Yamagata University Organic Thin Film Device Consortium

Greeting

“Yamagata University Organic Thin Film Device Consortium” [*] has developed “Flexible Substrates with Alternative Electrode of ITO (Indium Thin Oxide) for Organic Electronics” by university-industry collaboration. In this exhibition, the developed technologies and prototype OLED devices are demonstrated. The next consortium “Yamagata University Flexible Organic Electronics Practical Kay Technology Consortium (YU-FOC) are planned to be started in April 2016 as three years program. [*] supported by “R&D subsidiary program for promotion of academia-industry cooperation” of Ministry of Economy, Trade and Industry of Japan.

R&D Subjects

“Flexible Substrates with Alternative Electrode of ITO (Indium Thin Oxide) for Organic Electronics”
- Flexible substrates for organic electronics (ultra-thin glass, stainless steel foil, plastic film)
- Alternative electrodes of ITO
- Roll to roll (R2R) technologies

Project term

April 2013 – March 2016

R&D Contents

- Solution materials
- Evaporation materials
- Ultra-thin glass
- Stainless steel foil
- Plastic film
- Non-ITO transparent electrode
- Barrier / Planarization
- Flexible substrate

Features

- Technology Integration based on collaboration among companies with various technologies
  * substrates, materials, printing, equipment, devices, etc.
- Initiative of Yamagata University
  * Leaders are experts who left private companies.
- Introduction of original Roll-to-roll (R2R) equipment
- Contribution to the revival from 2011 Tohoku earthquake

Main members

- Prof. Dr. M. Koden (Project leader)
- Prof. H. Nakada (Technical fellow)
- Associate Prof. T. Furukawa (R2R technologies, printing)
- Associate Prof. Dr. T. Yuki (Non-ITO technologies)
- Associate Prof. Dr. H. Kobayashi (Flexible substrates)

Participating Companies (Jan. 2016)

- Dexerials
- DIC
- DNP
- FEBACS
- JNC
- Kaneka
- KOBELCO
- Koito Manufacturing
- Komori Machinery
- Merck Performance Materials Manufacturing
- Mitsubishi Materials
- Mitsubishi Plastics
- NEC Lighting
- Nippon Electric Glass
- NIPPON STEEL & SUMITOMO METAL / NIPPON STEEL & SUMIKIN MATERIALS
- Okura Industrial
- ISERIA
- Shin-Etsu Chemical
- Taiyo Kikai
- Teijin
- ZEON CORPORATION

Website

http://inoel.yz.yamagata-u.ac.jp/F-consortium/index2.htm

Prototypes

- Flexible OLED on ultra-thin glass
- Flexible OLED on stainless steel foil
- Flexible OLED on barrier film
- OLED with non-ITO transparent electrode

(Roll-to-R process is shown below.

- Sputtering and CVD (KOBELCO)
- Screen printing (SERIA)
- Gravure offset and Flexography printing (Komori Machinery / Taiyo Kikai)
- Wet clearing (FEBACS)

“Printable Electronics 2016”
(January 27-29, 2016, Tokyo Big Sight)
Flexible OLED lighting devices with ultra-thin glass

- **Features of ultra-thin glass**:
  - Flexibility (applicable to R2R)
  - Excellent gas barrier property, excellent temperature resistance, excellent chemical resistance, smooth surface, low thermal expansion, etc.

Flexible OLED lighting device (92mm□) with ultra-thin glass (fabricated by NEC Lighting)

Flexible OLED device with ultra-thin glass (supported with protecting film)

Flexible ultra-thin glass (Nippon Electric Glass)
- Ultra-thin glass roll (thickness: 50mm)
- Excellent gas barrier
- Excellent thermal stability
- Excellent chemical stability
- Smooth surface

Novel protecting film for ultra-thin glass (Mitsubishi Plastics)

Common protecting film with ultra-thin glass
- Large cracks

Novel protecting film with ultra-thin glass
- Small cracks

Contact:
Prof. M. Koden
koden@yz.yamagata-u.ac.jp

URL:
http://inoel.yz.yamagata-u.ac.jp/F-consortium/index2.htm

TEL: +81-238-29-0575
FAX: +81-238-29-0569

*OLED panel: fabricated by NEC Lighting Ltd.
UniversalPHOLED® Phosphorescent OLED Technology and Materials from Universal Display Corporation
*Ultra-thin glass: Nippon Electric Glass Co., Ltd.
*Stainless steel foil: NIPPON STEEL & SUMITOMO METAL CORPORATION Group

Substrate size: 92mm X 92mm
Emission area: 75mm X 75mm
Substrate size: 50mm X 50mm
Emission area: 32mm X 32mm
Flexible OLED lighting devices with stainless steel foil

Features of stainless steel foil

- Flexibility (applicable to R2R)
- Excellent gas barrier property, excellent temperature resistance, excellent chemical resistance, low thermal expansion, etc.
- Smooth surface with novel planarization layer developed by NIPPON STEEL & SUMITOMO METAL CORPORATION Group

Flexible OLED panel fabricated on stainless steel foil (NIPPON STEEL & SUMITOMO METAL CORPORATION Group / Yamagata University)

![Flexible OLED panel](image)

- **Ra:** 6.2nm / **Rmax:** 78.2nm
- **Ra:** 0.6nm / **Rmax:** 8.9nm

(a) Without planarization layer
(b) With Planarization layer

<table>
<thead>
<tr>
<th>Flexible film [*]</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Encapsulating layer [</strong>]**</td>
</tr>
<tr>
<td>Ag (20nm)</td>
</tr>
<tr>
<td>Au (1.5nm)</td>
</tr>
<tr>
<td>DPB:Liq (25%) (44nm)</td>
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<tr>
<td>Alq3:C545T (1%) (30nm)</td>
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<tr>
<td>HTL (40nm)</td>
</tr>
<tr>
<td>MoO3 (5nm)</td>
</tr>
<tr>
<td>ITO (10nm)</td>
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<tr>
<td>HP Planarization layer (3.0µm)</td>
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<tr>
<td>Stainless steel foil (50µm)</td>
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</tbody>
</table>

[*] supplied from Ajinomoto Fine-Techno


Flexible OLED lighting device (92mm□) with stainless steel foil (fabricated by NEC Lighting)

- **Substrate size:** 92mm X 92mm
- **Emission area:** 75mm X 75mm

*OLED panel:* fabricated by NEC Lighting Ltd.
*UniversalPHOLED® Phosphorescent OLED Technology and Materials from Universal Display Corporation*
*Stainless steel foil: NIPPON STEEL & SUMITOMO METAL CORPORATION Group*

Substrate size : 50mm X 50mm
Emission area : 32mm X 32mm
Flexible OLED lighting devices with novel barrier film

**Feature of novel barrier film**

- Novel barrier layer with only 2 layer consisting of one vacuum deposited and one wet coated layers (Teijin, KOBELCO, Merck PM-M, Yamagata University)

OLED device with novel barrier film consisting of only two barrier layers (Teijin, KOBELCO, Merck PM-M, FEBACS, Yamagata University)

Flexible OLED lighting device (92mm □) with barrier film (fabricated by NEC Lighting)

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**Flexible film [*]**
- Encapsulating layer [*]
  - Al (800nm)
  - DPB:Liq (25%) (44nm)
  - Alq:C545T (1%) (30nm)
  - α-NPD (80nm)
  - HIL (60nm)
- Wet barrier layer
- Dry barrier layer
- PEN (100μm)

[*] Laminate encapsulation (Kaneka)

**WVTR[*]** by Ca corrosion method

- **(40°C 90%RH)**
- WVTR = 1.6 × 10^-5 g/m²/day

**OLED storage test (60°C 90%RH)**

- Encapsulation with barrier film
- Encapsulation with glass

 [*] WVTR: Water Vapor Transmission Rate

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**Flexible OLED lighting device (92mm □) with barrier film (fabricated by NEC Lighting)**

**Stainless steel foil (50μm)**
- Fill material
- Cathode
- Organic layers (plural layers)
- IZO (130nm)
- HIL (60nm)
- Al (800nm)
- Dry barrier layer
- a-NPD (80nm)
- Alq:C545T (1%) (30nm)
- DPB:Liq (25%) (44nm)
- PEN (100μm)

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**UniversalPHOLED® Phosphorescent OLED Technology and Materials from Universal Display Corporation**

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**Contact**

- Prof. M. Koden
- koden@yz.yamagata-u.ac.jp
- Prof. H. Nakada
- nakada@yz.yamagata-u.ac.jp
- URL: http://inoel.yz.yamagata-u.ac.jp/F-consortium/index2.htm
- TEL: +81-238-29-0575
- FAX: +81-238-29-0569

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OLED lighting devices with non-ITO transparent electrode

Issues of ITO (Indium Tin Oxide):
- Cost • • ○ vacuum evaporation + photolithography, ○ rare metal (In)
- Brittle in bending

OLED lighting device using non-ITO electrodes fabricated by printing
(DNP, DIC, Komori Machinery, SERIA, Taiyo Kikai, FEBACS, Nippon Electric Glass, Yamagata University)

*① Supplied from Ajinomoto Fine-Techno
*② developed by Nippon Electric Glass
*③ developed by Mitsubishi Plastics

Substrate size: 50mm X 50mm
Emission area: 32mm X 32mm

OLED lighting device with non-ITO electrodes consisting of silver nanowire (AgNW) and transparent conducting polymer

Substrate size: 50mm X 50mm
Emission area: 32mm X 32mm

“Printable Electronics 2016”
(January 27-29, 2016, Tokyo Big Sight)
A new consortium “Yamagata University Flexible Organic Practical Key Technology Consortium (YU-FOC)” is planned to start in April 2016, aiming at academia/industry collaboration on flexible organic electronics. This consortium is a three year program, based on the activity of the current “Yamagata University Organic Thin Film Consortium (FY2013-2015) [*]”. This consortium is planned to develop practical key technologies which contributes to business of participating companies and to expansion of flexible organic electronics industry.

[*] http://inoel.yz.yamagata-u.ac.jp/F-consortium/index2.htm

1. Technology Integration for flexible organic electronics, based on collaboration among companies with various technologies (substrates, materials, printing, equipment, devices, etc.).
2. Business First! * Contribution to participating companies is first priority.
   * R&D in the consortium is based on the request from participating companies.

Contact
1-808-48 Arcadia, Yonezawa, Yamagata 992-0119, Japan
Innovation Center for Organic Electronics (INOEL)
Yamagata University
TEL +81-238-29-0575 FAX +81-238-29-0569
Prof. H. Nakada: nakada@yz.yamagata-u.ac.jp
Prof. M. Koden: koden@yz.yamagata-u.ac.jp
**Innovation Center for Organic Electronics**

**Yamagata University Flexible Organic Electronics Practical Key Technology Consortium (YU-FOC)**

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### Equipment of YU-FOC
- **Four original roll-to-roll (R2) equipment (Roll width: 30cm)**
- **Sheet-to-sheet printing equipment**

**Device fabrication equipment**
- Organic deposition
- Sputtering
- Vacuum laminator

**Analysis and evaluation equipment**
- Viscoelasticity measurement
- Hybrid confocal microscopy
- Precise position detector
- WVTR evaluation (Ca method)

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### Main members of YU-FOC

**Prof. Hitoshi Nakada**
- **Field:** Organic electronics device
- **E-mail:** nakada@yz.yamagata-u.ac.jp
- **Career:**
  - 1981 Graduated at Tohoku University
  - 1981~2013 Pioneer Corporation
  - 1988~2013 R&D of OLED display and OLED lighting
  - 2013~ INOEL, Yamagata University (current position)

**Associate Prof. Tadahiro Furukawa**
- **Field:** Fine patterning technology, Printing, Roll-to-roll technology
- **E-mail:** ta-furukawa@yz.yamagata-u.ac.jp
- **Career:**
  - 1984 Graduated at Saitama University (Master degree)
  - 1984~2011 Kyoto Printing Co., Ltd.
    - R&D and production of Color filter (CF)
    - R&D of flexible CF and LCD
  - 1988~2013 R&D of OLED display and OLED lighting
  - 2013~ INOEL, Yamagata University (current position)

**Associate Prof. Hideyuki Kobayashi (PhD)**
- **Field:** OLED, Thin film device, Physics
- **E-mail:** h-kobayashi@yz.yamagata-u.ac.jp
- **Career:**
  - 2000 Graduated at Tokyo Institute of Technology (PhD)
  - 2000~2003 Institute of Physical and Chemical Research (RIKEN)
  - 2003~2009 Fujifilm, Corporation, IMES, Rohm Co., Ltd. (R&D of OLED)
  - 2009~2013 Lumintec Inc. (OLED lighting manufacturing line, R&D of OLED)
  - 2013~ INOEL, Yamagata University (current position)

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**Prof. Mitsuhiro Koden (PhD)**
- **Field:** LCD, Display, OLED, Chemistry
- **Email:** koden@yz.yamagata-u.ac.jp
- **Career:**
  - 1983 Graduated at Osaka University (PhD)
  - 1983~2012 Sharp Corporation (Liquid crystal materials, LCD, OLED display, etc.)
  - 1998~2011 Guest prof. of Nara Institute of Science and Technology
  - 2012~ INOEL, Yamagata University (current position)

**Associate Prof. Toshinao Yuki (PhD)**
- **Field:** OLED (display, lighting, device), Polymer material engineering
- **E-mail:** t-yuki@yz.yamagata-u.ac.jp
- **Career:**
  - 1993~1996 Teijin Limited
  - 1996~1999 Graduated at Yamagata University (PhD).
  - 1999~2015 Tohoku Pioneer Corporation (PMOLED, AMOLED, Tiling OLED, OLED lighting, etc.)
  - 2015~ INOEL, Yamagata University (current position)

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**Collaboration with our members**
Collaboration with individual member is possible, being apart from YU-FOC.
Please to not hesitate to contact with us.

(Contact)
Prof. M. Koden koden@yz.yamagata-u.ac.jp
Prof. H. Nakada nakada@yz.yamagata-u.ac.jp
URL: http://inoel.yz.yamagata-u.ac.jp/F-consortium/index2.htm
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“Printable Electronics 2016”
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Publications

International conference

- M. Koden, SID’14 seminar (2014). (USA)
  "OLED Devices, Processes, Encapsulation, and Flexible Substrates”
- M. Koden, H. Nakada, Nanofair 2014 (2014). (Dresden) [Invited]
  "Flexible Substrate with alternative electrode of ITO for organic electronics”
  "Flexible Substrates and Alternative Electrodes of ITO for OLED Lighting”
  "Novel Roll-to-Roll Screen Printing Machine for Flexible Devices”
  "Patterned ITO Film by Roll-to-Roll Process on Ultra-thin Glass”
  "R2R Planarized Stainless Steel Foil for OLED Substrate”

Exhibition

- "Printable electronics 2014” (Jan. 2014)"
- "Printable electronics 2016” (Jan. 2015).
- "International Photonics Exhibition 2015” (Korea) (Oct. 2015).