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NIR perfect absorbers with thermochromic VO_2 layer

VO_2 薄膜による近赤外完全吸収層の実現

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Recently, optical coatings that can control optical absorption at near-infrared (NIR) or infrared (IR) region have received much attention as a thermal radiator or high-reflection/absorption coatings for thermal radiation. If the optical absorption of such coatings is tunable, they can actively control the energy transfer through optical absorption and thermal radiation. So we focused our attention on the thermochromic VO_2. The optical constants of VO_2 drastically change depending on its temperature because of its metal-insulator transition at around 68 °C. Therefore, it is easy to control the optical properties of VO_2 thin film by ambient temperature. In this study, we present a VO_2 NIR perfect absorber of which optical absorption is switchable by its temperature.

We introduce $VO_2/SiO_2/Ag$ mirror optical cavity structure shown in Fig. 1, in order to realize the perfect optical absorption at NIR region. Since we assumed a thick Ag mirror layer, optical transmittance of the structure is negligibly small and its optical absorption A is evaluated as $A = 1 - R$, where the R is its reflectance. The thickness of each layer was determined by optical calculation. The dashed lines in Fig. 2 show the calculated optical reflection spectra of the multilayered structure with 40-nm-thick VO_2 and 100-nm-thick SiO_2 layers. At the wavelength of 900 nm, the optical reflectance calculated for 100 °C goes to zero, which indicates the achievement of the perfect absorption, whereas that for 30 °C is above 0.47.

In order to demonstrate the reflectance switching experimentally, we fabricated VO_2(40 nm)/SiO_2 (100 nm)/Ag(200 nm) multilayered thin films using vacuum evaporation and reactive dc sputtering. The layer of VO_2 was prepared by sputtering of V in an O_2/Ar atmosphere at a substrate temperature of 600 °C. The solid lines in Fig. 2 show measured optical reflectance spectra of the sample at 30 °C and 100 °C, which agree well with the calculated spectra depicted by dashed lines. At the wavelength of 900 nm, the sample optical reflectance measured at 100 °C goes to zero whereas that at 30 °C remains 0.52. These results suggest that the $VO_2/SiO_2/Ag$ structure can realize NIR perfect absorber whose optical absorption is tunable by temperature.

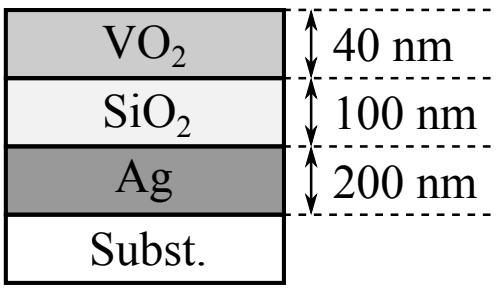

Figure 1: Schematic drawing of the sample structure.

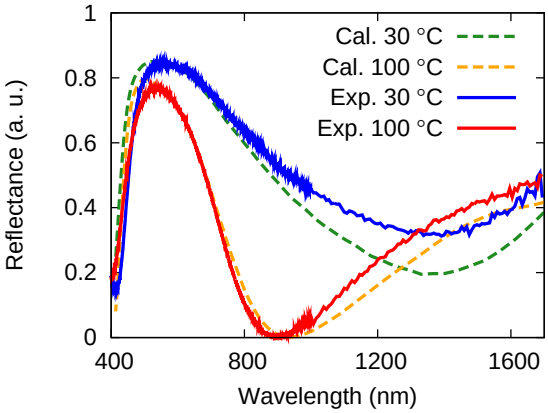

Figure 2: Reflectance spectra of the sample at 30 °C and 100 °C.