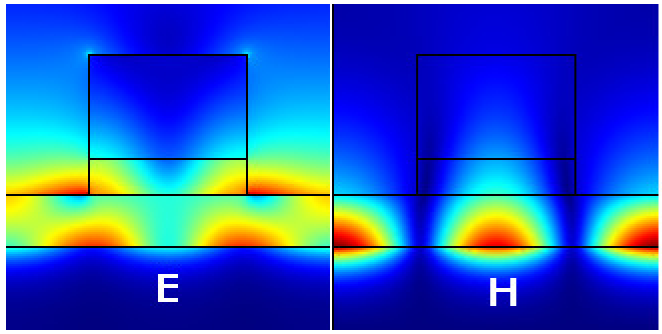

Fig. 10. Electric and magnetic field at SPR mode with λ = 670 nm.

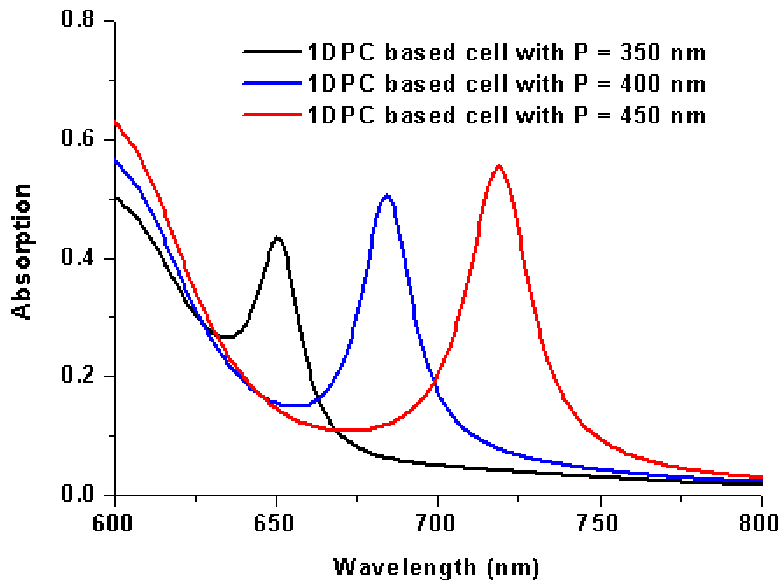

Fig. 11. Absorption in the active layer of a flat cell and of a 180 nm width 1D PC cell, for various periodicities.

Besides enhancement due to light scattering and SPR mode excitation, another resonance peak is observed at 440 nm wavelength. By modal analysis of the structure, we found a Bloch mode at k = 0 existing along the plane of the structure at 446 nm, which is close to the peak in the absorption spectrum. The field profile of the mode can be seen in Figs. 12(a) and 12(b), which show the amplitude of the electric and magnetic fields, respectively. Significant absorption enhancement is obtained by exciting this mode, although the field profile is mainly distributed above the active absorbing solar cell layer. Figure 12(c) shows the electric field distribution in the case of excitation at normal incidence at 440 nm wavelength. We see a correspondence between the profiles in Figs. 12(a) and 12(c), indicating that the absorption peak is really due to the excitation of this mode. Further optimization of the field profile to further shift the distribution into the active layer can still be performed by tuning the thickness of the ITO and PEDOT layer. In addition, the field profile significantly extends into the air layer above the structure, which is expected as the mode propagates through air in certain regions of the periodic structure. This could be reduced by filling the gaps with some dielectric substrate.

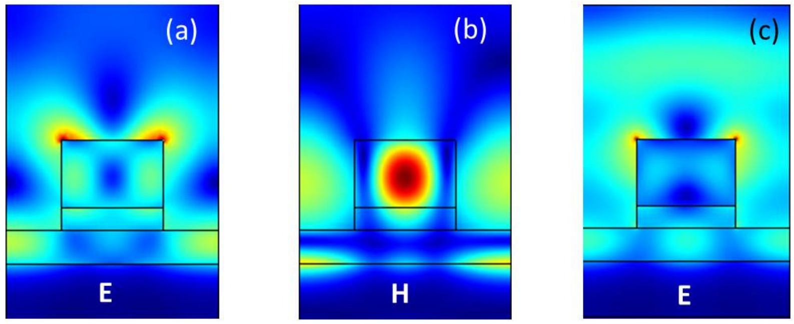

Fig. 12. (a) Electric and (b) magnetic field profiles of a guided Bloch mode at 446 nm. (c) Electric field profile in the case of normal incidence plane wave upon the structure at wavelength $\lambda = 440$ nm.

The use of a periodic dielectric structure may be more advantageous than the plasmonic geometry considered above, as the absorption enhancement is more evenly distributed throughout the active material. In metallic periodic structures the absorption enhancement, especially by LSPRs, tends to be concentrated close to the metal, which increases the possibility that the absorbed photons will not contribute to current generation. This is due to either improper passivation of surface states on the metal interface or other exciton quenching effects which depend on the distance from a metal interface. If the absorption enhancement by the metal structure is large enough, these loss mechanisms may not be so detrimental. We show here, however, the possibility of achieving comparable, although still smaller, absorption enhancement with a periodic dielectric structure. More studies need to be done, but the comparison here indicates that we may not need to rely on metal nanostructures to achieve a good absorption enhancement.

4. Conclusions

We have demonstrated the possibility of achieving absorption enhancement in thin-film OSCs by integrating Ag gratings inside the thin active layer or alternatively patterning the 1D PC on top of the cell. Ag gratings cause the excitation of LSPR modes at the grating surface and the coupling of these modes with SPR modes at the back contact surface. 1D PC based structures achieve enhancement due to scattering and light coupling into Bloch modes, and the excitation of SPR modes at the back contact surface. The realized optimal absorption enhancement in the case of Ag gratings is about 23.4%, and in the case of 1D PC we found about 18.9%. Although the enhancement factor from the 1D PC is smaller than that of the Ag grating, the fabrication of the former structure may be much easier, and still give significant enhancement.

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