Semi-Periodic Gratings for Broadband Absorption in Thin Film Solar Cells

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Thin film solar cells are a promising candidate to alternate fossil fuels due to their low cost compared to first generation solar cells; however, as the active layer thickness is decreased in such structures, absorption probability would reduce substantially [1]. One of the techniques to overcome this disadvantages is to use nano plasmonic back-gratings to trap light inside the active layer, due to both waveguide and plasmonic modes. While the first lengthens photon path length and the latter creates strong near fields and both increase the absorption probability inside the active layer [2].

In this paper semi-periodic gratings were implemented at the back of the silicon slab to effectively trap light inside the active layer. It is shown that semi-periodic gratings enhance absorption more than the periodic ones, as they lie somewhere between periodicity and randomness. Therefore semi-periodic gratings can excite several broad modes and although the excited modes are weaker than periodic ones, they are not as week as the complete random structures. A periodic back-grating as well as three semi-periodic gratings based on Fibonacci, Thue-Morse (TM) and Rudin-Shapiro (RS) semi-periodic sequences [3], were embedded at the back of a 400nm silicon slab. Simulations were done using Comsol Multiphysics which works based on finite element method and via wave optics module electromagnetic fields were calculated. In the case of Fibonacci sequence first 7 terms, for TM sequence first 4 terms and for RS sequence first 11 terms were kept as a semi-periodic supercell. Absorbed light inside silicon is calculated in a broad spectrum from 350nm to 1100nm in which solar illumination is strong according to AM1.5. The 400nm thick silicon slab acts as a cavity and excite Fabry-Perot modes around 500nm; and as a result back grating is not that important on this range. However between 600nm to 900nm back grating has a dominant effect, as in this range waveguides modes can be excited. In the Figure 1a, absorbed light the inside active layer is shown. In the case of periodic structure three sharp and narrow modes are excited; however, the rest of the spectrum is poorly absorbed. The RS sequence broadens the peaks and improved the absorption in ranges which were poorly absorbed by the periodic structure. All three sequences have higher absorption compared to periodic structure as it is shown in figure 1a, and it worth mentioning that RS sequences is closer to random structures and therefore, excite more modes inside the active layer and that is the reason it works better compared to Fibonacci and TM sequences.

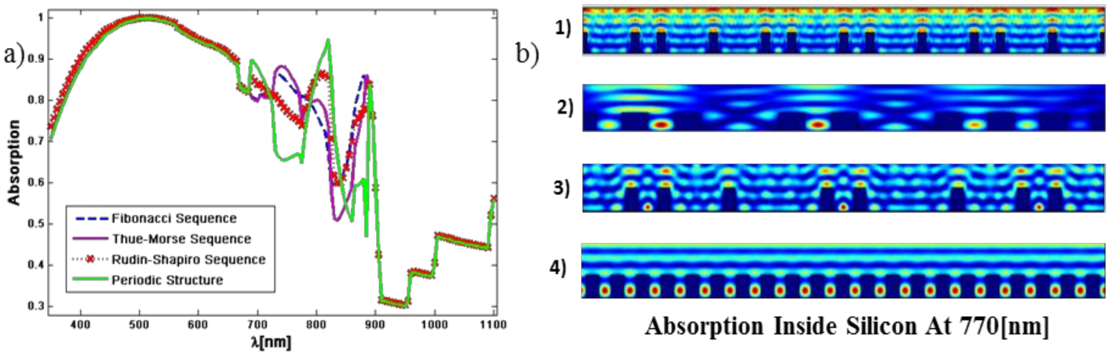

Fig. 1 a) Absorption inside silicon for all four structures. b) Absorption inside silicon for 1) Fibonacci 2) Rudin-Shapiro 3) Thue-Morse 4) Periodic structures at 770nm.

At 770nm a strong waveguide mode is excited inside the periodic structure, which caused the sharp absorption peak in the figure 1a. In figure 1b, absorption inside silicon slab at 770nm is depicted for the all of the mentioned structures, it can be seen that absorption is stronger in the periodic structure due to the excited strong waveguide mode. Although the absorption is broader in semi-periodic structures and this broadening results in a higher absorption inside silicon. It can be concluded from figure 1, that semi-periodic gratings due to exciting a broader mode spectrum outperform periodic gratings as in solar cells absorption should be broad band to gain a better efficiency.

References

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Results

	Periodic structure	Thue-Morse structure	Fibonacci structure	Rudin-Shapiro structure
Total absorption	51.7%	55.2%	55.0%	56.1%
Carrier generation rate enhancement	23.6%	30.5%	29.1%	32.6%

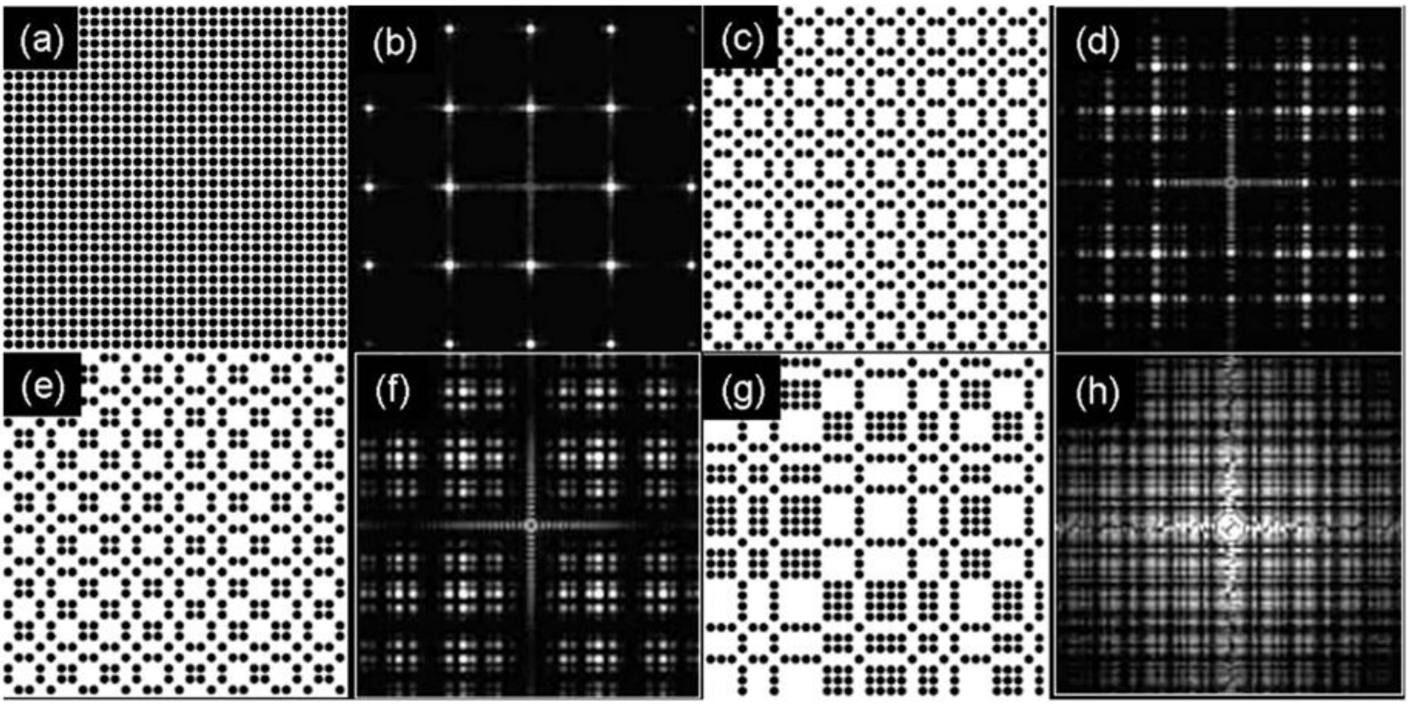
➢ To Conclude

- ➢ Semi-periodic structures are effective for photon management
- ➢ This technique is optimal to maximize the absorption within a broad wavelength range

Thanks for your attention

Questions?

2D-Semi-periodic structures



a) Periodic structure, c) Fibonacci, e)Thue-Morse, g) Rudin-Shapiro,