Metasurface Integrated in Thin Solar Cells for Index Modulation

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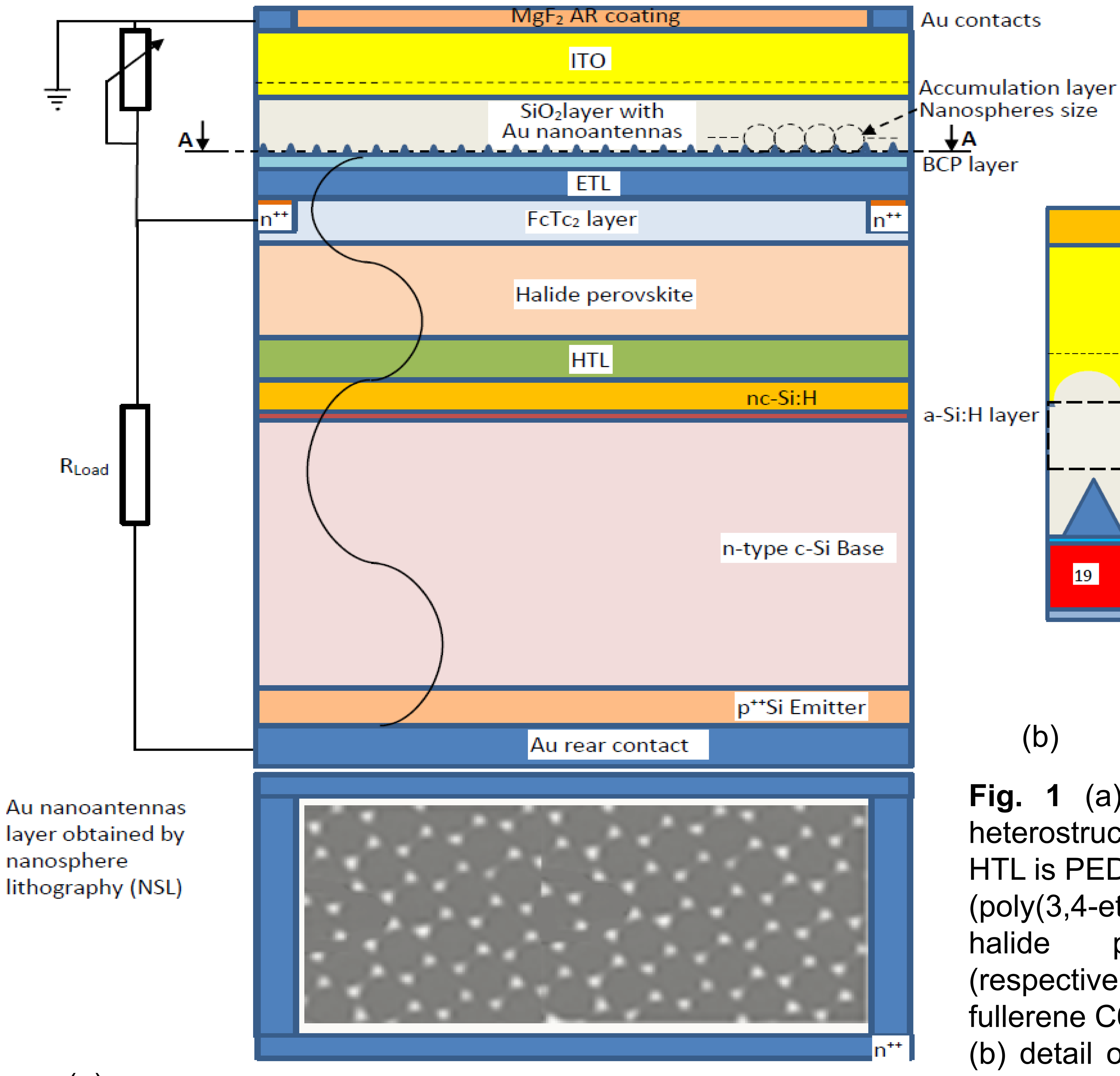
1.INTRODUCTION

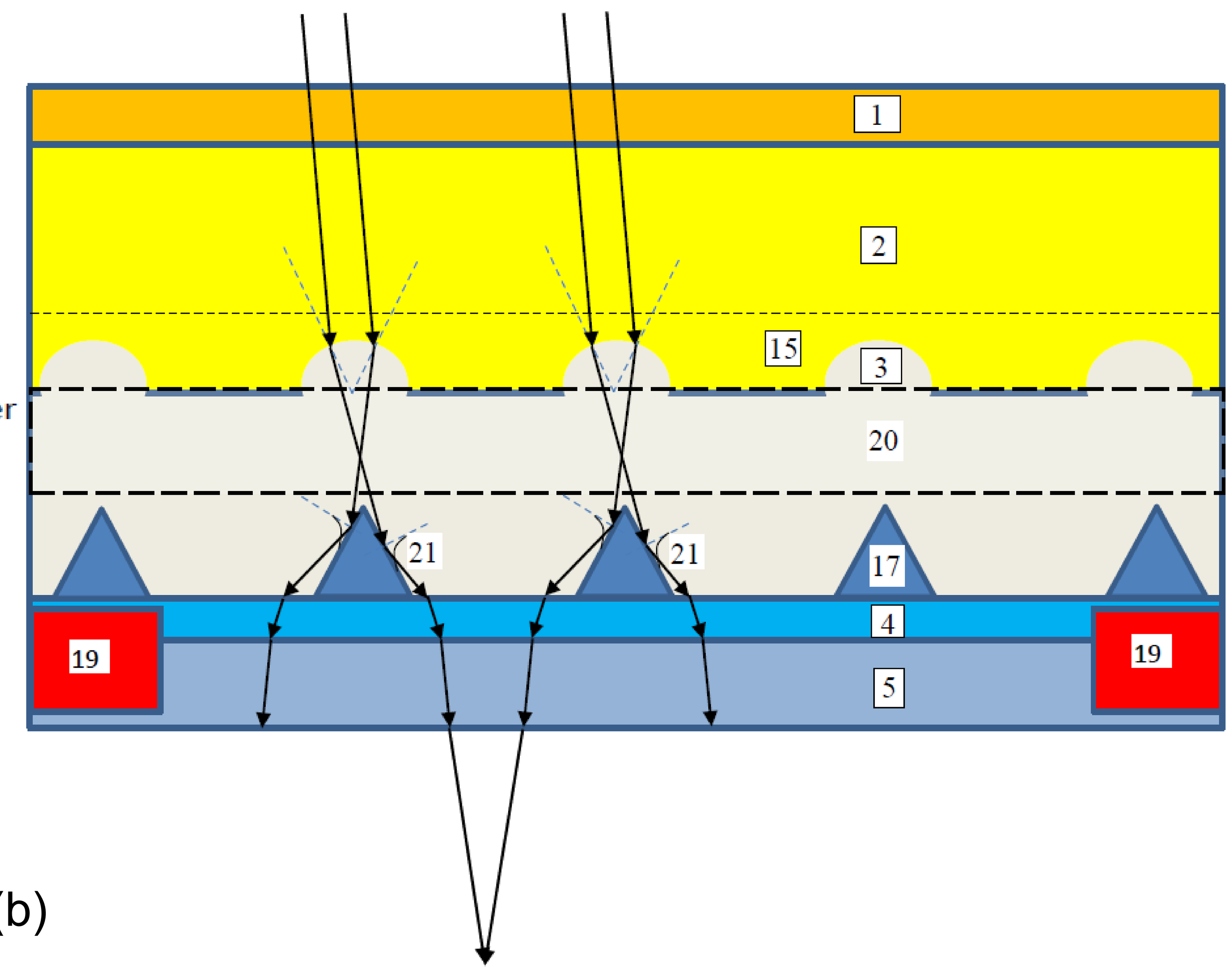
In order to exceed this limit of the single-junction device and also capable of reducing losses, *i.e.* thermalization loss and proper utilization of solar spectrum, is essential to form efficient tandem solar cells: perovskite solar cell (PSCs) on silicon single junction. Size-tunable Ag nanoantennas for integrated metasurfaces (MTS) achieved by nanosphere lithography enable that the refractive index for accumulation layer (ITO) of solar cell to be dynamic controlled by voltage on ITO/SiO_2 junction for focusing and traping sunlight in the active area of the tandem cell. The OptiFDTD and GenPro4 softwares allow us to design, analyze and test this modern photonic device with arbitrary model geometries and places no restriction on the material properties of the tandem cells for wave propagation, scattering, reflection, diffraction, polarization and nonlinear phenomena.

2. METHODOLOGY

The absorption of upper layers can be dramatically enhanced using a halide perovskite in order to obtain an absorber/Si solar cell architecture for environmentally friendly photovoltaic conversion technology. Adding an extra layer of ferrocenyl-bis-thiophene-2-carboxylate ($FcTc_2$) further enhancing the performance and stability of inverted perovskite solar cells is possible[2].
The upper layers can be optimized for index modulation to focus the sunlight in the active region based on carrier density, electron band diagram, permittivity of accumulation layer[3]. The modeled structure of the tandem solar cell is presented in Fig. 1(a), 1(b).



(a)



(b)

Fig. 1 (a) Tandem solar cells with the focusing heterostructure ITO/SiO_2 and A-A metasurface (MTS), where: HTL is PEDOT:PSS (poly(3,4-ethylenedioxythiophene):poly(4-styrenesulfonate)), halide perovskite is $[CH_3NH_3]_{1-x}[C_3N_2H_5]_xPbI_{2.6}Cl_{0.4}$ (respectively $MA_{1-x}IM_xPbI_{2.6}Cl_{0.4}$), IM is imidazolium, ETL is fullerene C60, and $x_{IM} = 0 \div 1.00$;
(b) detail of the MOS structure that integrates the MTS and the focus of the solar radiation in the first conversion junction.

3. RESULTS

The black dotted line in Fig. 2 represents the ~1.1eV bandgap of c-Si. Optical simulation indicated that the most efficient bandgap alignment of the subcells is 1.7eV for the top cell and 1.1eV for the bottom cell in a solar tandem. Combination of perovskite and silicon solar cells in tandem configuration is of great interest due to the possibility of boosting conversion efficiences above 40%. The maximum conversion efficiency can be further expanded by a suitable light trapping in the first active region by controlling the refractive index of the n-ITO semiconductor deposited on a SiO_2 layer profiled on a metasurface.

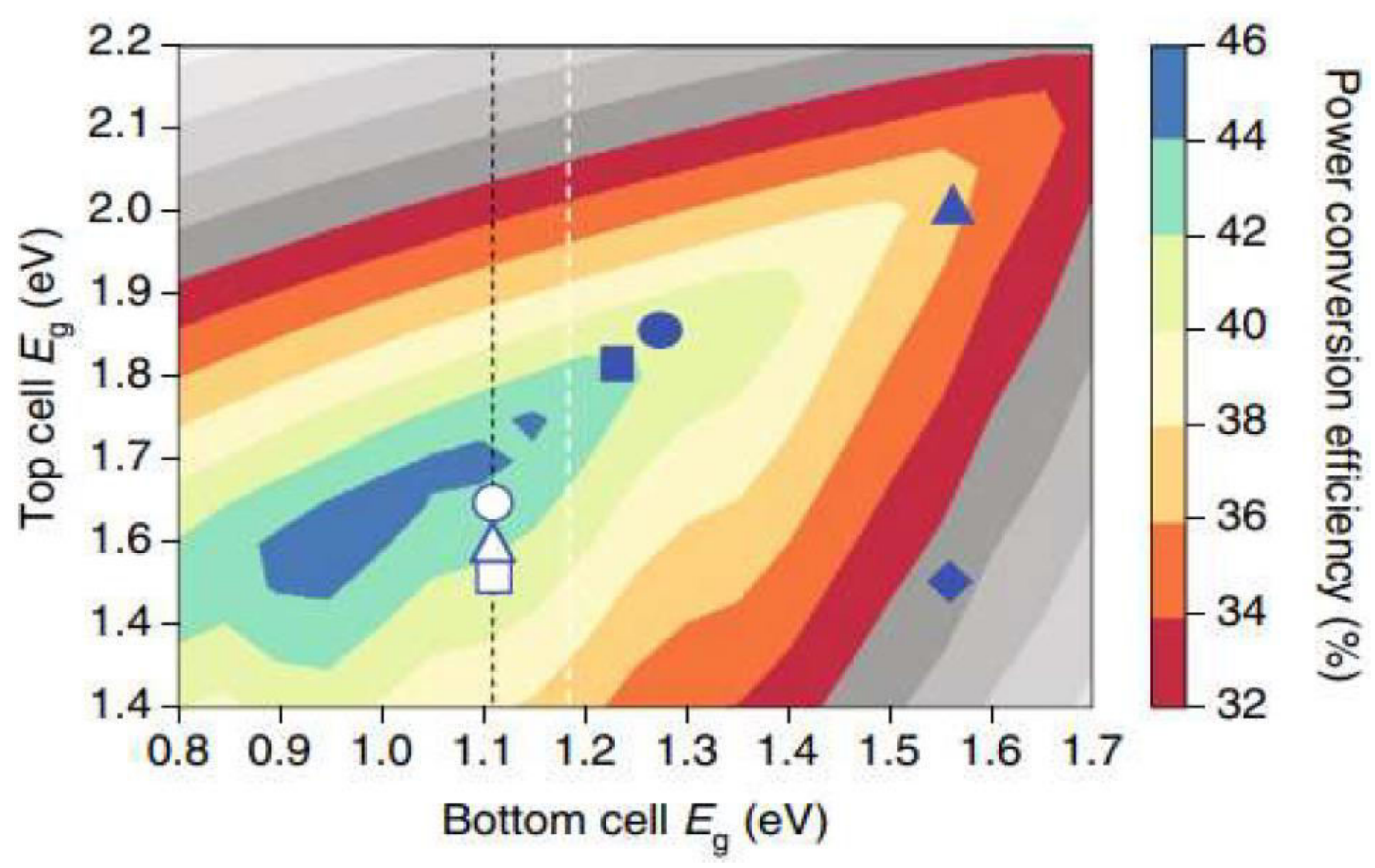


Fig. 2 Maximum power conversion efficiency for tandem solar cells is obtained for a perovskite top cell (molar ratio of IM=$C_3N_2H_5$ is x=0 for ○, x=0.06 for Δ, x=0.04 for □) and an infrared-enhanced silicon junction as bottom cell

REFERENCES

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[3] Feigenbaum, E., Kenneth Diest and Harry A. Atwater, "Unity-Order Index Change in Transparent Conducting Oxides at Visible Frequencies", Nano Lett. 10, 2111-2116 (2010).