Shielding Effectiveness Improvement Method of Optoelectronic Instrumental Windows Utilizing Transparent Mesh PET Film

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Abstract. In order to improve shielding effectiveness of optoelectronic instrumental windows, a filtering method is proposed using a transparent mesh PET film consisting of flexible PET film and conductive mesh film. And then an analysis model is built based on optical characteristic transfer-matrix theory of multi-layer optical films. Simulation and analysis indicate that shielding effectiveness can be improved by optimizing thickness of flexible PET films to make corresponding quarter-wavelength frequency move to low one in frequency-band of 10–20 GHz. Optimization results show that shielding effectiveness of optimized optoelectronic instrumental windows utilizing a transparent mesh PET film is higher than 16.8 dB by optimizing the thickness of a flexible PET film of 200 μm. So it can be concluded that the proposed filtering method utilizing a transparent mesh PET film can be used to improve shielding effectiveness of optoelectronic instrumental windows.

Keywords: Filtering method · Shielding effectiveness · Transparent mesh PET film · Optoelectronic instrumental window · Optimization

1 Introduction

With increasing electromagnetic interference and information leakage, optoelectronic instrumental windows require both high optical transparence and desired electromagnetic interference shielding against low-frequency (rf/microwave) interference [1–3]. Conductive metal mesh has been widely used as filters for microwave and optical signals and attracted much attention from the research community due to its capability of high transmitting optical signals and strong shielding against electromagnetic interference at the same time [4–6]. In order to obtain strong electromagnetic shielding, a filtering method for existing optoelectronic instrumental windows is presented using a transparent mesh PET (polyethylene terephthalate) film consisting of a flexible PET film and conductive metal mesh fabricated on PET film. And then a corresponding theoretical analysis model of the proposed high transparent multi-layer mesh films is built based on optical characteristic transfer-matrix theory of multi-layer optical film systems. Simulation and analysis indicate that the electromagnetic shielding effectiveness of optoelectronic measurement instrumental windows utilizing high

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transparent multi-layer mesh Films can be improved effectively by optimizing the thickness of the transparent flexible PET optical films to make the corresponding quarter-wavelength frequencies move to low ones in the frequency-band of 10–20 GHz. Optimization design results show that the electromagnetic shielding effectiveness of the optimized optoelectronic measurement instrumental windows utilizing high transparent multi-layer mesh films is higher than 16.8 dB by optimizing the thickness of the high transparent flexibel PET films of 200 μm in the frequency-band of 10–20 GHz. So it can be concluded that the proposed filtering method utilizing high transparent multi-layer mesh films can be used to effectively improve electromagnetic shielding effectiveness of optical windows of optoelectronic measurement instruments.

2 Filtering Method

Traditional filtering structure for optical window of electromagnetic shielding consists of a metallic mesh coating deposited on a quartz glass as shown in Fig. 1. The mesh optical window has an advantage of high optical transparency and strong electromagnetic shielding performance. But its electromagnetic shielding decreases as frequency increases. So it is necessary to design a filtering structure to improve electromagnetic shielding performance over interference microwave frequency band.

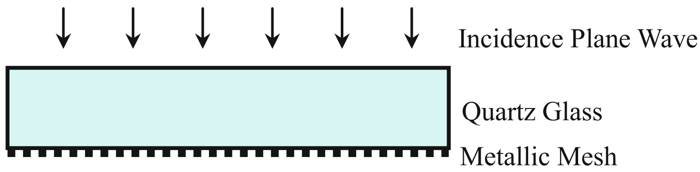

Fig. 1. Traditional filtering structure for optoelectronic instrumental window utilizing a metallic mesh on quartz glass.

In order to improve shielding effectiveness, a filtering method is proposed using a transparent mesh PET film covered on optoelectronic instrumental windows. As shown in Fig. 2, a transparent mesh PET film consists of a flexible PET film and conductive metal mesh fabricated on a PET film.

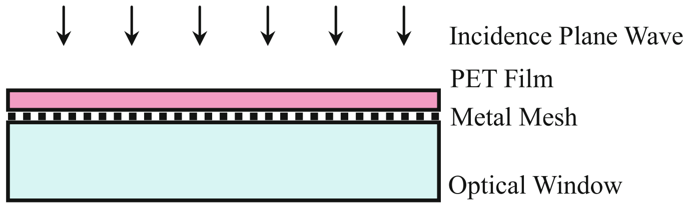

Fig. 2. Filtering structure for optoelectronic instrumental window utilizing a transparent mesh PET film.

3 Model and Optimization

The presented filtering structure of optoelectronic instrumental mesh PET windows is a three-layer film, and can be modeled based on transfer-matrix theory of multi-layer optical films [7–12]. An theoretical analysis model of the presented filtering structure of optoelectronic instrumental windows is built.

As shown in Fig. 3, metallic mesh coating consists of sub-millimeter sized period and micrometer size linewidth.

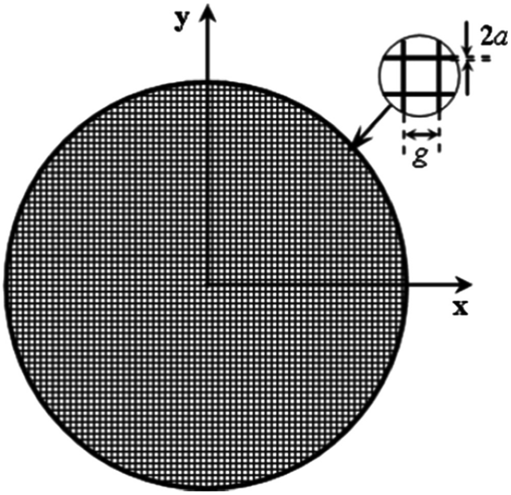

Fig. 3. Metallic mesh coating with sub-millimeter sized period and micrometer size linewidth.

As shown in Fig. 4, the presented filtering structure of optoelectronic instrumental windows is a three-layer film system, so it can be modeled based on optical characteristic transfer-matrix theory of multi-layer optical film systems.

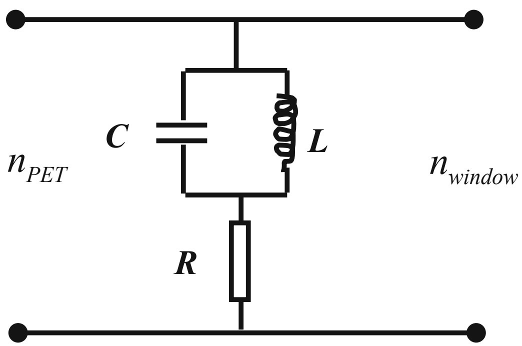

Fig. 4. Equivalent circuit model of transparent mesh PET optical window

Firstly, the transfer-matrix of conductive mesh is shown below:

$$M_{mesh} = \begin{bmatrix} A_m & B_m \\ C_m & D_m \end{bmatrix} = \begin{bmatrix} 1 & 0 \\ (R_m/Z_0 + jX_m/Z_0)^{-1} & 1 \end{bmatrix} \tag{1}$$

where *Rm* and *Xm* are the equivalent impedance and admittance of conductive mesh respectively. Z_0 is impedance of free space. Then the transfer-matrix of PET film and window substrate can be obtained based on optical film theory:

$$M_{PET(window)} = \begin{bmatrix} A & B \\ C & D \end{bmatrix} = \begin{bmatrix} \cos(2\pi nd/\lambda) & -\frac{i\sin(2\pi nd/\lambda)}{cn\varepsilon_o} \\ -icn\varepsilon_o \sin(2\pi nd/\lambda) & \cos(2\pi nd/\lambda) \end{bmatrix} \tag{2}$$

where ε_0 is dielectric constant of free space, c is light speed, λ is wavelength of incidence wave, n and d are refractive index and thickness of PET or window.

So the transfer-matrix of the presented three-layer film filtering structure of optoelectronic instrumental windows can be expressed:

$$M = M_{PET}M_{mesh}M_{window} = \begin{bmatrix} A & B \\ C & D \end{bmatrix} \tag{3}$$

The electromagnetic shielding effectiveness (SE) is given by:

$$SE(dB) = -20\log\left|\frac{A\eta_0 + B\eta_0^2 - C - D\eta_0}{A\eta_0 + B\eta_0^2 + C + D\eta_0}\right| \tag{4}$$

Shielding effectiveness of optoelectronic instrumental mesh PET film windows with different thickness of PET film is analyzed and shown in Fig. 5. The thickness of window substrate is 5 mm, mesh linewidth and period are 2 μm and 250 μm respectively.

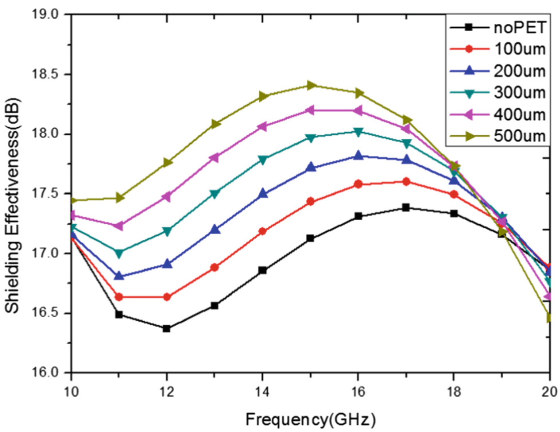

Fig. 5. Shielding effectiveness of optoelectronic instrumental mesh PET film windows.

It can be seen from Fig. 5 that simulation results indicate that shielding effectiveness of optoelectronic instrumental mesh PET film windows can be improved by optimizing the thickness of a transparent flexible PET film to make corresponding quarter-wavelength frequencies move to low ones in frequency-band of 10–20 GHz. Optimization results show that shielding effectiveness of the optimized mesh PET film window is higher than 16.8 dB by optimizing the thickness of a transparent flexible PET film of 200 μm.

4 Conclusion

A filtering method for existing optoelectronic instrumental window is presented using a transparent mesh PET film consisting of a flexible PET film and conductive metal mesh fabricated on PET film to obtain strong electromagnetic shielding. Theoretical analysis and optimization results show that shielding effectiveness of the optimized optoelectronic instrumental mesh PET film window is higher than 16.8 dB by optimizing the thickness of the flexible PET films of 200 μm. So it can be concluded that the proposed filtering method utilizing a transparent mesh PET film can be used to effectively improve shielding effectiveness of optoelectronic instrumental windows.

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