Fabrication of diffraction textured substrate for DSSCs

Ryutaro Kimura[*1], Chiemi Oka[*1], Seiichi Hata[*1], Junpei Sakurai[*1]
Department of Micro/Nano Mechanical Science and Engineering, Nagoya University

E-mail: kimura.ryutaro.n1@s.mail.nagoya-u.ac.jp

DSSCs (Dye-sensitized solar cells) have the advantages of ease of structure, inexpensive material cost, and high designability through the selection of dyes. On the other hand, DSSCs have a problem of low conversion efficiency (~13.0%) whereas one common solar cell, Si photovoltaics' conversion efficiency reaches 27.6% [1]. From the above, it is necessary to increase the conversion efficiency of DSSCs to use them more generally.

Our study proposed the internal structure of DSSCs for their higher conversion efficiency (Figure 1). We previously focused on light management, including light trapping, anti-reflection, and reduction of electrical resistance by using front glass textured with micro-, and nano-sized random dimples, and their combination (μ-Tx, n-Tx, W-Tx) on the incident side of the DSSCs [2, 3]. The result showed a difference in the improvement tendency for each shape (W-Tx was the best for DSSCs using N719 dye), and this suggests a correlation between the texture's shape and the dye's absorption wavelength.

From the result, in this study, we aimed to use the incident light of DSSCs' dye absorption wavelength more efficiently by fabricating a textured substrate that diffracts such a wavelength with high intensity and wide angle. From the optical simulation, the hole diffraction texture (Dif-Tx) of pitch 1400 nm and hole diameter 840 nm was determined.

The Dif-Tx substrate was fabricated with solvent-assisted room-temperature nanoimprinting on a glass substrate. The fabricated texture had a pitch of 1400 nm, a hole diameter of 980 nm, and a hole depth of 650 nm, the hole diameter was deviating from the intended design due to variations in the fabrication process (Figure 3).

After depositing FTO on the Dif-Tx substrate, diffusion transmittance (Figure 4) and sheet electrical resistance were measured. The diffusion transmittance of the FTO-coated Dif-Tx substrate was superior to that of the FTO-coated W-Tx. However, FTO on Dif-Tx had a higher rate of resistance increase compared to that on W-Tx. The higher resistance of the FTO on Dif-Tx was due to the insufficient connection of the layer (Figure 5).

DSSCs using Dif-Tx recorded 1.18 times the conversion efficiency of the non-textured one, while W-Tx recorded 1.26 times (Table 1). This is because the superior diffuse transmittance and higher resistance of Dif-Tx offset each other.

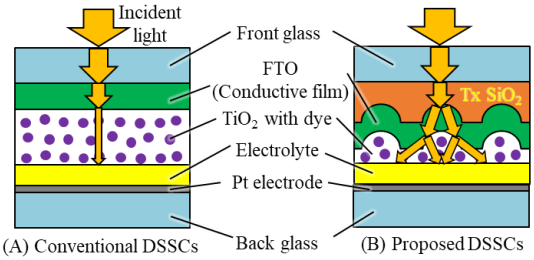

Figure 1 Schematics of DSSCs

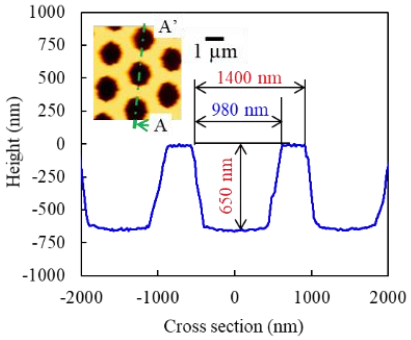

Figure 2 Actual shape of Dif-Tx on the glass substrate

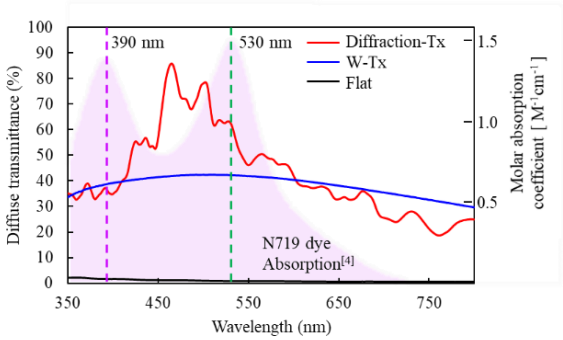

Figure 3 Diffuse transmittance of FTO-coated Dif-Tx, W-Tx

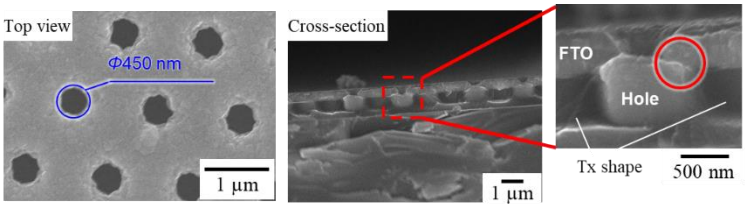

Figure 4 The top and cross-section view of FTO on Dif-Tx

Table 1 The performances of DSSCs Tx substrates

	This study		Previous study	
	Flat	Diff-Tx	Flat	W-Tx
η (%)	1.71	2.02 (1.18 times)	2.55	3.22 (1.26 times)
J_{sc} (mA/cm^2)	4.75	5.62	6.83	9.22
V_{oc} (V)	0.62	0.63	0.65	0.64
FF	0.64	0.64	0.57	0.54

[1] Green, Martin, et al. "Solar cell efficiency tables (version 57)." Progress in photovoltaics: research and applications 29.1 (2021): 3-15.

[2] Yang, Na, et al. "Fabrication of textured substrates for dye-sensitized solar cells using polydimethylsiloxane nanoimprint lithography." Advanced Optical Technologies 8.6 (2019): 491-497.

[3] Ryutaro, Kimura, et al. “Effect of Textured Glasses on Conversion Efficiency in Dye-Sensitized Solar Cells”, Advanced Optical Technologies, submit (2023)

[4] Fujikura Ltd., Takashi Yamaguchi, 'Dye-sensitized solar cells module,' Japanese Patent No. JP5712108B2, March 13, 2015.