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IFN CNR

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Thin-film solar cells with combined metallic enhancements

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ABSTRACT
Plasmonic elements, such as metallic gratings, in thin solar cells have a strong potential to increase the solar light absorption. Here, we numerically describe devices where multiple elements are combined, to create a more broadband and spatially distributed absorption. For organic solar cells, we introduce both a front and a back metallic grating, and show that both features act independently to create enhancement pathways. For amorphous silicon solar cells we introduce a metallic back grating and a dielectric front structure. By choosing different periods for these separate gratings, coupling to guided modes with plasmonic or photonic character is strongly optimized.

Keywords: Solar energy, surface plasmons, gratings.

1. INTRODUCTION
Thin absorbing layers in solar cells are desired to decrease the material costs, but also to enhance the electronic properties. Unfortunately thinner cells means that light has a greater probability to not be absorbed, therefore the field of light-trapping was created. Nowadays, active layers become so thin that traditional refractive elements become impractical. Therefore wavelength-scale dielectric features and subwavelength scale plasmonic features are introduced, in order to scatter light in more absorbing modes [1]. The inclusion of single elements already received much attention. However, the ultimate trapping structures will probably include various effects, and may therefore necessitate multiple scattering features.

We propose combined devices both for the organic and amorphous silicon platform. The particular implementations depend on the modelled platform, as the material properties and thicknesses vary, but the techniques are more generally applicable. In the organic case we insert metallic gratings on both the front and back side of the cell. For the amorphous silicon cell we introduce a dielectric and a metallic grating, with varying periods.

2. COMBINED PLASMONIC GRATINGS
Our proposed structure with metallic gratings on the front surface and on the back metallic electrode is shown in Fig. 1(a). The integrated absorption versus angle of incidence is shown in Fig. 1(b). A strong enhancement with respect to the planar case is observed, which is kept even for relatively large angles of incidence.

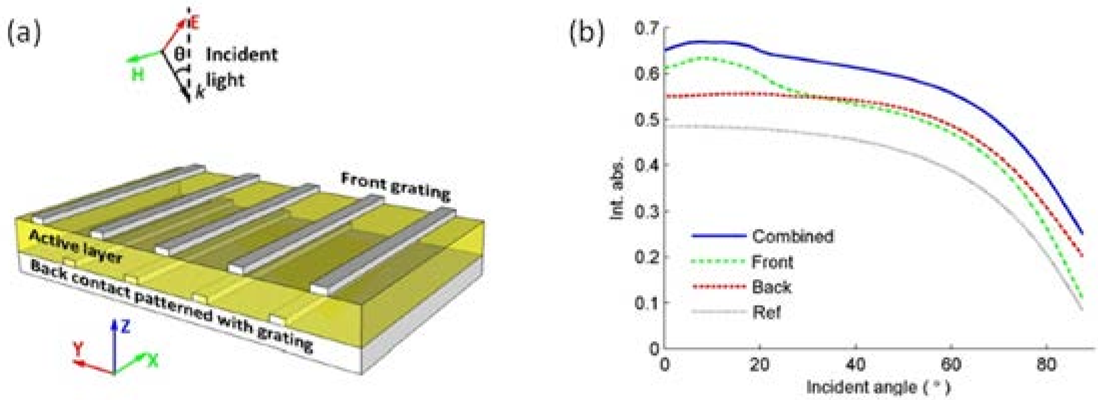

Figure 1 (a) Double grating geometry for an organic structure. (b) Integrated absorption versus angle of incidence in the case of combined grating (blue), front grating only (green), back grating only (red) and flat reference structure (grey).

The operation of the device is elucidated by comparing the absorption spectra with the dispersion of Bloch modes of the structure [2]. Strong absorption peaks appear for the coupling to Bloch plasmonic modes, which in this structure have a mixed localized (around the grating teeth) and propagating (along the back surface) character. Particular angular dependence stems from the tuning of so-called ‘bright’ (symmetric) and ‘dark’ (anti-symmetric) modes [3].

By superimposing the spectrum for single grating and double grating cases, we observe that the particular offset structure here provides an independent operation of both gratings. The offset creates resonances in separate wavelength areas that ultimately provide a broadband enhancement.

3. MULTIPERIODIC GRATINGS

Previously, we reported the combination of dielectric and metallic gratings in an amorphous Si context [4], leading to different functionality for both gratings. Here, we further optimize this structure by using different periods for both gratings, see Fig. 2.

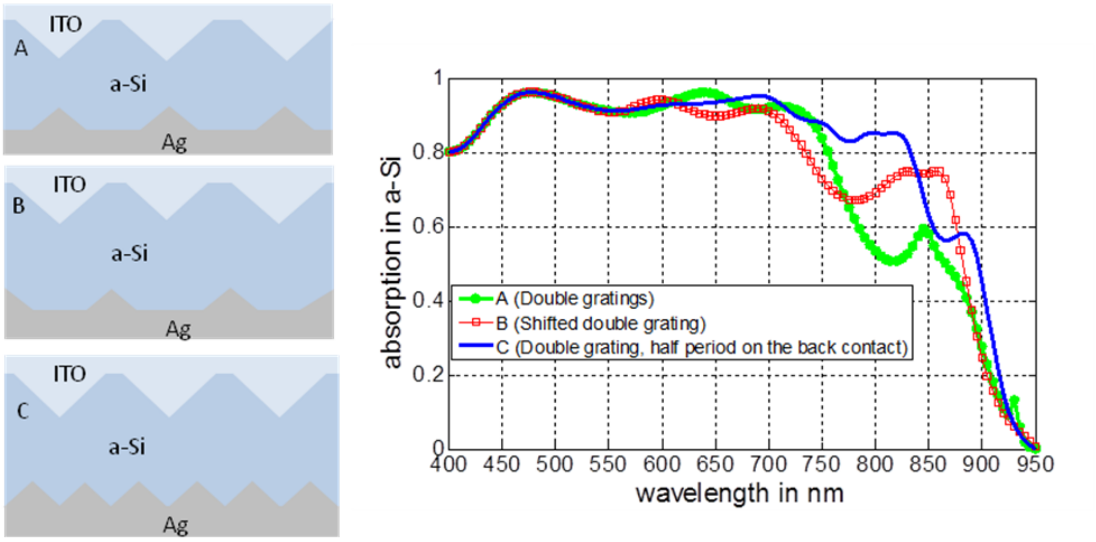

Figure 2 (left) Geometry with A: same period front and back; B: same period but offset; C: doubled period for the back grating.

A clear absorption enhancement of the double grating structure (C, blue curve in Fig. 2) is observed. A main contribution is that the doubled period bottom grating couples well to the *plasmonic* mode, giving a first order diffraction. In contrast, the top ITO front grating couples well to the *photonic* mode, again as first order. Dispersion calculations and period optimizations therefore lead to clear diffraction enhancements.

4. CONCLUSIONS

The inclusion of multiple elements is the next step towards ideal, broadband light-trapping devices. Here we introduce two pathways. First, the combination of front and back metallic gratings provides superimposed enhancements. Second, the optimisation of periods for dielectric and back gratings optimizes the coupling to modes of different character. These general techniques are useful for multiple thin-film solar platforms.

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