Fire Test and Thermal Properties Test of BIPV

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Contents

• Introduction of LIXIL
• Fire Protection Test of BIPV
• Thermal Properties Test of BIPV
LIXIL GROUP Information

- **Revenue**: $15.9B
- **Core Earnings**: $787M

**Evolution into a Global Group**
- 2012: $11.5 Billion
- 2017: $15.9 Billion

**Factories by Country and Region**
- EMEANA: 9
- Japan: 44
- Americas: 12
- APAC: 32
- Rest of Africa: 4

**Total 101 bases**

**R&D Investment**
- The LIXIL Group is expanding investment in R&D to enhance our range of globally competitive products.

**R&D Spend**
- JGAAP: $137M, $125M, $155M, $162M, $227M, $235M
- IFRS: $12, $13, $14, $15, $16, $17

**LIXIL Group Corporation**
- President & CEO: Kinya Seto
- Securities Code: 5938
- Registered Office: 2-1-1 Ojima, Koto-ku, Tokyo 136-8535, Japan
- Head office: 36F, 3-2-5 Kasumigaseki, Chiyoda-ku, Tokyo 100-6036, Japan
- Established: September 19, 1949
- Number of Employees: 58,248 (consolidated basis: As of March 31, 2017)
- Capital: 88.1 billion yen
- Fiscal Year-end: March 31
- Shares outstanding: 313,054,255

**Business Alliance**
- JXTG Nippon Oil & Energy
- Haier
- LG
- AGC

**Capital Alliance**
- Sharp
- Edion

**Joint Corporation**
- Secual
- Leapofco 21
- LIXIL
- Haier
- TEPCO
- AGC Glass Products
- LIXIL Window Products
- AGC-LIXIL Window Technology
Business Domain

- **LIXIL Water Technology**
- **LIXIL Kitchen Technology**
- **LIXIL Building Technology**
- **LIXIL Housing Technology**
Mega Solar Power Plant

AYABE Solar Power  KYOTO Pref.
4.78MW 4600MWh/a  Sep. 2015

SUKAGAWA Solar Power  FUKUSHIMA Pref.
6.35MW 7,800MWh/a  May. 2014

3.75MW 3,800MWh/a  Jan. 2011

AYABE Solar Power  KYOTO Pref.
4.78MW 4600MWh/a  Sep. 2015

TSUKUBA Solar Power  IBARAKI Pref.
3.75MW 3,800MWh/a  Jan. 2011

ARIAKE Solar Power  KUMAMOTO Pref.
3.75MW 3900MWh/a  Jan. 2011

CHITA Solar Power  AICHI Pref.
5.2MW 6000MWh/a  Sep. 2015
BIPV and BAPV for Detached House
BIPV for Commercial Building
Contents

• Introduction of LIXIL
• Fire Protection Experiment of BIPV
• Thermal Properties Experiment of BIPV
Positioning of BIPV

- BIPV module ÷ lamented glass?
- These Plates should be containing as the curtain wall system.
- BIPV requires the same performance as curtain wall.
Purpose of Fire Test

- The *flame insulation property* of facade is required corresponding for flames from outside and inside.

- CW are required *flame insulation property* of 20min.
Fire Test Method

- heating was carried out according to the ISO 834 and the following measurements were conducted.

- Measurement of *heating temperature*
- Measurement of *specimen temperature*
- Measurement of *radiation heat absorption*
- *Visual observation* of specimen during heating

COMPARISON

- Laminated glass
- PV module
- Mono-CS
- Thin film CS
Fire Test Equipment
Specimens

[Diagram showing measurements and labels]
Module

Mono-Crystalline Silicon

Thin film Crystalline Silicon
Set up specimen
Measurement Point of Frame
Measurement Point of Module and Glass
Details

- This specimen did not use the heat insulating material
Exposed to the fire

Thin film crystalline silicon (5m00s)
- Cracks occurred (3m35s)
- Cracks occurred BM (3m50s)

Mono-crystalline silicon (6m00s)
- Cracks occurred (4m38s)
- Cracks occurred BM (5m38s)
Exposed to the fire

- Thin film crystalline silicon (10m00s)
  - Cracks occurred annealed (6m20s)
  - Annealed glass fell off (8m00s)
- Mono-crystalline silicon (10m00s)
  - Cracks occurred T Glass (7m30s)
  - PV Cells began to melt & flow (9m00s)
Exposed to the fire

- Thin film crystalline silicon (15m00s)
  - PV Cells began to melt & flow (13m)
- Mono-crystalline silicon (17m45s)
  - Tempered glass fell off (15m00s)
Exposed to the fire

Thin film crystalline silicon (16m00s)
• The flame have blown out exceeding 10 sec. from the cracked portion of the non-heated side the BM (16m00s)

Mono-crystalline silicon (18m00s)
• The flame have blown out exceeding 10 sec. from the bottom frame of the non-heated side (17m45s)
Exposed to the fire

Thin film crystalline silicon (19m00s)
• The fire test was discontinued due to expand of flame blow out area.

Mono-crystalline silicon (20m00s)
• This photo indicates non heating side when the fire test has finished.
After Test Specimens

Thin film crystalline silicon
• This photo indicates each specimen state on heating side after fire test regarding each specimen.

Mono-crystalline silicon
Result of Fire Test

- Temperature behavior of BM and PV are similar.
- There is not severe problem of BIPV.
Conclusion and Future Task

- It is clarified that the BIPV module is more likely to be handled in the same way as the conventional laminated glass.
- I’ll conduct coupling numerical analysis and verify it.
Contents

- Introduction of LIXIL
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Introduction

Each country aims at Zero Energy Building by 2020-2030

Reference: H.ISHII: Study on application of Four Sided Structural Sealant Glazing Systems in Japan
ASTM international Selected Technical Paper 2014 6
Definition of ZEB in Japan

In the early stage towards Net ZEB, ZEB ready is defined as a 50% reduction in energy consumption.

Facade Required due to ZEB

In order to realize ZEB, efforts to reduce energy consumption and the use of renewable energy are important.

“BIPV” is necessary to realize both.

Evaluation of Thermal Properties on Facade

The performance of the facade is mainly mentioned by **G-value** and **U-value**.

**G-value**, **U-value** are most important in the facade. **G-value** means thermal insulation. **Heat Loss**

**U-value** means Solar Heat Gain Coefficient. **Heat Load**

Evaluation of G-value and U-value in “**BIPV**” is necessary.
Role of BIPV

Actual Role of BIPV as follows. ③,④ are hypothesis.

① power generation, ② shading sunlight (e.g. G-value)

③ reduce heat load due to power generation
   mitigate the sensible heat load to urban.
   G-value should be different depending on the presence or absence of power generation according to the law of conservation of energy.

④ BIPV Module is Equivalent to Conventional Glass
   BIPV doesn't depend on aperture ratio and the cell distance
Hypothesis Regarding G-value

The BIPV module absorbs the near infrared ray in the solar spectrum by the photoelectric effect.

It would be a waste to throw it away. Let's evaluate it effectively.
Verification of Hypothesis

We conducted an experiment to demonstrate the hypothesis. Experiment of G value was conducted in the power generation state.

<table>
<thead>
<tr>
<th>Established period of the test method</th>
<th>JSTM K 6101</th>
<th>ISO 19467</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conducted period of the test</td>
<td>2013 revised</td>
<td>2017</td>
</tr>
<tr>
<td>Continuous wave or not</td>
<td>2015-2016</td>
<td>Just under way</td>
</tr>
<tr>
<td>Article sun light</td>
<td>AC</td>
<td>DC</td>
</tr>
<tr>
<td>Wave length of article sun</td>
<td>Xenon arc lamp</td>
<td>Xenon arc lamp</td>
</tr>
<tr>
<td>Measurement while power generation</td>
<td>✓</td>
<td></td>
</tr>
</tbody>
</table>

JSTM K 6101, Soka Saitama Japan

ISO 19467, Tsukuba Ibaraki Japan
**Experiment of G-value**

**G-value** was carried out according to JSTM K 6101 artificial sun. **We created new test method of G-value for BIPV.** It is noteworthy that there is a **load resistance device.**

---

Experiment of G-value

Glass Constitution for Experiment

Conventional Float Glass

- BM: Benchmark
  - 1. Laminate Transparent Glass
  - 2. IGU

- Normal BIPV
  - 3. Laminate BIPV Module
  - 4. IGU

- Wide Inter cell Distance
  - 5. Laminate BIPV Module Wide Size
  - 6. IGU

Low-E Coated Glass

- 7. Summer Transparent Glass
- 8. Winter Transparent Glass

- Aperture Ratio 100%
- Aperture Ratio 20-40%
- Aperture Ratio 20-40%
Experiment Parameter of G-value

BM Benchmark
①, ②, ⑦, ⑧
BM 100%

Module size is W 1025mm × H 1025mm
W, H indicates the inter-cell distance
Normal Size for G-value W × H = 10 × 10mm
Wide Size for G-value W × H = 20 × 20mm

G-value

②, ④, ⑨, ⑩ See Glass Constitution

①, ⑥, ⑪, ⑫

## Experimental Result of G-value

<table>
<thead>
<tr>
<th>Glass Types</th>
<th>Laminated</th>
<th>IGU (not Low-E)</th>
<th>Low-E Coated IGU</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Aperture Ratio (%)</strong></td>
<td><strong>G-value</strong></td>
<td><strong>Ratio</strong></td>
<td><strong>G-value</strong></td>
</tr>
<tr>
<td>100 BM</td>
<td>-</td>
<td>0.77</td>
<td>1.00</td>
</tr>
<tr>
<td>20 BIPV Open</td>
<td>③</td>
<td>0.40</td>
<td>0.52</td>
</tr>
<tr>
<td>Closed</td>
<td>③</td>
<td>0.38</td>
<td>0.49</td>
</tr>
<tr>
<td>30 BIPV Open</td>
<td>③</td>
<td>0.44</td>
<td>0.57</td>
</tr>
<tr>
<td>Closed</td>
<td>③</td>
<td>0.43</td>
<td>0.56</td>
</tr>
<tr>
<td>40 BIPV Open</td>
<td>③</td>
<td>0.46</td>
<td>0.60</td>
</tr>
<tr>
<td>Closed</td>
<td>③</td>
<td>0.43</td>
<td>0.56</td>
</tr>
<tr>
<td>30 Wide BIPV Open</td>
<td>⑤</td>
<td>0.43</td>
<td>0.56</td>
</tr>
<tr>
<td>Closed</td>
<td>⑤</td>
<td>0.42</td>
<td>0.55</td>
</tr>
</tbody>
</table>

**G value** is enable to **improve by power generation.**
Surface Temperature of G-value (Low-E coated glass)

<table>
<thead>
<tr>
<th></th>
<th>⑨ Laminated IGU</th>
<th>⑩ Laminated IGU</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Ｇ glass</td>
<td>ział</td>
</tr>
<tr>
<td>⑩ 20% Open</td>
<td>59.0</td>
<td>62.4</td>
</tr>
<tr>
<td>⑩ 20% Close</td>
<td>57.4</td>
<td>60.2</td>
</tr>
<tr>
<td>⑪ 30% Open</td>
<td>59.7</td>
<td>63.3</td>
</tr>
<tr>
<td>⑪ 30% Close</td>
<td>56.4</td>
<td>59.8</td>
</tr>
<tr>
<td>⑫ 40% Open</td>
<td>60.9</td>
<td>64.4</td>
</tr>
<tr>
<td>⑫ 40% Close</td>
<td>57.8</td>
<td>61.0</td>
</tr>
</tbody>
</table>

Surface temperature of closed circuit (generated) is lower than open circuit (not generated).
Hypothesis Regarding U-value

The **U-value** should not be affected due to the thermal conductivity (\(\lambda\)) of the cell is high. That is, the thermal resistance (\(R\)) is small.

\[
U = \frac{1}{R} = \frac{1}{\sum \frac{\delta_j}{\alpha_i} + \frac{1}{\lambda_j} + \frac{1}{C_a} + \frac{1}{\alpha_o}}
\]

<table>
<thead>
<tr>
<th>e.g.</th>
<th>(\lambda) [W/m(\cdot)K]</th>
<th>(\delta) [m]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Silicone</td>
<td>160</td>
<td>0.0002</td>
</tr>
<tr>
<td>Glass</td>
<td>1</td>
<td>0.0050</td>
</tr>
<tr>
<td>EVA</td>
<td>0.28</td>
<td>0.0018</td>
</tr>
</tbody>
</table>

**Experiment of U-value**

**U-value** was evaluated according to JIS A 4710. JIS A 4710 is approx. Similar ISO 12567-1.

Experiment of U-value

Experiment of U-value

Experiment Parameter of U-value

# Experimental Result of U-value

<table>
<thead>
<tr>
<th>Glass Types</th>
<th>Laminated</th>
<th>IGU</th>
<th>Low-E coated IGU</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Aperture Ratio (%)</td>
<td>Not Low-E (W/m²·K)</td>
<td>Not Low-E (W/m²·K)</td>
</tr>
<tr>
<td></td>
<td>100 BM</td>
<td>① 5.12</td>
<td>② 3.11</td>
</tr>
<tr>
<td></td>
<td>20 BIPV</td>
<td>③ 5.09</td>
<td>④ 3.15</td>
</tr>
<tr>
<td></td>
<td>30 BIPV</td>
<td>③ 5.08</td>
<td>④ 2.96</td>
</tr>
<tr>
<td></td>
<td>40 BIPV</td>
<td>③ 5.14</td>
<td>④ 2.99</td>
</tr>
<tr>
<td></td>
<td>30 Wide BIPV</td>
<td>⑤ 5.08</td>
<td>⑥ 3.06</td>
</tr>
</tbody>
</table>

**U value** is **Equivalent to Conventional Glass**

**U value** doesn’t **depend on aperture ratio** and the **cell distance**.
CONCLUSION

• **G value** in BIPV **improves** by **1.6 to 2.9 times** compared with BM.
• **G value** is enable to **improve by power generation**.
• **G value improves** the max. **12% by the law of energy conservation**.
• We could **prove** the **hypothesis** regarding Near infrared region of the solar spectrum was converted by photoelectric effect.
• **U value** is **Equivalent to Conventional Glass**.
• **U value** doesn't **depend** on **aperture ratio** and the **cell distance**.

• In the future, the consistency with ISO or IEC is aimed at and the new evaluation method of thermal properties in BIPV is to be proposed.
Acknowledgements

This research is based on the result of the international standardization of international standard development BIPV power generation module of 2015 fiscal year entrusted project by Ministry of Economy, Trade and Industry (METI). We’d like to express our gratitude to everyone for your great cooperation. And also, Thank you for colleagues. Dr. Michio. Kondo (AIST), Masafumi. Saito (TAISEI Corporation.), Hiroko. Saito (PVTEC), Jiro. Ohno (Architect former NIHON SEKKEI Inc.) and Masayuki. Hayashi (AGC)