Developing highly transparent colored reflectors for building-integrated photovoltaics (BIPV)

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Introduction

1. BIPV combines photovoltaics and buildings.
2. Colors of conventional PV modules are dark.
Therefore: aesthetic appearance with favorable colors is essential for BIPV applications

Swedish Research Institute[4] Port of Singapore[4]

Covering colored glasses is one of the applicable methods to achieve colored PV modules

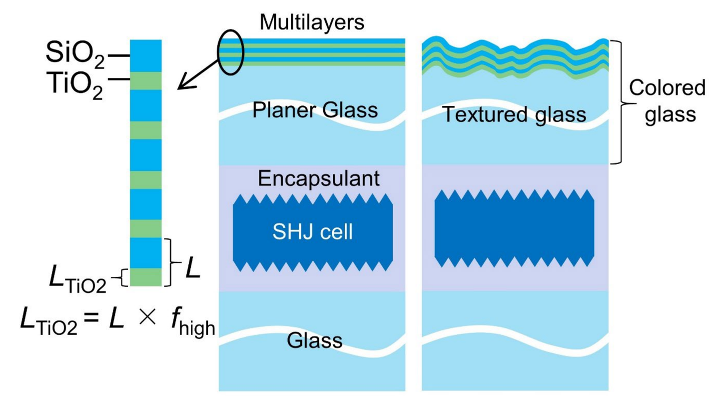
- Chemical pigments[5]:
  NG: degradation
  Sensitive to UV, T, and H
- Structured colors[6]:
  NG: nonuniform colors
  Sensitive to angles

In this study, we focus on structured colored glass

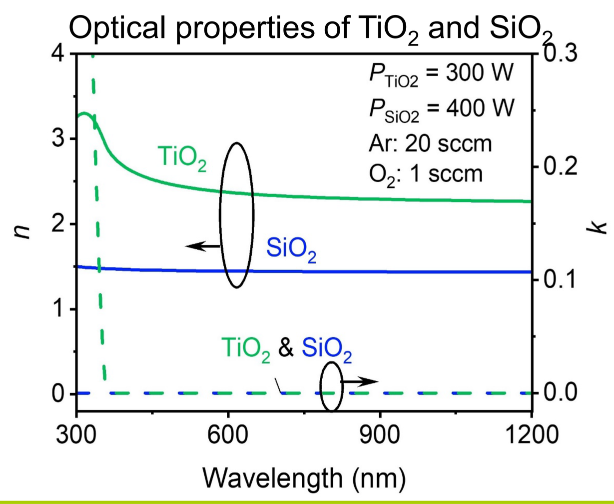
Purpose: Fabrication of colored glasses & high η colored PV modules
Method: Dielectric multilayers + Texturing glass sheet + Encapsulation with cells.

Experiment

- Optical simulation: RSoft (RCWA)
- Sample preparation
  - Planer and textured (sandblasted) glasses
  - Multilayers with TiO_2 and SiO_2 (RF sputtering)
  - Mini-modules with SHJ cells
- Characterization
  - Ellipsometry
  - UV/VIS spectrometer
  - Laser microscope
  - J-V

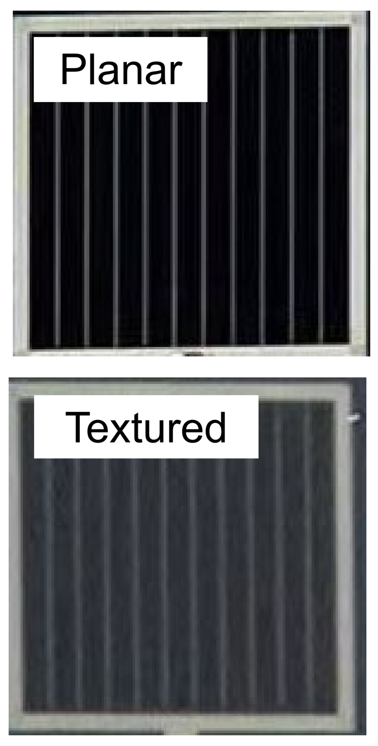


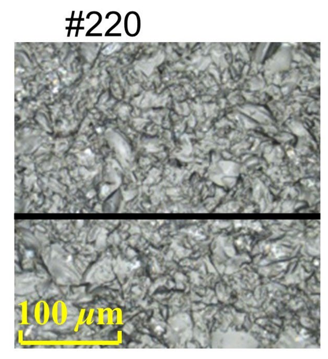
Multilayer parameters: f_{high} and L

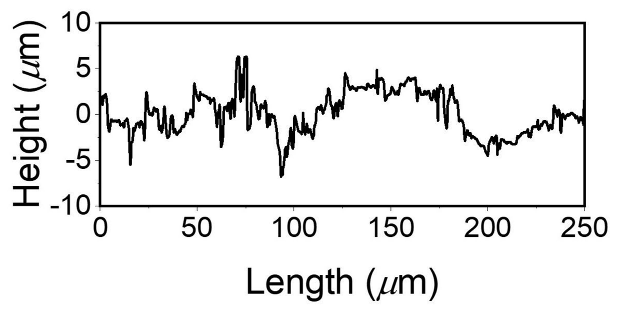


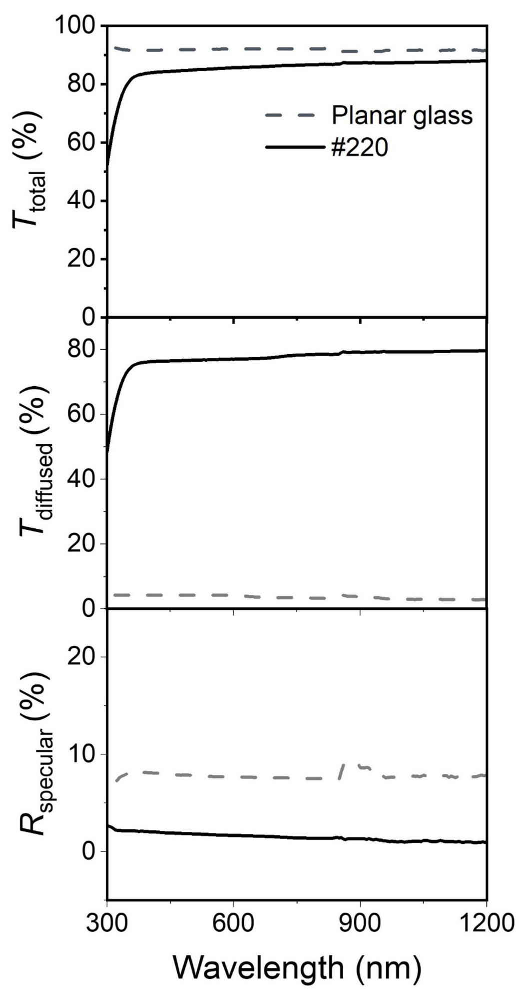
Results and discussion I

- Comparison of planer/textured glasses
  - Textured glass sheets prepared by the sandblasting (#220) show rough surface, highly diffusive surface.

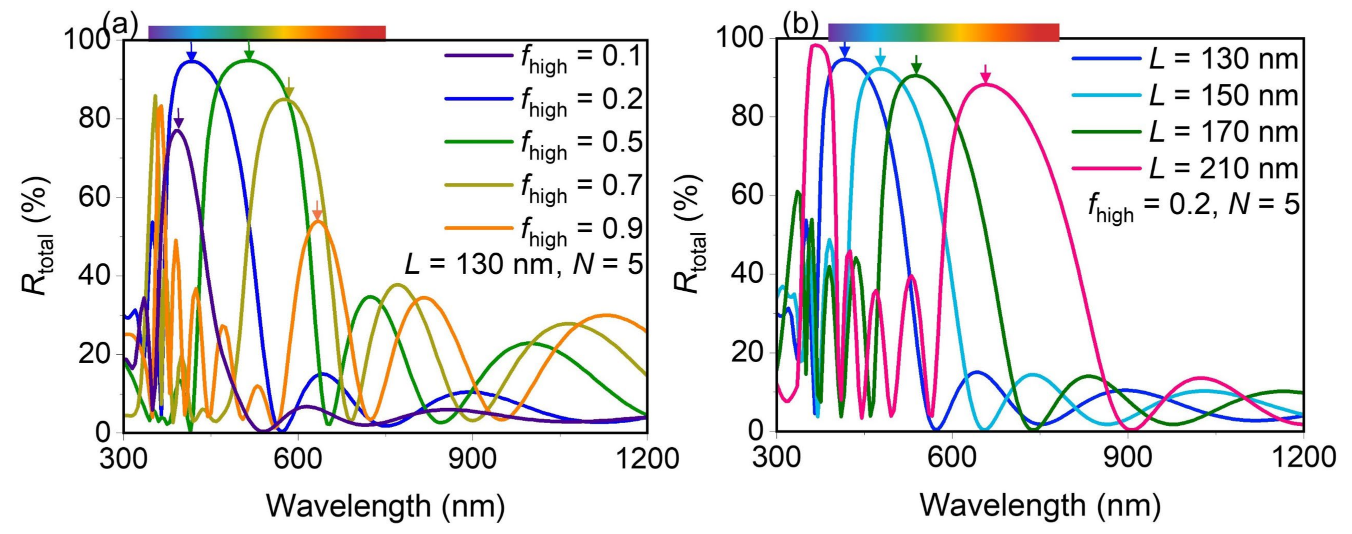








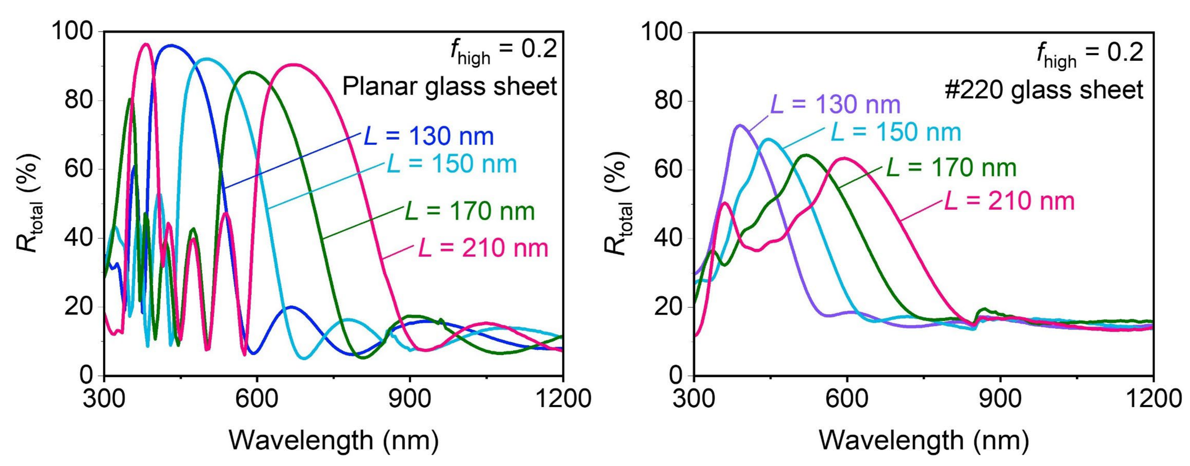
- Optical simulation results
  - TiO_2/SiO_2 Multilayers (MLs) on planer glass, 10 layers (fixed)

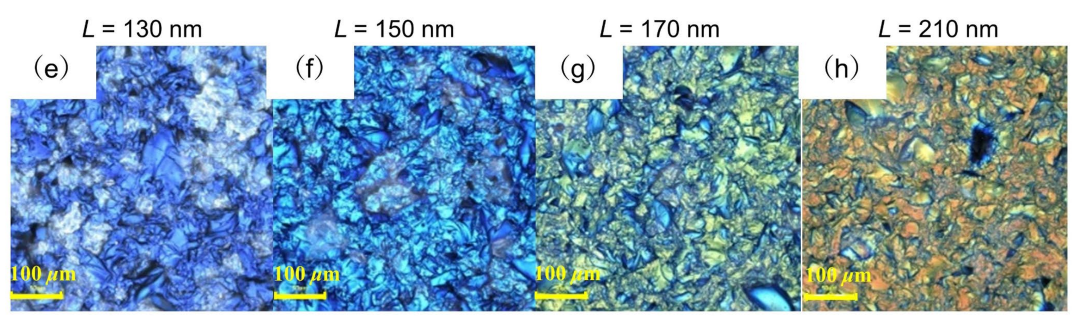


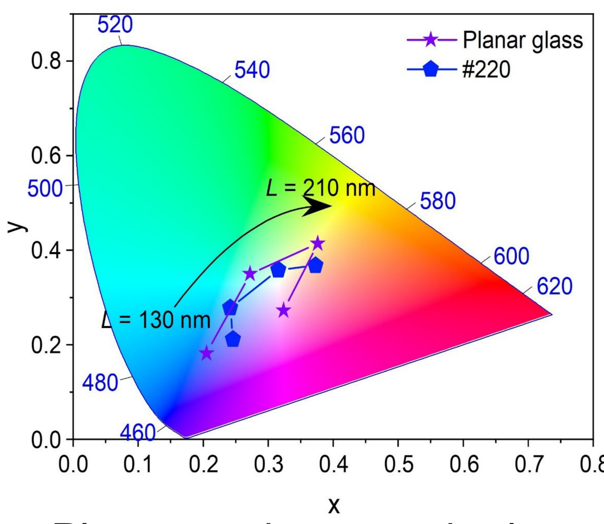
1. The width, the height and the position of the main R peak are strongly dependent on f_{high} and L, according to the interference principle
2. We choose $f_{high} = 0.2$ to fulfill a distinguishable color and an acceptable optical loss.
3. The R peak is shifted to longer λ with increasing of L, indicating that color is widely controllable.

Results and discussion II

- Fabrication and characterization of MLs on planar and textured (#220) glass sheets



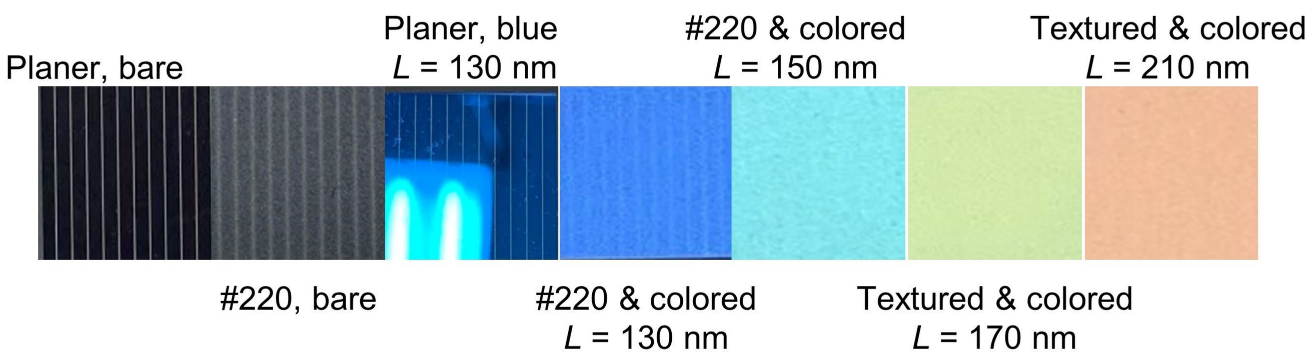




Planar and textured glasses with wide range of colors, from blue to red are achieved.

Next: Encapsulation with cells

- Colored minimodules



Glass type	MLs	J_{SC} (mA/cm²)	V_{OC} (V)	FF	η (%)	Δη (rel. %)
Planar	Bare	39.1	0.710	0.800	21.7	−0.0
	Blue (L = 130nm)	29.5	0.710	0.801	16.4	−24.6
Textured (#220)	Bare	35.8	0.713	0.801	20.6	−4.9
	Violet (L = 130 nm)	32.5	0.712	0.804	18.1	−16.5
	Cyan (L = 150 nm)	32.2	0.711	0.798	18.2	−16.3
	Green (L = 170 nm)	29.7	0.710	0.803	17.2	−20.9
	Orange (L = 210 nm)	27.5	0.711	0.802	15.5	−28.4

Conclusion & Next plan

- Conclusion:
1. We investigated the possibility of color control in PV modules for BIPV applications by means of structural colors (TiO_2/SiO_2 multilayers).
2. The hues of colored glasses are widely controllable by simply varying the layer parameters, even on textured glasses.
3. Colored textured glasses show more uniform appearance with anti-glare effect.
4. Colored modules with violet, cyan, green and orange with efficiencies from 15% to 18% were successfully developed.

- Next plan:
Overcoming the nonuniform colors due to different incident light angles.
Reduction of optical loss by colored glasses using optimization of structure of MLs.

References

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Acknowledgement

This project is financially supported by NEDO.
The authors would like to thank Y. Sato, M. Tanabe, T. Oku for sample preparation and technical support.