Microfabrication of Planar Spectrum Splitting and Beam Concentration Diffractive Optical Element for Lateral Multijunction Photovotaic System

B.G. Quan, D.F. Lin, J.J. Li, C.Z. Gu, Q.B. Meng, and G.Z. Yang
Beijing National Laboratory for Condensed Matter Physics, Institute of Physics, Chinese Academy of Sciences, Beijing, 100190, China
jjli@iphy.ac.cn

Sunlight is one of the important candidates for the renewable, sustainable and environmentally friendly energy sources. Photovoltaic cells are the most widely used devices to directly convert the solar energy into electrical power. Unfortunately, the efficiency for a single p-n junction photovoltaic device is limited by its band gap, leaving the photons from other parts of spectrum of sun-light dissipating into heat after carrier thermalization. Vertical multijunction tandem photovoltaic devices are capable of efficiencies greater than 40%, but suffering from many drawbacks as complex fabrication process, material compatibility, current matching between junctions, transparency loss and resistive loss. Therefore, generating electricity from solar energy is not still economically viable due to the limited efficiency of single-junction photovoltaic device. An attractive way to increase the efficiency of these devices is to split the incident solar spectrum into different bands and to use laterally arranged multijunction photovoltaic system with band gaps matched to the corresponding spectral bands.

Recently, much research was focused on the design of micro-optical lenses with spectrum splitting or spectrum splitting[1] and beam concentration simultaneously[2]. The latter referred to multilevel broadband diffractive optical element (DOE) can further reduce the cost of photovoltaic cell materials used by light management. For cost-effective mass production of the DOE, the as fabricated DOE can be used as a master, and the master is then placed in an electrolytic bath to grow a metallic negative mold. Once a negative mold is ready, the fabrication cost of each element decrease significantly with the number of pieces by replication techniques such as embossing, casting, or injection molding.

In this work we have designed and fabricated a 32-level broad-band DOE to simultaneously split and concentrate the sunlight for lateral multijunction photovoltaic system. The 32-level DOE was fabricated by using 5 consecutive binary masking layers followed by 5 dry etchings. The DOE in this work is comprised of 4096 discrete one-dimensional pixels with each pixel of 5.18 μm,

---

[1] A. Dorodnyy, V. Shklover, L. Braginsky, C. Hafner, J. Leuthold, Sol. Energy Mater.Sol. Cells **136**, 120 (2015).
[2] G. Kim, J. A. Dominguez-Caballero, H. Lee, D.J. Friedman, R. Menon, Phys. Rev. Lett. **110**, 123901 (2013).

and the maximum thickness of 6.95 µm. Figure 1a shows the 3D interferometric microscope image of the 32-level DOE on a 2-inch wafer of fused silica covering an area of 2×2 cm^2. The concentrating and splitting performance the surface-relief DOE was characterized by measuring the spectrum as a function of position in the reconstruction plane, with a geometric concentration factor of about 10 x, as shown in Figure 1b.

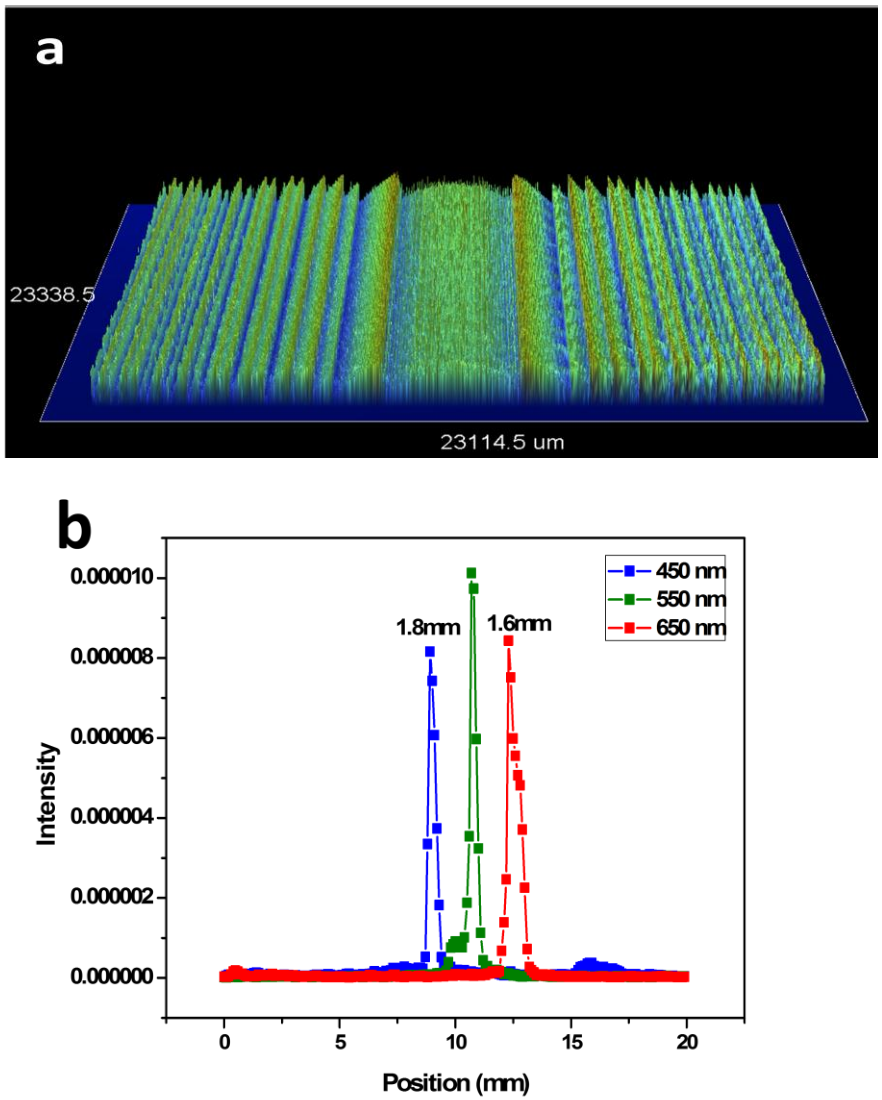

Figure 1: Characterization of the 32-level DOE: (a) 3D interferometric microscope image of 32-level DOE. (b) Energy distribution of the DOE was characterized by measuring the spectrum for three wavelengths ($\lambda 1 = 450$ nm, $\lambda 2 = 550$ nm, $\lambda 3 = 650$ nm) as a function of position in the reconstruction plane.