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DUAL-INTERFACE GRATING SUPERCELLS FOR BROADBAND ABSORPTION

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1) Context / Study Motivation

Recently, people began to study more complex periodic structures combining multiple gratings and found that complementary effects resulting in an overall broadband absorption enhancement is possible [1,2].
Here, we propose the usage of dual-interface grating (DIG) supercells with multiperiodicity as shown in Fig. 1(c) and numerically study their extensive mode-coupling possibilities. We consider a-Si solar cell systems which have active layer thickness that is comparable to the size of the grating geometry. At such thickness regime, the grating structure heavily affects the eigenfield profiles of the guided modes. We show how DIG supercells offer much possibility in improving higher order diffraction coupling conditions to guided modes, while maintaining lower order diffraction coupling efficiency. In addition, including symmetry-breaking or blazing properties in DIG structures can lead to excite previously inaccessible modes efficiently, and thus further broadens the enhancement range.

2) Description of approach and techniques

Higher order diffraction coupling through grating structures can be improved by having higher order periodicity components in the grating structure. Higher order periodicity components are higher order fourier components of the total grating system with k-vector of $n \times \frac{2\pi}{P}$ with P being the macro periodicity of the system and n being an integer. Instead of only lumping these higher order components on one interface, we introduce two grating structure at the front and back. We focus on systems with the back grating having half the periodicity of the front grating (Fig. 1(c)).
Additionally, we compare blazed systems (Fig. 3(b)) with unblazed symmetric systems. We wish to study the necessary requirements for opening the access to antisymmetric guided modes for incoming normal incident light.
We specifically study the combination of triangular plasmonic grating structures at the back side of a solar cell and a non plasmonic grating structure at the front (Fig. 1(a-c)) with light plane waves coming at normal incidence. Here we show results for 1D grating structures. Full field 2D simulations and eigenmode analyses are done using the finite element method with COMSOL multiphysics, by simulating a unit cell and using Bloch-Floquet conditions in the direction of the periodicity. We consider Transverse Magnetic (TM) polarization only.

3) Results / Conclusions / Perspectives

An example of performance comparison between a DIG supercell system and single periodic DIG systems is shown in Fig. 1(d). The DIG supercell gives overall better coupling conditions as compared to single periodic gratings. The field profiles at the resonances above 750nm wavelength of the DIG supercell are given in Fig. 2, showing that the excited resonances are of higher diffraction order. High coupling efficiency to both higher and lower diffraction coupling order is achievable.
An example of the effect of blazing is given in Fig. 3, in which we compare a blazed and a symmetric DIG system. Additional resonances appear when we apply blazing without destroying the absorption performance. The change of eigenmode field profiles for the newly appearing mode is shown in Fig. 4. The antisymmetric nature of the guided modes is broken with the blazing, and thus makes it accessible for normally incident light. We also compare the absorption spectrum of DIG structures with blazing at the front or back side of the cell only in Fig. 5. We see that we only get all the new resonances in Fig. 4 if we apply blazing on both sides.
DIG structures offer much design flexibility with multiple optimization routes for various photonic phenomena for light trapping.

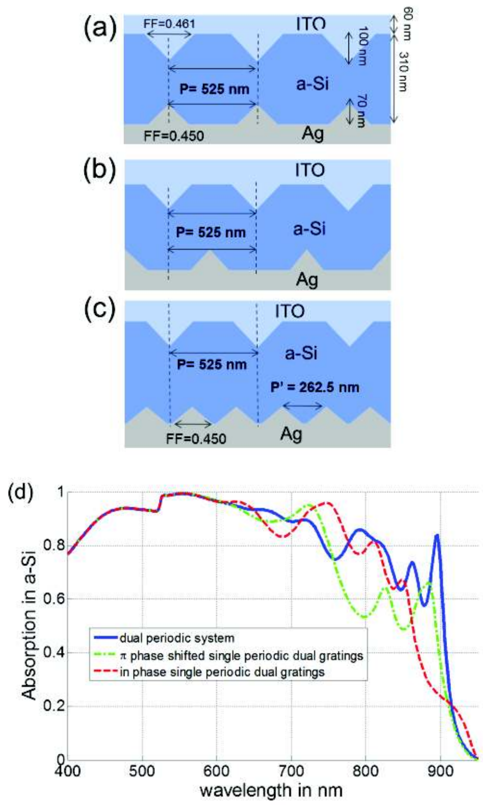


Figure 1. Comparing single and dual periodicity DIG systems. Schematics of the compared grating structure for single periodic P=525nm (a) in phase gratings, (b) π phase shifted gratings, and (c) dual periodic grating system with the same macro periodicity as P=525nm and smaller periodicity of P'=262.5nm. (d) The absorption spectrum of the structures in (a-c).

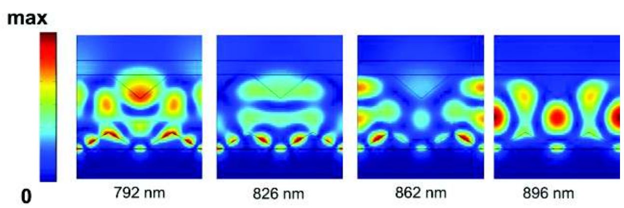
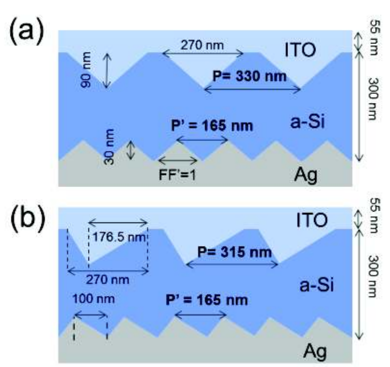


Figure 2. $|H_z|$ total field profiles at the resonances above 750 nm for the DIG supercell structure in Fig. 1(d) (blue line).



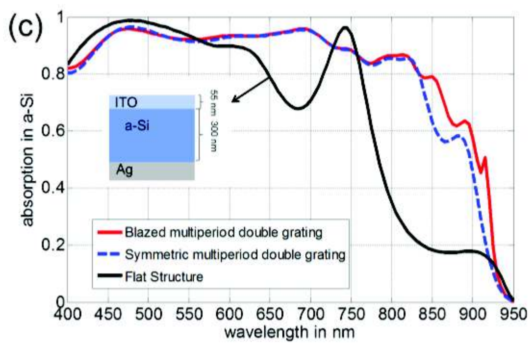


Figure 3. Structure schematic for (a) a symmetric DIG structure and (b) when blazing is applied on the system. (c) Absorption spectrum of the two structures in (a) and (b) and a planar reference structure at normal incidence.

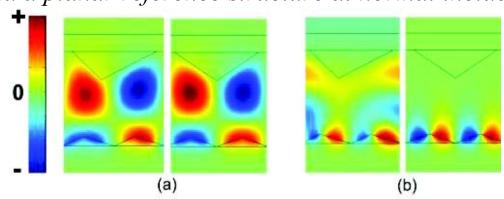


Figure 4. Dark mode H_z profiles in the symmetric system and the accessible form of it in the blazed grating system. (a) First order waveguide mode in the two systems: blazed (left) and symmetric (right). (b) SPP mode: blazed (left) and symmetric (right).

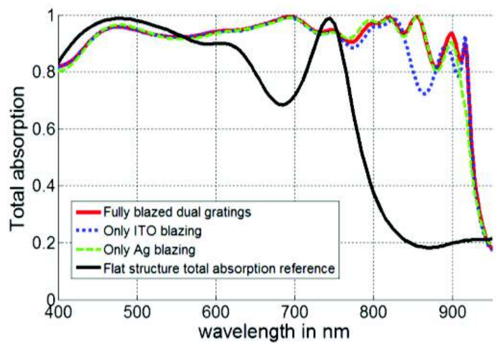


Figure 5. Comparing total absorption spectrum for fully blazed (Solid red line) with partly blazed DIG structures on the ITO front grating only (blue dotted line), Ag back grating only (green dashed line), and the flat structure reference when there is no grating (black solid line).

Acknowledgements

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