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Errata: Optimization of the planar microcavity structure in bottom-emitting gallium nitride light-emitting diode

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Some results in the previously published paper [*Opt. Eng.* **52** (9), 091715 (2013)] had been incorrectly calculated. In this errata, the corrected results are shown and discussed. Here, the absorption of the dielectric reflector is considered, and the results are more accurate.

Figure 3 in the previous paper should be replaced by Fig. 3 shown below. When the conditions $R_t \approx 1$ and $R_b \approx 1$ ($T_b = 1 - R_b$) are satisfied, I_m/I_0 will be largely increased. When the conditions $\Delta\varphi_1 = 2p\pi$, $\Delta\varphi_2 = 2q\pi$, $R_t \approx 1$, and $R_b \approx 1$ are satisfied, I/I_0 will be greatly enhanced. So, the SiO$_2$ antireflection film in the optimized sample should be replaced by the Si reflector for larger emission intensity. The thickness of the Si layer is denoted by the parameter b. For increasing the reflection and suppressing the absorption of the output reflector, the Bragg reflector is usually utilized in the conventional microcavity structure.[1] The optimized structure in this paper includes no Bragg reflectors. And hence the fabrication of the structure can be simplified. Although the condition $R_b \approx 1$ cannot be strictly satisfied, the intensity from this microcavity will be effectively improved by the parameter optimizations. For the lightwaves of various wavelengths, incident angles, and polarizations, the reflections of the optimized SiO$_2$/Ag reflector and Si reflector are about 0.90 to 0.98, and 0.55 to 0.90. The curves of $R_t = 0.9$ and $R_t = 0.95$ are labeled by arrows in Fig. 3. The range of R_b from 0.55 to 0.90 is labeled by a box.

For the planar multilayered structure constituted by the isotropic materials, $I(\lambda_0, 0\,\text{deg})/I_0$ is independent of the polarization [transverse magnetic (TM) or transverse electric (TE)]. In other words, $I(\lambda_0, 0\,\text{deg}, \text{TM})/I_0$ is equal to $I(\lambda_0, 0\,\text{deg}, \text{TM})/I_0$. Here, $I(480\,\text{nm}, 0\,\text{deg})/I_0$ is chosen to be optimized. Figures 4 and 5 in the previous paper should be replaced by Figs. 4 and 5 shown here. In the calculations, the absorption of the Si reflector is considered and the refractive index of Si at 480 nm wavelength is set to be $4.416 + 0.094i$.[2] Figure 4 shows the distribution of $I(480\,\text{nm}, 0\,\text{deg})/I_0$ versus parameters t and b. When the parameter b is larger than 200 nm, the intensity is very low because of the large absorption of the thick Si layer. The peak (about 19.0) in the lower left corner is chosen to be investigated. Figure 5 exhibits in detail the region near the peak labeled by an arrow in Fig. 4. The discretization step in the optimizations of parameters t and b is set to be 1 nm. The optimized parameters t and b are determined to be 49 nm and 29 nm, respectively. For the light of 480 nm wavelength and 0 deg incident angle in the optimal sample, the results

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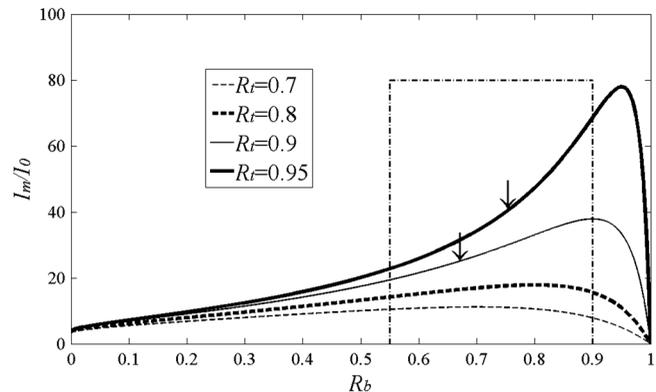
Fig. 3 $I_m(\lambda, \theta)/I_0$ versus R_b for different R_t values.
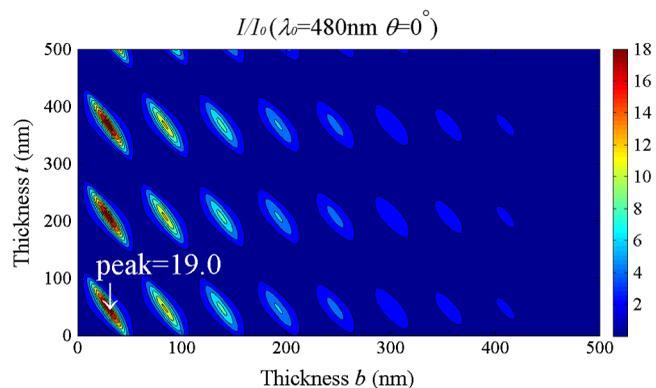

Fig. 4 The calculated $I(480\,\text{nm}, 0\,\text{deg})/I_0$ versus parameters t and b represented by the contour figure.
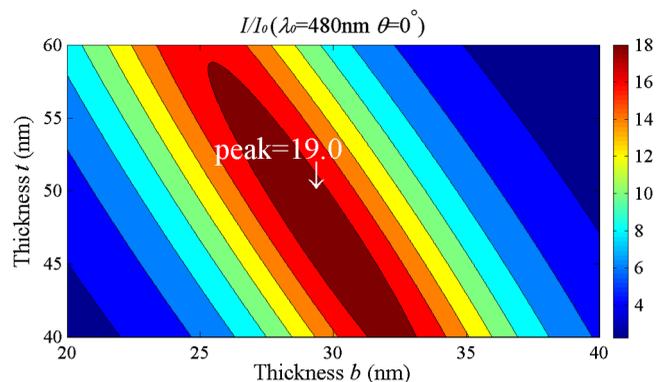

Fig. 5 The region near the peak shown in Fig. 4.
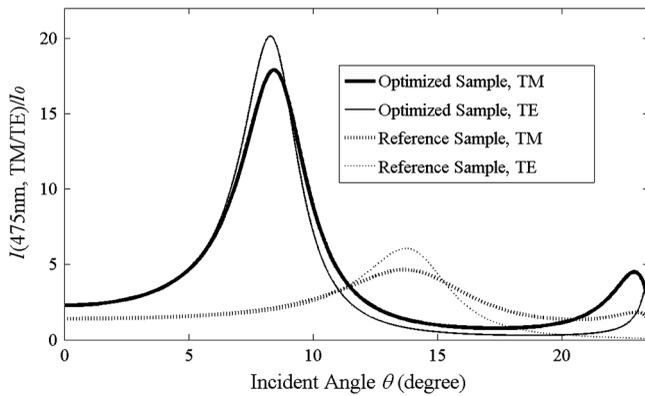
Fig. 6 The calculated $I(475\,\mathrm{nm}, \mathrm{TM/TE})/I_0$ versus θ of the optimized and reference samples.
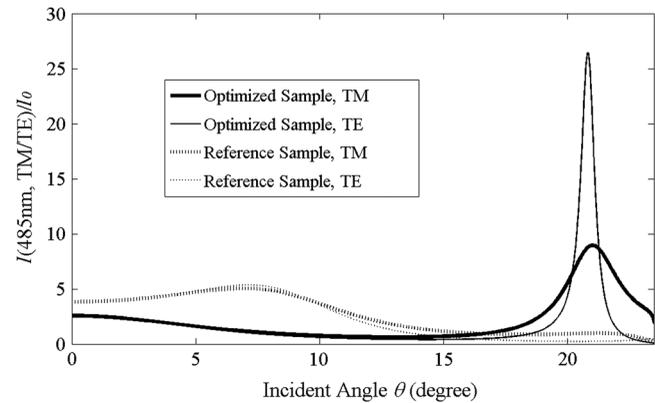
Fig. 8 The calculated $I(485\,\mathrm{nm}, \mathrm{TM/TE})/I_0$ versus θ of the optimized and reference samples.
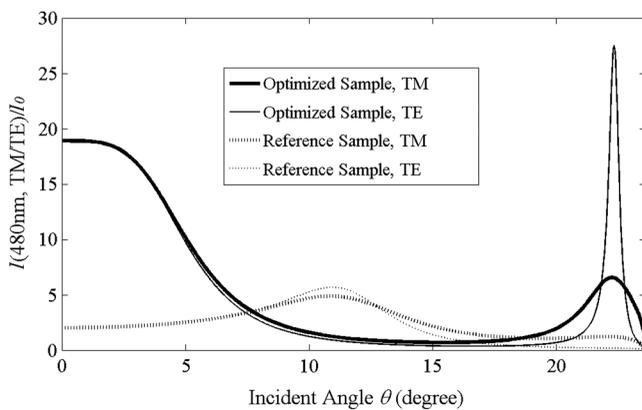
Fig. 7 The calculated $I(480\,\mathrm{nm}, \mathrm{TM/TE})/I_0$ versus θ of the optimized and reference samples.

$\Delta\varphi_1 = 2.0622 \times 2\pi$, $\Delta\varphi_2 = 12.6356 \times 2\pi$, $R_t = 0.946$, and $R_b = 0.553$ are obtained by the TMF.

In addition, Figs. 6 to 8 in the previous paper should be replaced by Figs. 6 to 8 shown here. The simulated $I(\lambda, \mathrm{TM/TE})/I_0$ versus θ at 475 nm, 480 nm, and 485 nm wavelengths of the optimized and reference samples are shown in Figs. 6, 7, and 8, respectively. The refractive indexes of Ag at 475 nm and 485 nm wavelengths are set to be $0.1413 + 2.7147i$ and $0.1383 + 2.7849i$.[2] The refractive indexes of Si at 475 nm and 485 nm wavelengths are set to be

$4.442 + 0.090i$ and $4.391 + 0.083i$.[2] In Fig. 7, the TM or TE intensity of the optimized sample at $\theta = 0$ deg is about 19.0. This is because $I(480\,\mathrm{nm}, 0\ \mathrm{deg})$ is chosen to be optimized. The intensity in the normal direction at 480 nm wavelength is increased by about 9.5 times, compared with the reference samples. The TM intensities integrated over the incident angle at 475 nm, 480 nm, and 485 nm wavelengths are increased by about 1.5, 1.9, and 1.1 times. The TE intensities integrated over the incident angle at 475 nm, 480 nm, and 485 nm wavelengths are increased by about 1.7, 2.2, and 1.4 times. The peaks of the TM and TE intensity of the optimized sample at $\theta = 8$ deg is observed in Fig. 6. For the TE-polarized light of 480 nm wavelength and 22 deg incident angle in the optimized sample, the results $\Delta\varphi_1 = 1.8527 \times 2\pi$, $\Delta\varphi_2 = 11.0002 \times 2\pi$, $R_t = 0.963$, and $R_b = 0.794$ are obtained. So, the TE-polarized resonance at 22 deg incident angle in Fig. 7 is observed. The TE resonance at a large incident angle in Fig. 8 is also observed. The resonances indicate that the intensity of the optimized sample is relatively high when the emission angle θ' is greater than 40 deg.

References

1. E. F. Schubert et al., "Highly efficient light-emitting diodes with microcavities," *Science* **265**(5174), 943–945 (1994).
2. E. D. Palik, *Handbook of Optical Constants of Solids*, Vol. 1, Academic, San Diego, CA (1985).