Plasmonic color filter for multispectral imaging from visible to near-infrared

Atsutaka Miyamichi¹, Atsushi Ono², Hiroki Kamehama¹, Keiichiro Kagawa², Keita Yasutomi², and Shoji Kawahito²

¹Graduate School of Science and Technology, Shizuoka University
²Research Institute of Electronics, Shizuoka University
Purpose

Development of multispectral imaging sensor from visible to near-infrared range.

Image sensor integrated with RGB-NIR plasmonic filters

Nanostructured metallic thin film
~ 200 nm

Plasmonic filters realize the multispectral imaging of visible and NIR light by integrating onto a single image sensor.
Our proposed plasmonic filter

Visible and NIR lights are filtered by our proposed plasmonic filters.

Conventional color filter

Filtering of visible and NIR lights is difficult due to external IR cut filter.
**Imaging application: NIR information + RGB information**

- **Range measurement imaging** using NIR LED as light source.

- **Biological imaging** for hemoglobin (HbO₂) concentration.

**Range image + Color image**

- Range image
- Distance (m)

**Color image + Tissue image**

- Color image
- Absorption spectra
- Extinction coef.
- Wavelength (nm)

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Simultaneous imaging provides **reduction of conventional system size** and **improvement of image recognition**.
Our proposed plasmonic color filter

We demonstrate plasmonic color filtering from visible to near-infrared range.
Color filtering principle by surface plasmon resonance

Transmission color selectivity is tuned by changing the corrugation period.

Analysis of transmission characteristics by using FDTD algorithm

Period $p$ (nm):

Depth $d$ (nm):

Transmittance (%)

Transmittance (%)

Wavelength (nm)

Wavelength (nm)
Summary of the simulation results

Filtering property:
- Transmittance of ~28%
- FWHM of ~100 nm

- **Blue**: 200, 30, 60, 60
- **Green**: 400, 60, 140, 80
- **Red**: 500, 80, 180, 90
- **NIR**: 600, 100, 220, 110 (nm)

![Graph showing transmittance vs wavelength (nm)]
Summary of the simulation results

Filtering property:
- Transmittance of ~28%
- FWHM of ~100 nm

Transmitted light distribution at peak wavelength $\lambda_{\text{peak}}$ was calculated.

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<tr>
<td>Blue</td>
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<td>Green</td>
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<td>Red</td>
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</table>
| NIR    | 600  | 100  | 220  | 110  | (nm)
Transmission distribution for peak wavelength

Continuous wave

\[ \lambda_{\text{peak}} = 650 \text{ nm} \]

Ag film

Transmission light distribution

\[ |E_x|^2 \quad \text{Plasmon coupling} \]
\[ |E_z|^2 \]

Beaming transmission at peak wavelength of 650 nm.

Coupling between incident light and surface plasmon.
Corrugation vs. Flat bottom surface

Periodical grooves in bottom-side transmits $\lambda_{\text{peak}}$ as a beaming light.

Bottom-side grooves are appropriated to improvement of transmittance and color cross-talk.
Fabrication process

**EB exposure**
EB resist (~90 nm)
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Glass

**Development**
Grooves

**Vacuum Evaporation**
- Metal corrugation
  - Ag film (~180 nm)

**FIB drilling**
- Aperture (~100 nm)

Nanostructured corrugations are easily fabricated on both sides of a single metal film along the resist pattern.

Bird-view SEM image

Period $p = 600$ nm

Corrugation edges were observed.
The plasmonic color filters were fabricated with period of 300 nm to 700 nm with 100 nm steps.

Transmitted light distribution of fabricated plasmonic filter

Transmitted light of selected wavelength was observed at the central aperture.
Multi-band color filtering from visible to near-infrared

We demonstrated the multispectral transmission from visible to near-infrared range.

FWHM: ~100 nm
Groove number dependence for transmission spectrum

**Groove number**

Groove number dependence for transmission spectrum.
Multi-band color filtering by plasmonic array filters

Transmission image  Bright field image

Unit cell: Three grooves

Multi-band color transmission was observed in plasmonic array filter by increasing corrugation period.
Conclusions

- We analyzed transmission characteristics of plasmonic color filter with periodic corrugation leading to peak transmission of ~28 % by FDTD simulation.
  - The central wavelength of the filter is tunable by changing corrugation period and groove depth.

- We demonstrated the multi-band color filtering from visible to near-infrared range by our proposed corrugated metallic thin film.
  - Transmission spectral band with FWHM of ~100 nm was obtained in each plasmonic filter with a single aperture.