

課題番号 : F-16-HK-0047
利用形態 : 機器利用
利用課題名(日本語) :
Program Title (English) : Plasmon-induced solar energy conversion using coupling between cavity mode and localized surface plasmon resonance
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1. 概要(Summary)

Light harvesting is essential for the thin film solar cell, which is promising for the low-cost solar energy harvesting. However, the large mismatch between the photon absorption length scales (up to micrometers) and the short electronic carriers extraction distances (usually a few tens of nanometers) is a stern challenge for efficient solar energy conversion in the thin film solar cells. Here, we proposed to construct a novel Au-NIs/TiO₂/Au-film plasmonic structure, achieving light-matter coupling of the cavity mode in TiO₂ thin film and Au-NIs plasmon resonance, as an active photoelectrode for photoelectrochemical solar energy conversion.

2. 実験(Experimental)

【利用した主な装置】

原子層堆積装置 (Picosun SUN ALE-R)、ヘリコンスパッタリング装置(ULVAC MPS-4000C1/HC1)、高分解能電界放射型走査型電子顕微鏡 (JEOL JSM-6700FT), STEM/TEM (JEOL ARM 200F)

【実験方法】

A 130-nm Au film was sputtered on the surface of silica glass by Helicon sputter (ULVAC, MPS-4000C1/HC1). Titanium dioxide thin films were deposited onto Au film using a commercial hot-wall flow-type ALD reactor (SUNALE-R, Picosun). The surface morphology were observed by field-emission scanning electron microscopy (FE-SEM, JSM-6700FT, JEOL). Cross-section was analyzed with high resolution transmission electron microscopy (HR-TEM, JEOL ARM (200F) 200 kV FEG-STEM/TEM).

3. 結果と考察(Results and Discussion)

In this study, we constructed a novel plasmonic absorber, which is constituted from a sandwich structure of Au nanoislands (Au-NIs)/TiO₂/Au-film (as shown in Figure 1a), for plasmon-enhanced photocurrent generation. Au film was sputtered on a silica glass, then a TiO₂ thin film with a thickness of ~tens of nanometers was deposited on the Au film by an atomic layer deposition method, and finally a monolayer of Au-NIs with an average size around 12 nm was fabricated by annealing the 3-nm-thick Au thin film on it. By studying systematically, we clarified that the strong light absorption originates from the coupling of the cavity mode in TiO₂ thin film and the plasmon resonance of Au-NIs. The absorption, which was calculated by 1-T-R, showed a more than 90% light absorption at wavelength region of 550~650 nm (as shown in Figure 1b). Photocurrent measurements were performed by using a three electrode system with a saturated calomel electrode (SCE) as reference electrode, a Pt wire as counter electrode and 0.1 mol/dm³ KOH solution as an electrolyte solution. From the IPCE action spectrum measurement, we found that photocurrent was observed according to the 1-T-R spectrum which almost corresponds to 1-T-R spectrum of Au-NIs. Importantly, the IPCE value reached almost 0.8% which is larger than that reported before (~0.4%) because of the strong light absorption.^{1,2} Note that the 1-T-R spectrum was broadened and divided into two peaks according to inlaying Au-NIs partially in TiO₂ layer due to the

stronger coupling between plasmon and cavity modes, and the similar spectrum modulation can be also seen in the IPCE action spectrum, as shown in Figure 1b and 1c. These dual-band 1-T-R spectrum and the corresponding IPCE action spectrum observations indicate that hybrid states are formed due to the coupling between plasmon and cavity modes. The concept of strong light-matter coupling can be applied to the broadband solar energy harvesting as well as the photoelectric devices.

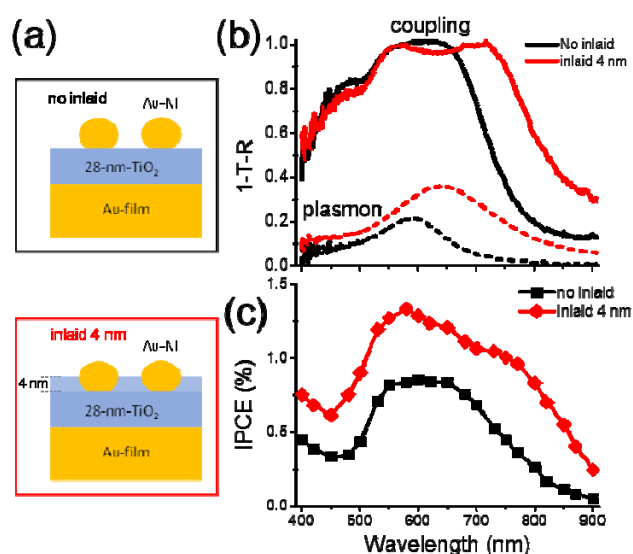


Figure 1. (a) Schematic of the Au-NIs/TiO₂/Au-film plasmonic structure with inlaid depth of Au-NIs of 0 and 4 nm. (b) The optical absorption spectra of the strong coupling induced dual-band absorption in Au-NIs/TiO₂/Au-film plasmonic structure with inlaid depth of Au-NIs of 0 and 4 nm, and (c) the corresponding IPCE action spectra.

4. その他・特記事項 (Others)

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5. 論文・学会発表 (Publication/Presentation)

なし

6. 関連特許 (Patent)

なし