

# Fabrication and characterization of plasmonic band-stop filter using Ag grating

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**Abstract.** This study proposes a plasmonic band-stop filter with surface plasmon resonance in a double-layer wire grid structure targeting short-wavelength visible and near-ultraviolet regions for applications in ultraviolet photography. Using Ag and Al, the rigorous coupling wave of analysis method revealed that the maximum absorption was approximately 90% at 450 nm and 375 nm. The experiments using Ag produced similar results in a simulation. These results demonstrate that plasmonic band-stop filters in the visible and near-UV region can be realized at 450 nm and 375 nm using Ag or Al.

## 1 Introduction

Ultraviolet (UV) photography is used in various fields, including medicine, science, engineering, criminal investigation, and visual arts. The most popular method of photographing is to expose UV rays to an imaging film or device. The most convenient and simple UV light source is direct sunlight. However, the intensity of the UV rays is highly dependent on the atmospheric conditions. For example, in sunny and dry highlands, the UV intensity of sunlight is high. Electronic flashes are additional examples of UV light sources that can be used in everyday life. Surface reflection by an aluminum reflector can be used for more effective irradiation of UV rays by an electric flash.

In using non-monochromatic light for UV photography, it is necessary to prepare appropriate filters to transmit or stop transmitting a specific wavelength. To solve this problem, we propose a plasmonic filter using the propagating surface plasmon polariton in a wire grid (WG) structure. In a previous study, experiments demonstrated by designing the structure of the double-layer WG structure, the extraordinary transmission can be achieved at a specific incident angle and light wavelength [1, 2]. In addition, results of transmittance mapping indicate that transmission phenomena can be explained by the propagating surface plasmon polariton in the double-layer WG structure.

If the conditions of the structure for absorbing light can be determined, the WG structure can be used as a band-stop filter. In a previous study, Hu simulated extraordinary transmission by a nanohole array in the UV region [3]. In addition, Jaksic fabricated a band-pass filter for the UV region by surface-plasmon-polariton-assisted metal-dielectric multilayers [4]. Mazulquim fabricated a band-pass color filter enabled by resonant modes and plasmons near the Rayleigh anomaly [5]. Furthermore, Liang fabricated plasmonic structural color

thin films through the aluminum oxide process in an anodic aluminum oxide thin film [6].

In this study, we propose band-stop filters that stop transmitting light at 450 nm and 375 nm using extraordinary absorption by propagating surface plasmon resonance of the Ag double-layer WG structure.

## 2 Design and fabrication method

As illustrated in Fig. 1, the double-layer WG structures were designed and fabricated on a glass substrate. The light wavelength was 450 and 375 nm. The thickness of the Ag and Al layer and the electron beam (EB) resist are presented in Table 1. Reflectance mapping was obtained by the rigorous coupling wave of analysis method using MATLAB-based commercial software (rcda-1d [SourceForge, <http://rcwa-1d.sourceforge.net/>]) by arranging the calculation results of the transmittance with respect to the incident angle obtained for each period. The double-layer WG structure was fabricated using EB lithography (EBL) and direct current (DC) magnetron sputtering. It should be noted that the transmittance, reflectance, and absorption of p-polarized light depends on the incidence angle.

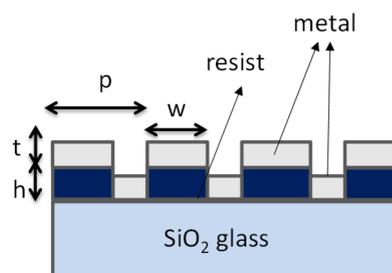


Fig. 1. Schematic drawing of double-layer wire grid structure.

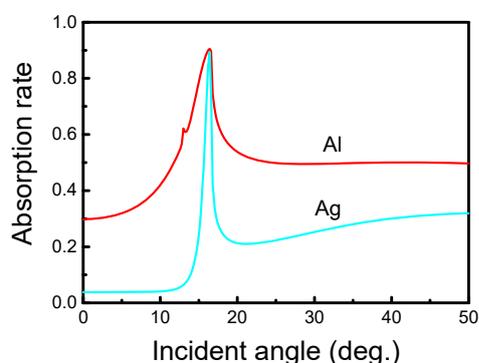
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**Table 1.** Parameter of wire grid structures.

Wavelength $\lambda$ (nm)	450		375	
Metal	Ag	Al	Ag	Al
Period $p$ (nm)	350	350	350	350
Width of resist $w$ (nm)	262.5	122.	182.0	287.0
duty ratio $w/p$	0.75	0.35	0.52	0.82
Thickness of resist $h$ (nm)	100	100	100	100

### 3 Results and discussion

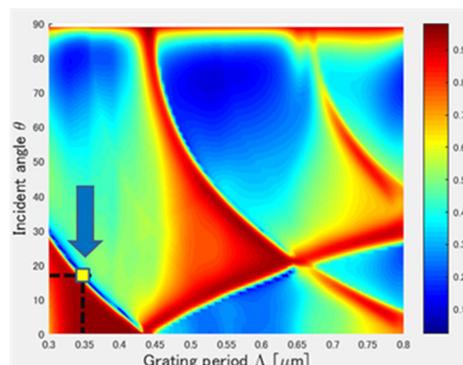
Fig. 2 presents the angle spectra of the absorption at 450 nm. The results demonstrate that the absorption peak occurred together with the reflectance dip at  $16.4^\circ$  and that the maximum absorption was 91.2%. In addition, in the experiment, a peak in the absorption rate was observed at the almost same angle. In the case of Al, the absorption peak occurred at almost the same angle. The structure using Ag was sharper; however, the average absorption was larger in the structure using Al. These results demonstrate a structure capable of absorbing light with a wavelength of 450 nm.



**Fig. 2.** Angle spectra of absorption rate at 450 nm.

To consider the peak of the absorptance, Fig. 3 presents the reflectance color mapping, in which the abscissa axis represents the structural period and the ordinate axis represents the incident angle. Here the two-layer Ag WG structure is used as an example. This figure reveals the dispersion relation, and the curve formed by the low reflectance corresponds to the excitation curve of the surface plasmon. The incident angle of  $16.4^\circ$  at which the absorption peak (reflectance dip) occurred in the structure using Ag (structure period 350 nm) is on the excitation curve. Therefore, the generated abnormal absorption phenomenon can be considered an effect of surface plasmons. This phenomenon was also confirmed in the structure using Al. The absorption characteristics at 375 nm were also simulated. At  $4.0^\circ$ , a sharp absorption peak was obtained using Al and Ag. In the experiment using Ag, the absorption peak at almost the

same angle was obtained. These results can be used to obtain plasmonic band-stop filters in the visible and near-UV region.



**Fig. 3.** Reflectance color mapping.

### 4 Conclusion

In this study, we fabricated plasmonic band-stop filters for visible and near-UV light using a WG structure. The results demonstrate that plasmonic band-stop filters in the visible and near-UV region can be realized at 450 nm and 375 nm using Ag or Al.

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