Experimental Demonstration of Broadband Optical Tamm States in Photonic Crystal

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***Abstract*—We present the theoretical and experimental investigations of optical bound state at the interface of photonic crystal and metal film. The reflectance of the wide-gap photonic crystal can be suppressed by absorption in broadband spectral range.**

***Index Terms*—photonic crystal, Tamm state, plasmon-polariton, broadband absorber/**

I. Introduction

Optical Tamm states [1] are bound states in photonic ctystals (PhC) localized at the interface of the periodic structure. These states concentrate the light field near the surface of the PhC and can be observed by dips in the reflectance spectrum. The concentration of light can be used to enhance the nonlinear-optical effects and to increase the sensitivity of optics-based biosensors like surface-enhanced Raman substrates. The latter case needs the field enhancement in wide spectral range, as well as the broadband optical absorbers, photodetectors and light sources [2]. In this work we found the conditions leading to the excitation of Tamm plasmon-polariton (TPP) in broadband optical range.

II. Results

We consider the PhC as multilayer stack of alternating dielectric slabs of two refractive indexes covered with metal film at the top interface. The TPP is localized wave with zero projection of the wave vector in the plane of the sample. To fulfill the non-propagating phase condition of TPP excitation, phases acquiring in metal and PhC should be matched. The thicknesses of metal layer and first period of PhC were varied to match the phase condition. The optical spectra of multilayer structures were calculated by the transfer-matrix method.

According to calculations, various metals deposited on PhC lead to different phase shifts. The chromium layer with thickness of 6 nm can be used to excite the TPP in the spectral range of 660 to 760 nm (fig. 1). The reflectance coefficient at these conditions was as low as 10% and the photonic band gap is completely suppressed.

Experimental samples were produced by porous silicon technique [3] followed by sputter coating of metal films (Ag, Cr) with thickness of 2 to 50 nm. The measured reflectance spectra match theoretical calculations. We experimentally demonstrate the broadband TPP between Cr layer and PhC that can be excited at the whole region of photonic band gap.

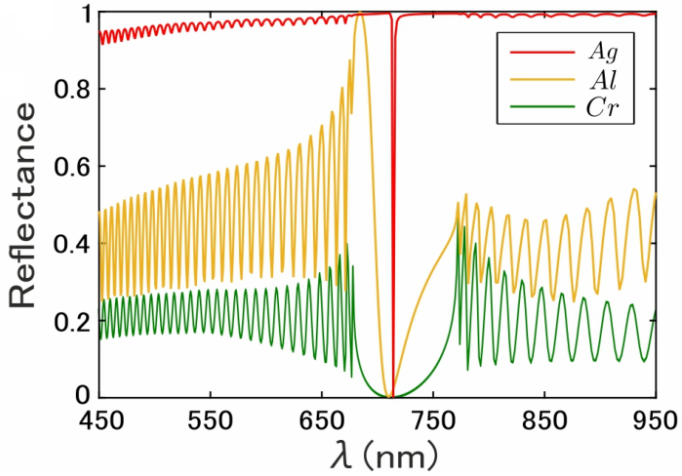

Fig. 1. Calculated reflectance spectra of photonic crystal with sputtered metal films of various materials: silver ($d_{Ag} = 50$ nm), aluminum ($d_{Al} = 5$ nm) chromium ($d_{Cr} = 6$ nm).

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