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Optical Single Bragg Mirror Filters for Porous Silicon Multilayered Structure in Visible Wavelength Spectrum

Md. Sakibul Islam
Department of Electrical and Electronic Engineering, Shahjalal University of Science & Technology, Sylhet-3114, Bangladesh
sakibulislamsazzad@gmail.com

Abstract: A distributed bragg reflector is designed to get an optical reflectance on visible electromagnetic spectrum i.e. ~800 nm in this work. Device is realized based on Abele's matrix for TE mode. © 2021 The Author(s)

Distributed bragg reflector that has a mirror structure for alternating different reftractive indices. Periodicity of this alternating mirror layers are responsible to increase photonic bandgap, for which incident light is filtered. Thus single bragg mirror multilayered structures can be designed to filter a certain wavelength. These types of RGB (red, green, blue) color engineering is known as structural color. Structural color in visible range is a phenomenon of reflectance/ scattering for the incident light on nanoscale features in a material. Specialized engineering approach has been followed to design a passband wavelength in any kind of mesoporous material [1]. Such design has a sensitivity application like monitoring of drug release [2], tenacity to assemble dust particle [3].

In this work porous silicon (pSi) is used as a substrate to design a multilayered bragg reflectors that works as a filter for 400 nm to ~900 nm wavelength region. To demonstrate the concept, only red region is shown as passband. Layer of thickness variability (for 100`nm to ~180 nm) hope to work as passband for other colors in visible electromagnetic wavelength spectrum. To get the reflectance at the designated wavelength, electric filed intensity for multilayered structure is calculated by following Abele's matrix formalism [4]. It is widely used method to analyze electric field intensity on thin films for reflectance, transmission and absorption calculations. Co-efficient of matrix is calculated for TE mode. The bragg mirror has an alternating high and low porosity layers where refractive indices of layers are 1.3 and 1.4 respectively with thickness of 143 nm for high porosity layers and 168 nm for low porosity layers. To get the desired wavelength which is red in this work, alternating layers are repeated 25 times. Changing of layer thickness and repeats will change the peak wavelength according to the proportional relation with thickness and wavelength, $t_{layer} = \frac{\lambda}{4*n_{layer}}$, where t is layer thickness, λ is desired wavelength, n_{layer} is refractive index of the desired layer.

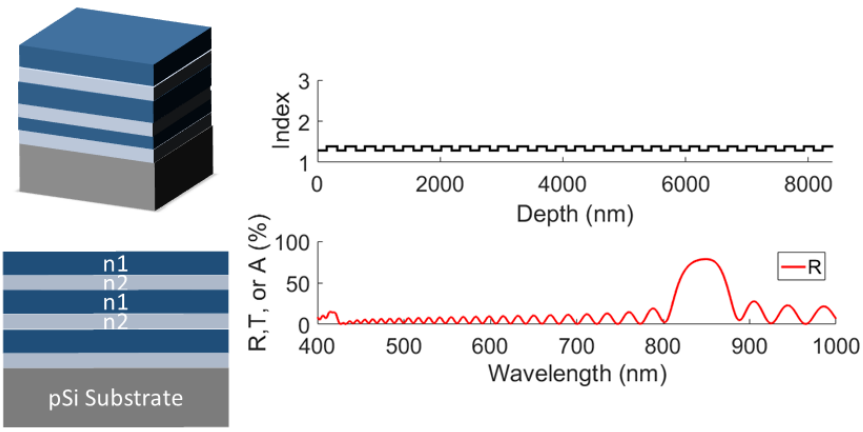

Figure 1: A schematic design with multilayer structure is shown with the peak reflectance in "red" color.

An experimental effort shows that for 100 nm layer thickness for higher porosity and 140 nm layer thickness for lower porosity with 25 times repeats matches with the matrix formalism. Reason behind the lower thickness in the experimental data is that dispersive property was not considered in the matrix. Mesoporous silicon thin films are fabricated using current densities of 100 mA and 140 mA for 6s each alternatively to form a bragg grating. Each cycle was repeated 25 times. Reflectance measurements are done in an oceanview reflectometer.

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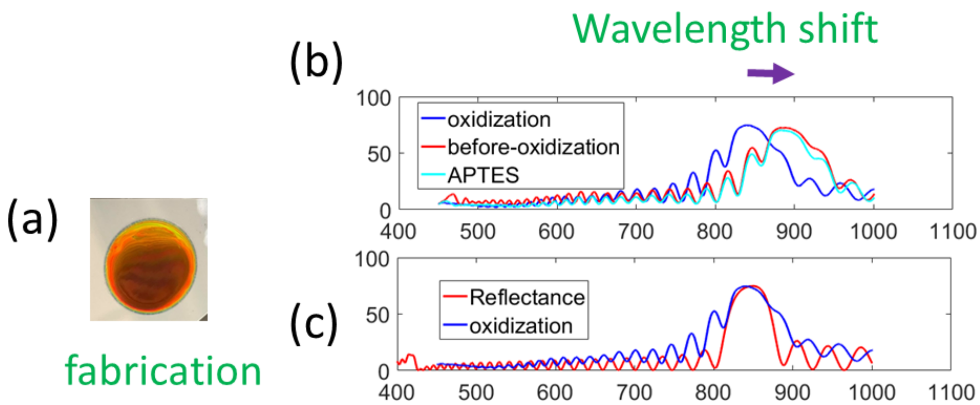

Figure 2: (a) Fabriacted pSi multilayered structure in (b) reflectance spectrum during pre-oxidization, after oxidization and analyte (APTES) attachment. Wavelength shift of ~50 nm is observed during oxidize and APTES attachment. (c) Simulated matrix formalism for bragg mirror perfectly matches with experimental fabrication.

In summary, a single bragg mirror is successfully designed in a pSi substrate that shows a passband region at "red" color. Experimental data perfectly matches with matrix formalism. This RGB color filtering can have sensing opportunities in visible light spectrum in pSi sensing applications.

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