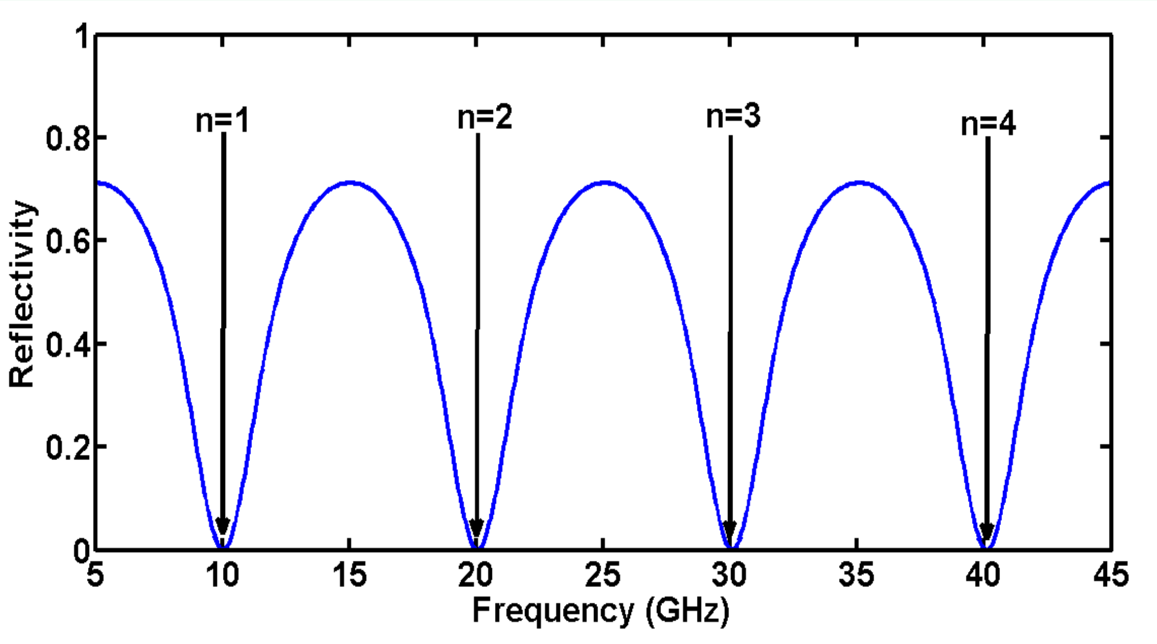


Figure 1. RF Window's Reflectivity variation over the frequency

Design and modelling

- The material and thickness of the disc are chosen to provide zero reflectivity at the desired frequency. The coolants primarily applied for face (surface) cooling of the RF window as well as it should possess zero reflectivity.

- Two coolants FC-75 and Ethylene glycol is used between the dielectric discs of AlN and Quartz, respectively, with a common design goal to achieve the zero reflectivity at 10 GHz.

- CST microwave studio is chosen as Electromagnetic simulation tool.

    - Design parameter and CST model of both RF window is shown in Figure in upcoming slides.

Design Parameters

TABLE 1 Theoretical Design Parameters of 10 GHz RF Window with Coolants

Parameters	Values
RF window with Ethylene Glycol	
The thickness of Quartz discs	3.35 mm
the dielectric constant of Quartz	3.8
The thickness of Ethylene Glycol	0.9 mm
The dielectric constant of Ethylene Glycol	7
The Loss tangent of Ethylene Glycol	0.8
RF window with FC-75	
The thickness of Alumina Nitride discs	5 mm
the dielectric constant of Aluminum nitride	9.05
The thickness of FC-75	6 mm
The dielectric constant of FC-75	1.85
The Loss tangent of FC-75	0.01

Model

Coolants are introduced between two dielectric discs, and this middle coolant region is shown by using the Cyan colour.

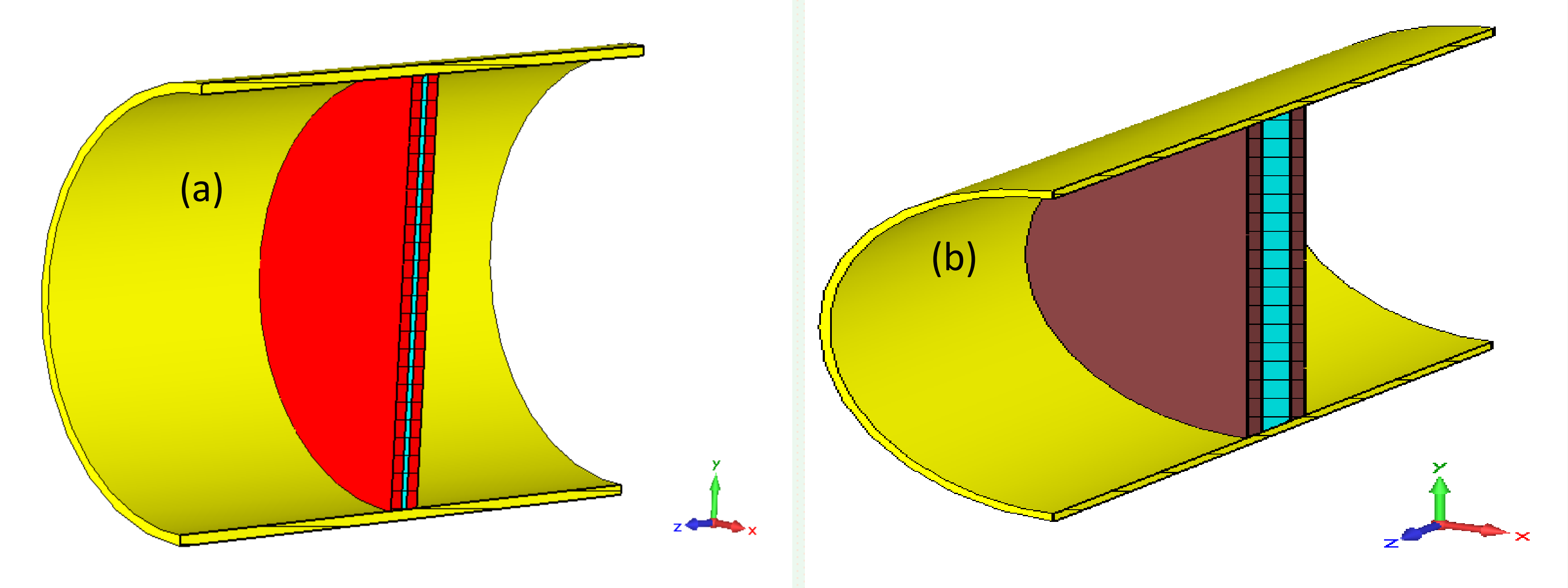
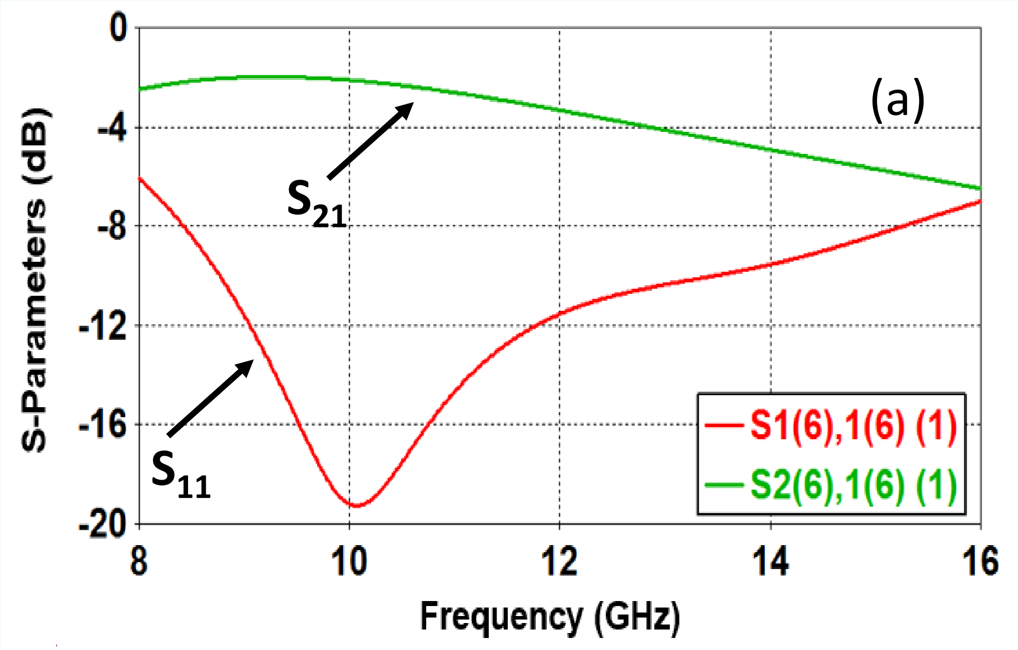


Figure 2. CST model of Double Disc (a) Quartz RF window with EG and (b) aluminum nitride with FC-75

RF propagation study

S_{11} of Quartz window with EG is -19 dB which confirms the negligible reflectivity however its S_{21} is near to -2.5 dB.

AlN RF window with FC-75 possesses S_{11} of -30 dB, and S_{21} of is near to -0.05 dB.



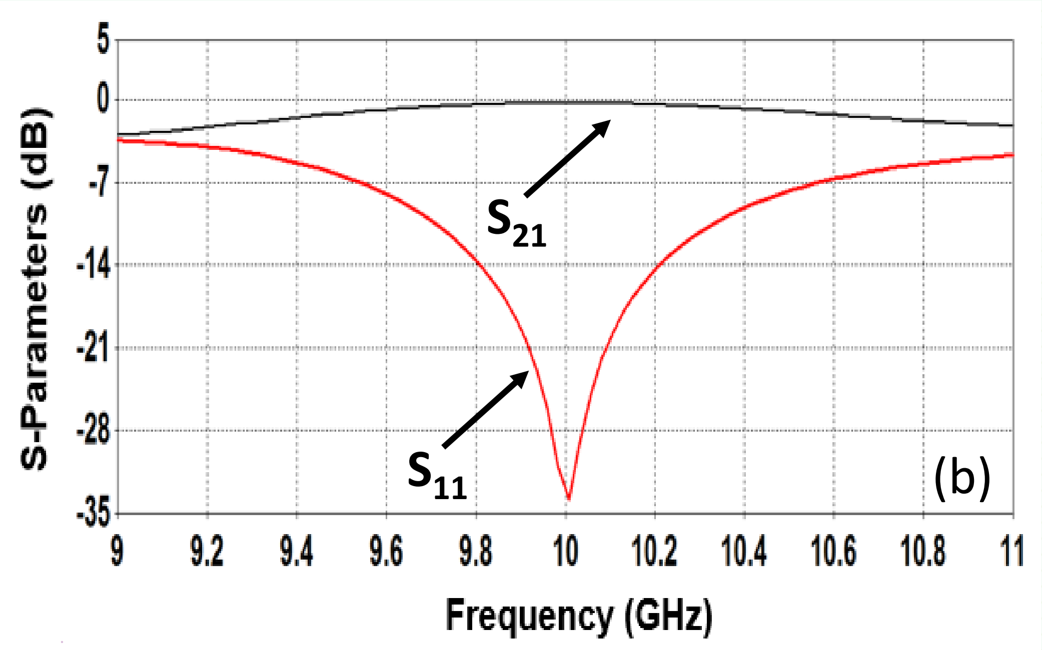


Figure 3. S-parameter of (a) EG in double disc Quartz RF window (b) FC-75 in double disc AlN RF window.

RF propagation study

Despite the thin layer of Ethylene glycol, the electric field propagation shows the absorption of RF power as the electric field intensity decreases after the propagating through the RF window.

However, the electric field intensity for the FC-75 window is uniform which confirms minimal absorption.

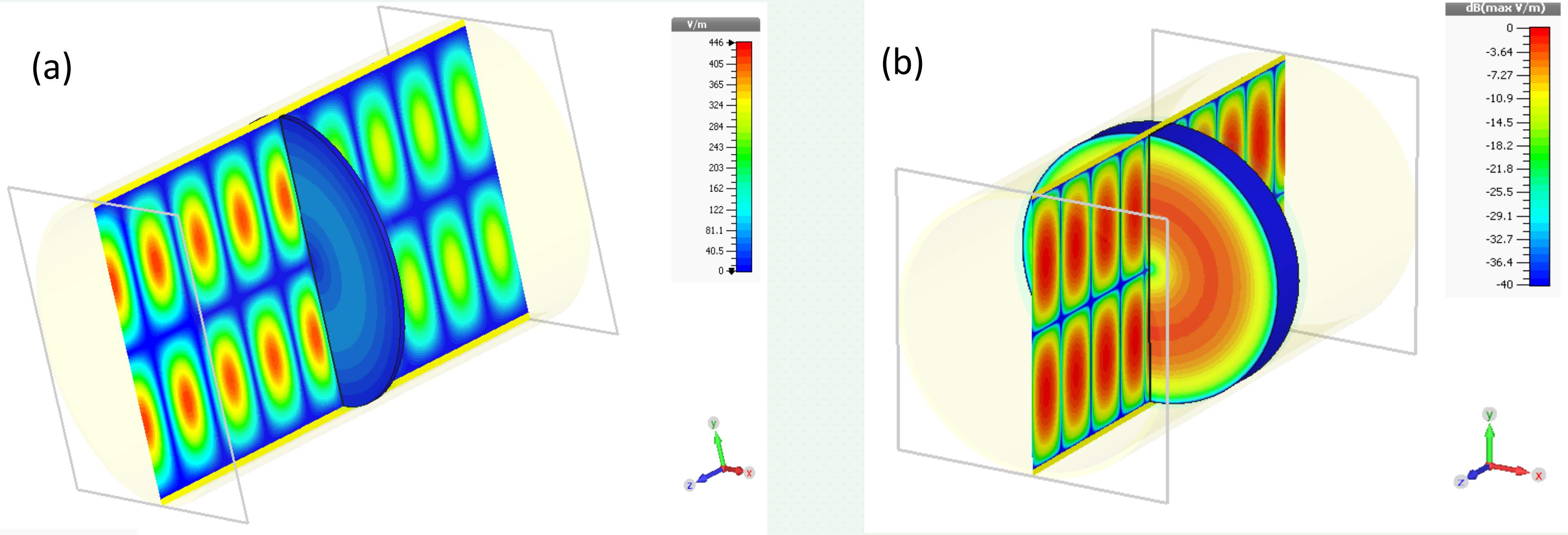


Figure 4. RF wave propagation and its Electric field absorption in (a) EG based double-disc Quartz RF window (b) FC-75 based double disc AlN Quartz RF window

Conclusion

- Obtained scattering parameters with their electric field confinements confirms that FC-75 has better RF propagation characteristics and Ethylene glycol shows absorptive nature.

- The authors would hope that present preliminary investigation on Ethylene glycol as face coolant for RF window will help to eliminate the toxic FC-75.

- Present paper is limited to Electromagnetic study, and Multiphysics study of coolants for RF window is ongoing.

Reference

[1] A. V. Gaponov-Grekhov and V. L. Granatstein, Eds., Applications of High-Power Microwaves. London, U.K.: Artech House, 1994.

[2] M. Thumm, "Development of output windows for high-power long-pulse gyrotrons and EC wave applications", *Int. J. Infrared Millim. Waves*, vol. **19**, pp. 3-14, 1998, DOI: 10.1023/A: 1022514528711.

[3] R.J. Sengwa, "A comparative dielectric study of ethylene glycol and propylene glycol at different temperatures,"*Journal of Molecular Liquids, 2003*, **108**, pp. 47-60, DOI: 10.1016/S0167-7322(03)00173-9.

Thank you for your interest

Your Comments and suggestions are welcomed

Feel Free to contact me for query
anshu.rs.ece14@iitbhu.ac.in
anshu.s.singh@ieee.org