Optical Color Filter Based on Surface Plasmon Resonance Using Corrugated Metallic Thin Film for Image Sensor

Atsutaka Miyamichi[1], Atsushi Ono[2], Hiroki Kamehama[3], Keiichiro Kagawa[2], Keita Yasutomi[2], and Shoji Kawahito[2]
1 Graduate School of Integrated Science and Technology, Shizuoka University
3-5-1 Johoku, Hamamatsu, 432-8011 Japan
2 Research Institute of Electronics, Shizuoka University
3-5-1 Johoku, Hamamatsu, 432-8011 Japan
3 Graduate School of Science and Technology, Shizuoka University
3-5-1 Johoku, Hamamatsu, 432-8011 Japan
E-mail: ono.atsushi@shizuoka.ac.jp

Abstract The purpose of our study is the development of optical color filter having high color selectivity for image sensor. In order to achieve our purpose, we propose a new optical color filter of periodic corrugated metallic nano-structures based on surface plasmon resonance. By patterning the metal surface with a concentric periodic corrugation, light of the wavelength coupled with surface plasmons is transmitted as a beaming light through the sub-wavelength aperture. The beaming light transmission has an advantage to reduce the spatial color cross-talk in the conventional image sensor. We demonstrated the proposed corrugated metallic thin film filter had transmission color selectivity.

Keywords: color filter, surface plasmon resonance, metallic thin film

1. Introduction

Light transmission through a nano-hole array structure in an optically thick metal film based on surface plasmon resonance (SPR) has been studied as an optical color filter completely different from conventional organic color filters [1-6]. Plasmonic hole array filter has a high color selectivity, which is possible to control any wavelength depending on a structural parameters and type of metal.

The paper by Lezec at al. [7] demonstrated that a single aperture surrounded by a periodic corrugation in the metal surface transmits a selected wavelength as a beaming light. This beaming light transmission is expected to reduce the spacial color cross-talk between pixel by integrating onto an image sensor.

By focusing on the color selectivity and the beaming light transmission, we proposed the metallic thin film filter with periodic corrugation as a new optical color filter. In this work, we fabricated the silver thin film filter with periodic corrugation, and measured the transmitted spectrum and the transmitted light distribution.

2. Analysis of a transmission characteristics by 2D FDTD simulation

We analyzed transmission characteristics of two-dimensional periodic corrugated silver thin film by simulating the transmission spectrum. The transmission spectrum was simulated by finite-difference-time-domain (FDTD) algorithm. The model of the cross sectional view of the proposed silver thin film filter was shown in Fig. 1. The silver thin film is deposited with a constant thickness, and has subwavelength aperture at the center.

In simulation, the transmission spectrum dependence on the corrugation period, the film thickness, the groove depth, and the aperture diameter was investigated. Fig. 2 shows a transmission spectrum of the silver thin film filter which is optimized to operate at the color of red. The transmission efficiency of 28 % at the wavelength of 650 nm was obtained from the filter with the corrugation period of 500 nm, the film thickness of 180 nm, the groove depth of 80 nm, and the aperture diameter of 90 nm. The spectrum width of a full-width at half-maximum (FWHM) was 100 nm. Fig. 3 shows the two-dimensional view of intensity distribution of transmitted light from sub-wavelength aperture. The light source of continuous wave at the wavelength of 650 nm is irradiated from the topside. In this figure we can see, the peak wavelength of 650 nm coupled by SPR is transmitted as a beaming light in the normal direction.

3. Fabrication and spectral measurement

According to the structural parameters optimized by FDTD simulation, we fabricated the silver thin film filter on a glass substrate by using electron beam lithography, vacuum evaporation, and focused ion beam. Fig. 4 shows the scanning

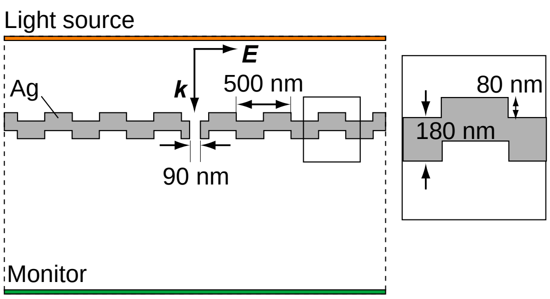

Fig. 1. Schematic view of two-dimensional periodic corrugated silver film.

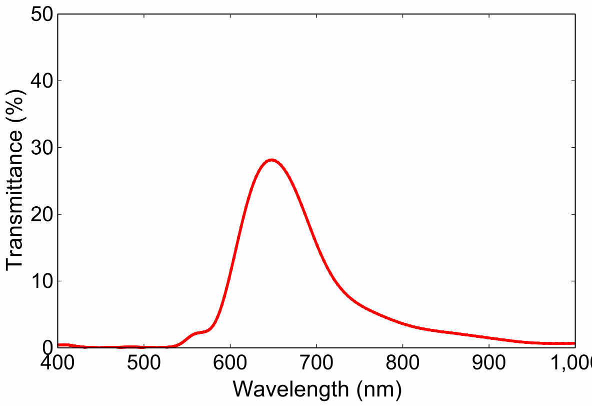

Fig. 2. The simulated transmission spectrum of two-dimensional periodic corrugated silver film.

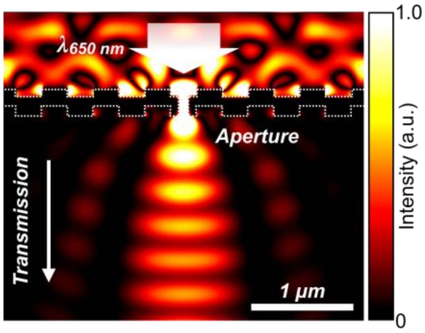

Fig. 3. The two-dimensional view of intensity distribution of transmitted light from sub-wavelength aperture.

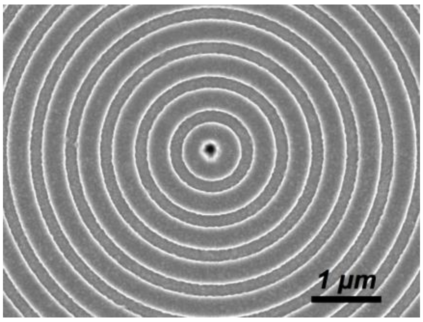

Fig. 4. SEM image of the center aperture of the fabricated silver thin film filter.

electron micrograph (SEM) image of the fabricated filter with the corrugation period of 500 nm, the film thickness of 185 nm, the groove depth of 100 nm, and the aperture diameter of 120 nm.

Transmitted spectrum was measured by illuminating the Xenon lamp at normal incidence. The transmitted spectrum of the fabricated filter to operate at the red is shown in Fig. 5. The transmission peak wavelength of 600 nm was observed in the measurement spectrum. The spectrum width of FWHM was 91 nm.

From the measured back illuminated microscope image, the transmitted light having a small emission spot was observed at the center aperture of the fabricated filter to operate at the red (Fig. 6).

4. Conclusion

We analyzed transmission characteristics of the silver thin film filter with periodic corrugation by FDTD simulation. According to results of the structural parameters optimization, we fabricated the silver thin film filter. The transmission peak wavelength of 600 nm was observed by transmission spectrum measurement from the fabricated filter with the corrugation period of 500 nm, the film thickness of 185 nm, the groove depth of 100 nm, and the aperture diameter of 120 nm. We demonstrated that the proposed silver thin film filter with periodic corrugation had transmission color selectivity.

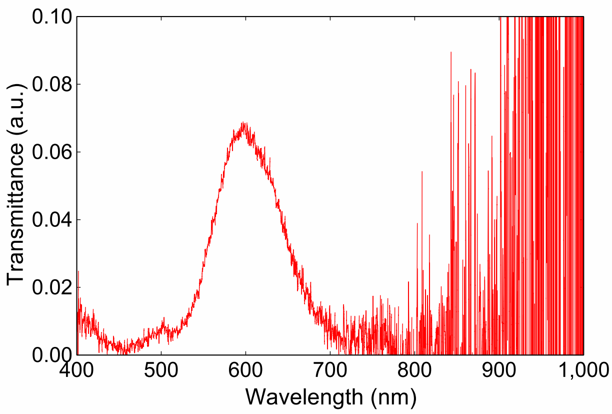

Fig. 5. The measured transmission spectrum of the fabricated silver thin film filter.

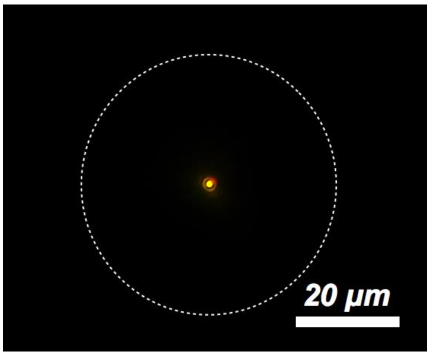

Fig. 6. The measured back illuminated microscope image of the fabricated silver thin film filter.

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