Embedding grating mirror in resonant cavity-enhanced absorber structures for mid-infrared detectors applications

Mark Auslender,[1] Moshe Zohar,[1] Shlomo Hava,[1] L. Faraone[2]

[1] Ben-Gurion University of the Negev, Department of Electrical and Computer Engineering, POB 653, Beer-Sheva 84105, Israel
[2] The University of Western Australia, School of Electrical, Electronic and Computer Engineering, Crawley 6009, Australia
marka@ee.bgu.ac.il

Abstract

Incorporating a photosensitive (optically active) layer into Fabry-Perot (FP) cavity enhances the layer's sensitivity (emissivity) due to reflections of light between the cavity mirrors. Strongest enhancement occurs when the phase difference between each succeeding reflection (round-trip phase), satisfies the resonance condition (which is in fact that of highest resonant transmission through empty FP cavity)

$$\delta_0 = 4\pi n_{\mathrm{c}} \;\; \lambda_0 \;\; t_{\mathrm{c}}/\lambda_0 + \varphi_{\mathrm{f}} \;\; \lambda_0 \;\; + \varphi_{\mathrm{b}} \;\; \lambda_0 \;\; = 2\pi m\,, \qquad (1)$$

where λ_0 is a resonance wavelength, m is an integer; n_c and t_c is refractive index (RI) and length of the cavity; φ_{f} and φ_{b} is the reflection phase of front and back FP cavity mirror, respectively.

High performance photo-detectors (PDs) and imagers in MWIR range (3-10μm) are attracting increasing interest due to the wide applications in security surveillance, chemical sensing, and industrial processes monitoring [1, 2]. Promising technology is using the resonant cavity enhanced (RCE) absorption [3]. So far, the RCE PDs designs commonly employed [3] distributed Bragg reflectors (DBRs), i.e. stacks of quarter-wave pairs of high/low (H/L) RI layers, both for the front mirror (one that is further away from the illuminated side) and back mirror, as shown in e.g. Fig.1(a).

In this presentation, we propose RCE PDs in which the front mirror is a grating structure, designed to act as perfect retro-reflector, and the back mirror is a DBR. Optical absorbance of a thin semiconductor embedded in the resonant cavity of this novel type (assuming that the absorption is efficiently converted into photoconductive or photovoltaic response) is further maximized. We apply this idea to $Hg_{0.7}Cd_{0.3}Te$ in a CdTe cavity [4]. In our design shown in Fig. 1(b) the irradiation and back mirror ($Hg_{0.6}Cd_{0.4}Te$/CdTe DBR grown on a CdZnTe substrate) scheme is the same as in the conventional design [4], shown in Fig.1(a), while the front mirror is the Ge-grating/layer structure, instead of Ge/SiO DBR. For a fair comparison, we optimized both conventional and grating-based RCE HgCdTe(MCT)-absorber structure using smart round-trip and mirrors' phases engineering.

The optimization results are presented in Table 1 and the simulated absorption (*A*) spectra of the structures are shown in Fig.2. Some of the structural parameters in Table 1 are depicted in Fig.1 and some defined in its caption. The optimized grating-mirror based RCE MCT-absorber attains efficiency ~100% with the mirrors twice thinner than in the conventional one that cannot be optimized furthermore.

The obtained results indicate that the novel grating-mirror based type of RCE PDs meets the combined challenges of significantly increasing the efficiency and reducing the overall complexity and size of the entire device, in comparison with the conventional RCE PDs.

Table 1 The parameters of designed conventional and grating-based RCE MCT-absorber structures, RCE-C and RCE-G, respectively; t_{FM} and t_{BM} is the front and back mirror total thickness, respectively

Structure	d_b, μm	t_a, μm	d_f, μm	t_{FM}, μm	t_{BM}, μm	t_g, μm	Λ, μm	*W*/Λ	Peak *A*
RCE-C	0.272	0.075	0.433	2.082	12.15	–	–	–	83 %
RCE-G	0.05	0.075	0.429	0.880	5.867	0.255	1.383	0.36	97 %

References

[1] J. Wang, J. Hu, P. Becla, A.M. Agarwal, L.C. Kimerling, Opt. Express., vol. 18 (2010) 12890.

[2] A. Rogalski, J. Antoszewski, L. Faraone, J. Appl. Phys., vol. 105 (2009) 091101.

[3] M. S. Unlu, S. Strite, J. Appl. Phys., vol. 78 (1995) 607.

[4] J.G.A. Wehner, R.H. Sewell, J. Antoszewski, C.A. Musca, J M. Dell, L. Faraone, J. Electron. Mater., vol. 34 (2005) 710.

Figures

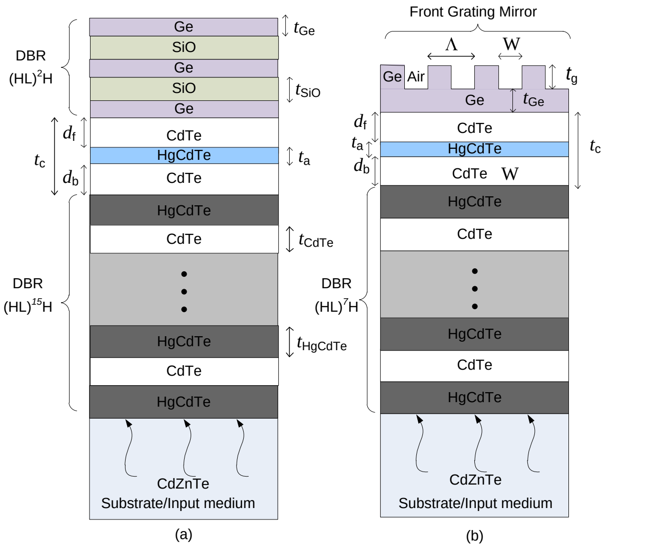

Fig.1. RCE MCT-absorber structures with $(HL)^mH$ back mirror and the DBR $(HL)^kH$ front mirror **(a)** or the grating-based front mirror **(b)**.

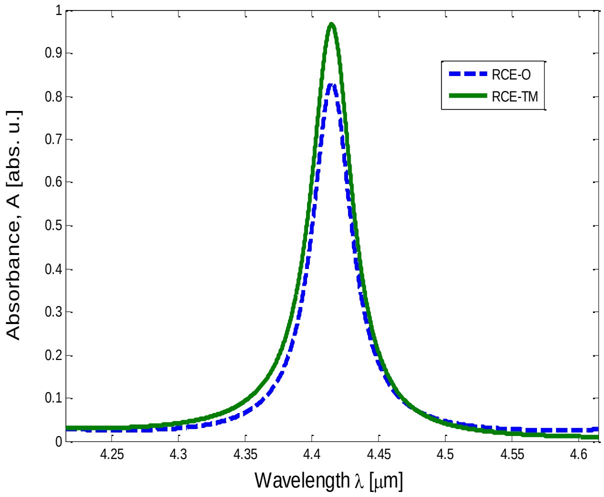

Fig.2. Absorbance spectra of the conventional and grating-mirror based optimized RCE MCT-absorber structures, displayed in Table 1