INOEL Yamagata University Innovation Center for Organic Electronics

山形大学 Yamagata University

Research Group for Flexible Technologies (Nakada/Furukawa/Yuki/Koden)

Academia-Industry Cooperation "Needs First"

Research Group for Flexible Technologies (Nakada/Furukawa/Yuki/Koden)

2021

Professor
Hitoshi Nakada

Associate Professor
Tadahiro Furukawa

Associate Professor
Dr. Yoshihiro Yuki

Professor
Dr. Mitsuhiro Koden

"Award from Minister of State for Science and Technology Policy" Cabinet Office of Japan (2017)

Printable Electronics 2017 Award

JFlex Award (2019, 2020)

Homepage： https://inoel.yz.yamagata-u.ac.jp/F-consortium/home-e.html

INOEL Yamagata University Innovation Center for Organic Electronics

山形大学 Yamagata University

Research Group for Flexible Technologies (Nakada/Furukawa/Yuki/Koden)

Activity

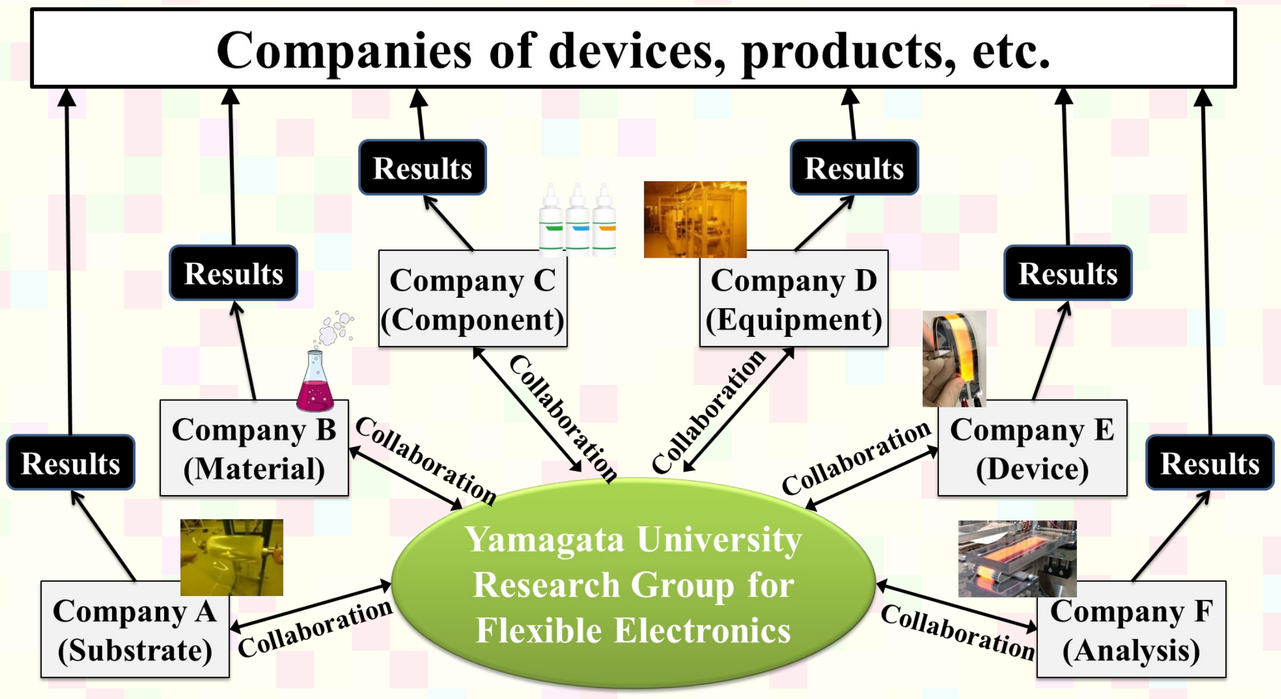
Academia-Industry Collaboration "Needs First!"

In flexible organic electronics technologies, we offer academia-industry collaboration with "Needs First", in which needs and requests from collaborating companies are first priority.
We contribute R&Ds of the collaborating companies, aiming at practical technologies and actual businesses.
Our activity with "Needs First" was awarded from Minister of State for Science and Technology Policy, Government of Japan in 2017.

"Award from Minister of State for Science and Technology Policy"
Cabinet Office,
Government of Japan (2017)

(Main technologies)

- Devices and processes of organic electronics (OLED, OPV, OTFT, etc.)
- Materials and components for flexible organic electronics
- Barrier technologies / Barrier evaluation and analysis / Flexible encapsulation
- Printing and roll-to-roll (R2R) technologies for flexible organic electronics



Collaboration scheme

Discussion
↓
Planning
↓
Contract
↓
Experiment, evaluation, etc.
↓
Feedback

Unique points

- "Needs First" (Business First)
  Company's needs are first priority.
- Merits in IPs
- Self-supporting accounting system
  An unique model based on collaboration with industry

Collaborations

- Device fabrication with collaborating company's technologies and feedback of all results to the company
- Data for proofing potential of the technologies of collaborating company.
- Prototype samples
- Coordination of plural companies
- Individual collaboration / Consortium / International collaboration

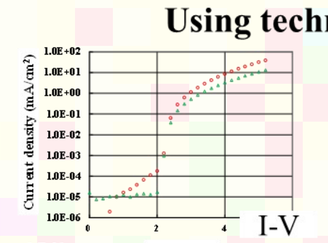
Skills of members

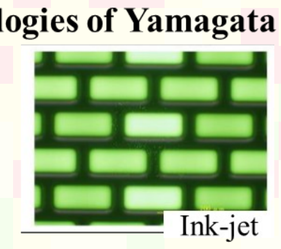
- Substantial experience in the practical development at previous companies.
- Rich knowledge on organic electronics (OLEDs etc.), displays, flexible, R2R, printing, etc.
- Rich information about trends of technologies and businesses.
- Rich human network in academic society and industrial fields.

Evaluation / Developmental support

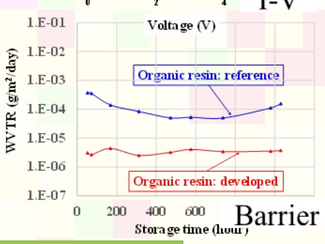
Company's technologies → Devices &evaluation → Feedback

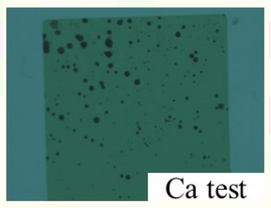
Using technologies of Yamagata Univ.

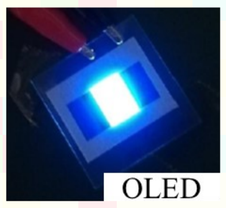



Ink-jet


Bending test



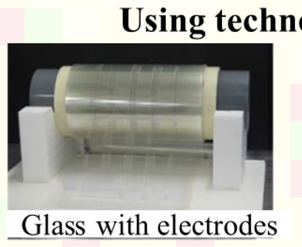

Ca test

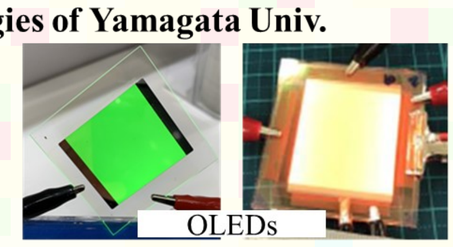

OLED

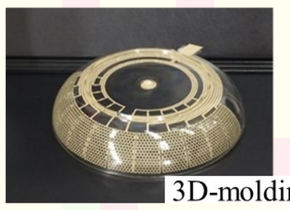
Prototype / Lab. sample

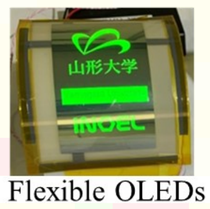
Company's technologies → Lab. samples → Utilizations in company

Using technologies of Yamagata Univ.


Glass with electrodes


OLEDs


3D-molding



Flexible OLEDs

Activities

- Academia-Industry Cooperation Consortium (p.3～p.5)
- National Project (p.3)
- Individual Collaboration
- Evaluation support (p.8) : WVTR (Water Vapor Transmission Rate) evaluation with MORESCO

Activity

Consortium / National Projects

Based on the concept of "Needs First", we promote academia-industry collaboration consortiums and participate various national projects.

Academia-Industry Collaboration Consortium

FY2013 FY2014 FY2015 FY2016 FY2017 FY2018 FY2019 FY2020 FY2021 FY2022

"Award from Minister of State for Science and Technology Policy", Cabinet Office, Government of Japan (2017)

Prof. Koden

Yamagata University Organic Thin Film Device Consortium

21 companies

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, SERIA, Shin-Etsu Chemical, Taiyo Kikai, Teijin, ZEON

Supported by MITI

Profs. Nakada & Koden

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

10 companies

FEBACS, Kaneka, The Japan Steel Works, NEC Lighting, Nippon Electric Glass, Nippon Steel & Sumitomo Metal / Nippon Steel & Sumikin Materials, SERIA, Shin-Etsu Chemical, TOYO INK, Teijin

Mr. Furukawa

Yamagata University Flexible Electronics Japan-Germany International Collaborative Practical Utilization Consortium (YU-FIC)

16 companies

FUJIKURA KASEI, The Japan Steel Works, KEIHIN RAMTECH, Mitsubishi Chemical, Mitsuboshi Diamond Industrial, Nippon Electric Glass, NIPPON STEEL Chemical & Material, Nishimu Electronics Industries, SEIEIDO PRINTING, SERIA ENGINEERING, SurFtech, Taica, TAKEDA PRINTING, TEIJIN, Tokyo Process Service, WIREDGATE

Dr. Yuki

Yamagata University Flexible Electronics Consortium for Academia-Industry Cooperation (YU-FLEC)

17 companies

Supported by MEXT

National Projects

FY2013 FY2014 FY2015 FY2016 FY2017 FY2018 FY2019 FY2020 FY2021 FY2022

MEXT: Regional Innovation Strategy Support Program

MEXT: Regional Innovation Eco-system Program

MEXT: Construction Program of Open Innovation Organization

JST: A-STEP

JST: OPERA Program Grant Number JPMOP1614

JST: OPERA Program Grant Number JPMOP1844

MITI: "R&D subsidiary program for promotion of academia-industry cooperation"

NEDO: Development of high efficient OLED materials

NEDO Project

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Research Group for Flexible Technologies (Nakada/Furukawa/Yuki/Koden)

山形大学 Yamagata University

Consortium

Yamagata University Flexible Electronics Japan-Germany International Collaborative Practical Utilization Consortium (YU-FIC)

Yamagata University Flexible Electronics Japan-Germany International Collaborative Practical Utilization Consortium (YU-FIC) collaborates with companies and institutes in Germany, aiming at novel flexible electronics products.

Project term

October 2017 ～ March 2021

Participants

16 Companies

FUJIKURA KASEI CO., LTD.
The Japan Steel Works, LTD.
KEIHIN RAMTECH CO., LTD.
Mitsubishi Chemical Corporation
Mitsuboshi Diamond Industrial Co., Ltd.
Nippon Electric Glass Co., Ltd.
NIPPON STEEL Chemical & Material Co., Ltd.
Nishimu Electronics Industries Co., Ltd.
SEIEIDO PRINTING Co., Ltd.
SERIA ENGINEERING, INC.
SurFtech Transnational Co., Ltd.
Taica Corporation
TAKEDA PRINTING CO., LTD.
TEIJIN LIMITED
Tokyo Process Service Co., Ltd.
WIREDGATE Inc.

(Nov. 2020)

Subjects

- **LAOLA**: Large Area Organic Lighting Applications on flexible substrates
- **IonT**: Internet on Things - Intelligent OLED-OPV based signage for interactive advertisement
- **F2E**: Free Form Electronics - Freedom in design by thermo-formed printed electronics

Leaders



- **Project leader: Associate Prof. T. Furukawa**
- Fellow: Prof. T. Takahashi
- Secretary: Prof. M. Koden

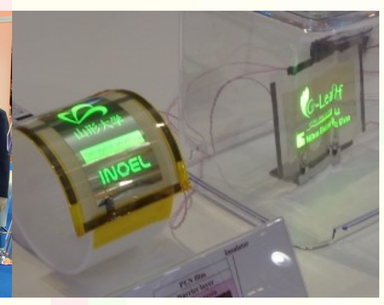
Collaboration with German activity

YU-FIC collaborates with 24 German companies and institutes which are organized by Organic Electronics Saxony (OES), having twice visits a every year, respectively.

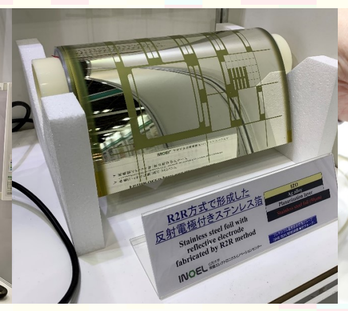
Activity

- ✓ Mutual visits between Germany and Japan.
- ✓ Frequent remote meeting between Germany and Japan.
- ✓ Demonstrations of collaborated results at conferences and exhibitions.




Germany（Nov. 2017, Mar. & Sep. 2018, Mar. & Sep. 2019）



“JFlex”（2018, 2019, 2020）

“LOPEC”/Germany（2018, 2019）


Japan（Feb. 2018, Jan. 2019, Jan. 2020）

“Flex Japan 2019”（2019）

Related program

- JST: OPERA Program Grant Number JPMOP1614 [FY2016～FY2020].
- MEXT: Construction Program of Open Innovation Organization [FY2018～FY2022].
- MEXT: Regional Innovation Eco-system Program [FY2018～FY2019].

Web page

- Home page：https://inoel.yz.yamagata-u.ac.jp/yu-fic-en/
- You Tube：https://www.youtube.com/watch?v=ybZVgQkVVJI&feature=youtu.be

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山形大学 Yamagata University

Consortium

Yamagata University Flexible Electronics Consortium for Academia-Industry Cooperation (YU-FLEC)

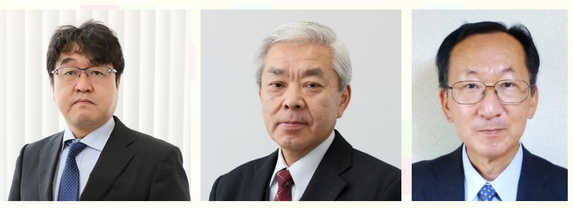
Yamagata University Flexible Electronics Consortium for Academia-Industry Cooperation (YU-FLEC) is constructed by one-by-one collaborations with individual companies, promoting practical development based on the concept of "Needs First". We would appreciate it if you are interested in YU-FLEC.

Mission and Subjects

Practical R&D in flexible electronics

- **Flexible substrates**
- **Flexible encapsulation and barrier**
- **Novel electrodes**
- **Process technologies**
- **Next-generation materials and devices**

Leaders



- **Project leader: Associate Prof. T. Yuki**
- **Fellow: Prof. H. Nakada**
- **Secretary: Prof. M. Koden**

Project term

January 2018 ～ March 2023

Unique points

- **Academia-industry collaboration led by scientists having rich experience in actual businesses**
- **Large size equipment for various prototypes**
- **Creation of business competitiveness**

Main applications

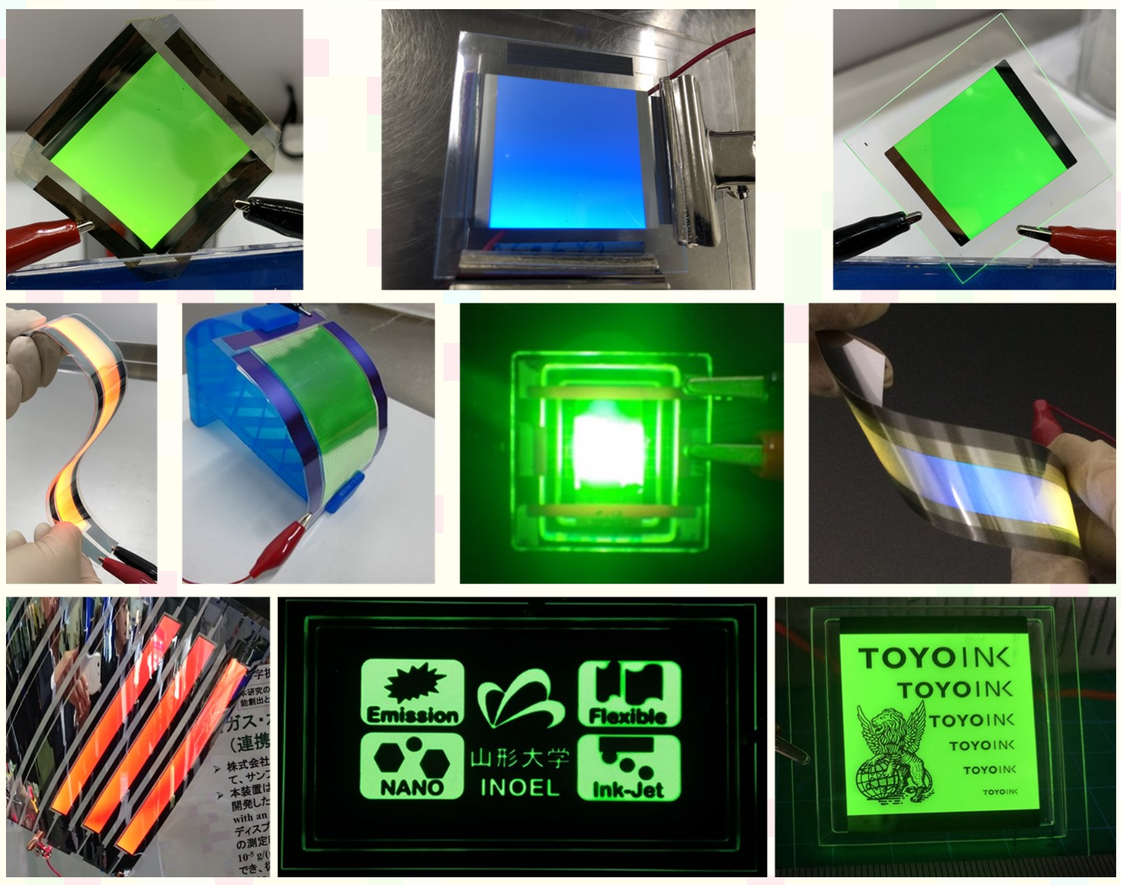
- **Small flexible OLED displays (mobile, etc.)**
- **Large size OLED displays (TV, etc.)**
- **Flexible OLED lighting**

Participants (total)

17 Companies (November 2020)

Activities

- **Application of flexible substrates to OLEDs**
  - **Stainless steel foil (p.12)**
  - **High temperature tolerance barrier film (p.18)**
- **Flexible encapsulation**
  - **TFE (Thin Film Encapsulation) (p.16)**
  - **PSA encapsulating technology (p.21)**
  - **Laminating encapsulation**
- **OLED devices and processes**
  - **OnDemand patterning of OLED (p.17)**
- **Non-ITO transparent electrode**
  - **Metal mesh electrode (p.19)**
- **Novel materials for emission devices**
  - **Evaporation materials**
  - **Solution materials**
- **Novel emission devices**
- **Novel components for organic electronics**
- **Equipment for organic electronics**



Related program

- **MEXT: Construction Program of Open Innovation Organization [FY2018～FY2022].**

Seminar

- **Monthly report for YU-FLEC members by Prof. Nakada "Trend of organic electronics"**
- **Webinar in Virtual exhibition "JIVM2020" (July 2020. https://www.youtube.com/watch?v=2o93-84WdSc**
- **1st YU-FLEC seminar (Aug. 2019 Tokyo).**

Web page

- **Home page: https://inoel.yz.yamagata-u.ac.jp/yu-flec-en/**
- **YouTube: https://www.youtube.com/watch?v=qYumaF1W2Ss&feature=youtu.be**

Background technologies

OLED Device Fabrications

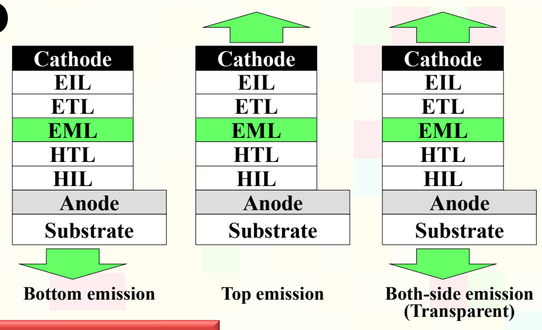
Various types of OLED devices are able to be fabricated, based on the requests from collaborating companies. The fabricated OLED devices are utilized for technological evaluations, prototype samples, etc.

Materials

Various types of OLED materials shown below can be applied to OLED devices.
- Small molecular OLED materials
- Polymer OLED materials
- Fluorescent, phosphorescent and TADF materials
- Quantum dot (QD) materials

Device structures

Various types of OLED devices can be fabricated.
- Bottom emitting OLED
- Top-emitting OLED
- Transparent OLED (Both side emitting)
- Multi-photon
- White emitting



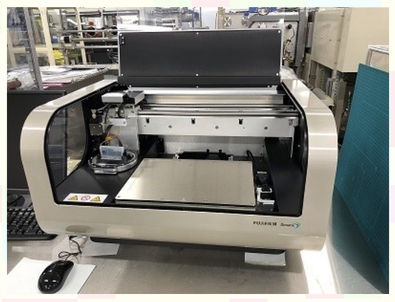
Barrier layers

- Inorganic barrier layer: CVD, Sputtering, ALD
- Inorganic/organic alternatingly stacked barrier layer

R2R sputtering & CVD

ALD (Atomic Layer Deposition)

Sputtering

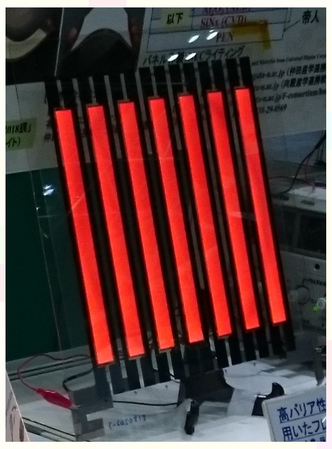


Ink-jet

Large size OLEDs

Large size OLED devices can be fabricated.
The maximum substrate size: 30cm × 30cm

OLED vacuum evaporation equipment “ELVESS” (Tokki)



Processes for organic layers

- Dry process: Vacuum evaporation
- Solution process: Spin-coat, Ink-jet, Spray, etc.

Vacuum evaporation

Ink-jet

Spin-coat

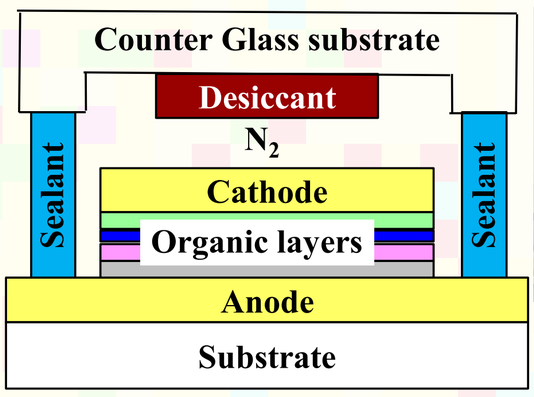
Spray

Wet cleaning

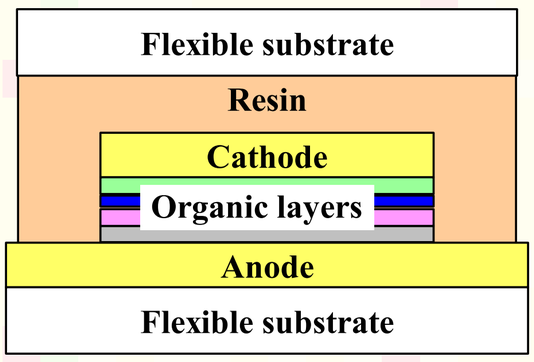
Plasma cleaner

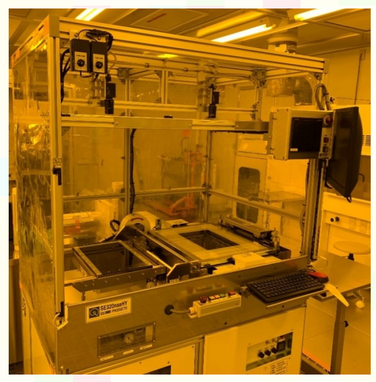
Encapsulations

Various encapsulating technologies are applied.
- Common encapsulation with desiccant
- Flexible all-solid type encapsulation



Sheet-type lamination





Roll-type lamination

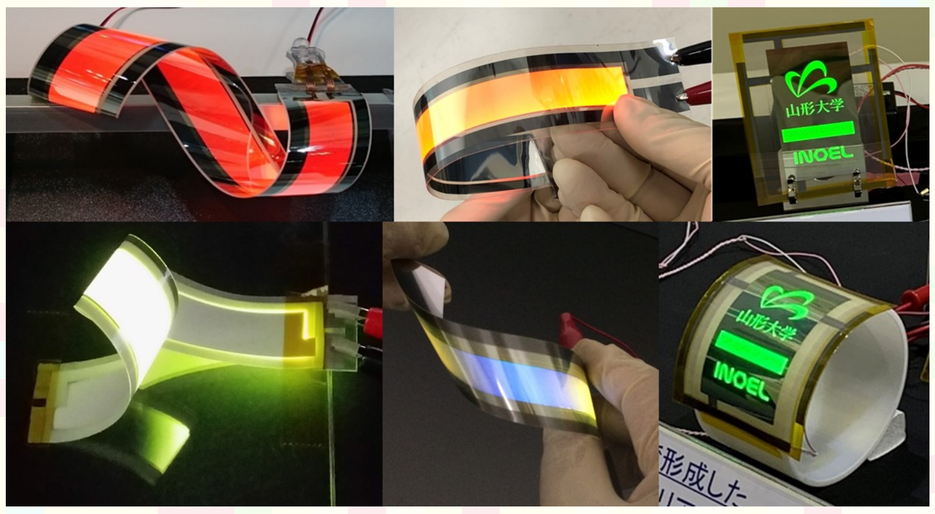
Large size OLEDs

Large size OLED devices can be fabricated.
The maximum substrate size: 30cm × 30cm

OLED vacuum evaporation equipment “ELVESS” (Tokki)

Flexible OLEDs

Flexible OLED devices with various designs can be fabricated.



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山形大学 Yamagata University

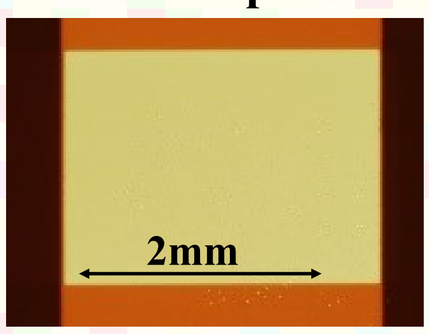
Background technologies

Evaluation of OLED Materials and Devices

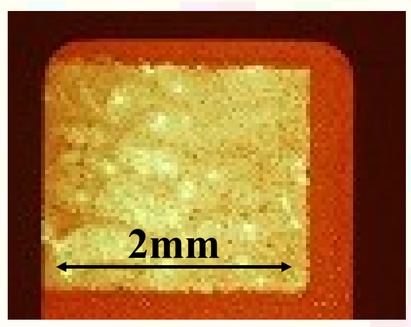
OLED devices with various technologies (materials, components, device architectures, processes, equipment, etc.) of collaborating companies are evaluated from practical points of view. All evaluating results are feedbacked to the collaborating company and can be utilized for not only the next development but also the demonstration to their customers.

Emission uniformity

- **Emission quality such as uniformity, defects, etc. of OLED devices are evaluated by visual microscopic observations.**



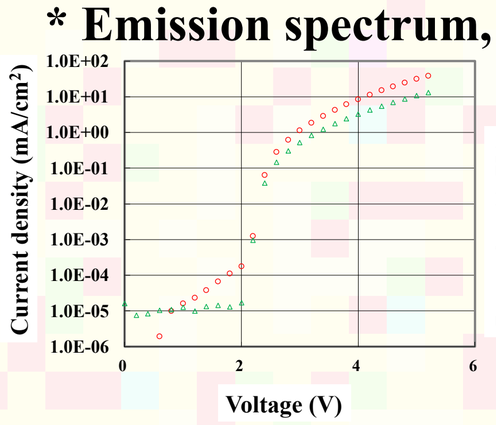
Uniform emission



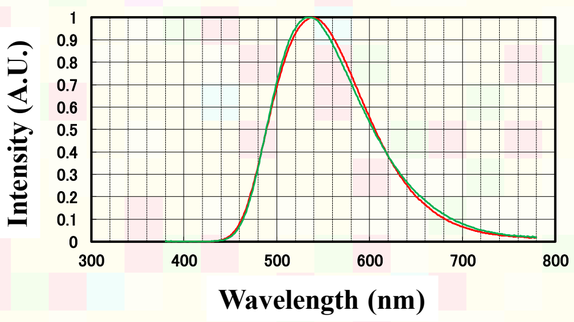
Non-uniform emission with defects

Device characteristics

- **OLED device characteristics are evaluated.**
  - *** I-V characteristics**
  - *** L-I characteristics**
  - *** Emission spectrum, etc.**



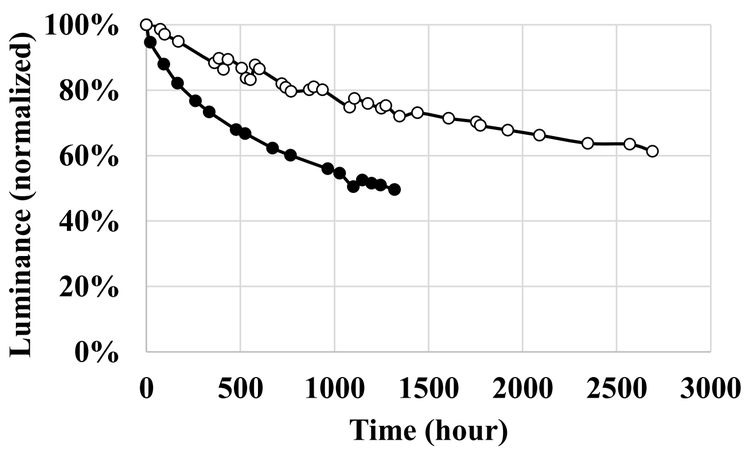
I-V characteristics



Emission spectrum

Driving lifetime

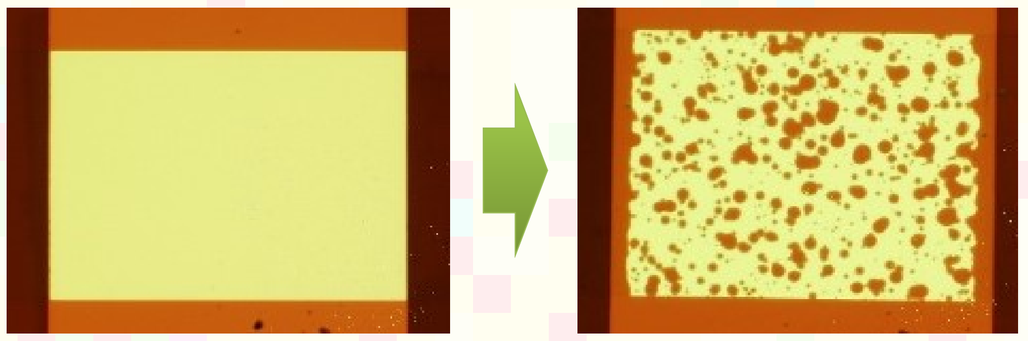
The reduction of emission intensity of OLED devices under constant current driving is evaluated.



Driving lifetime

Storage lifetime

The change of emission is observed after storage test with high temperature and high humidity.

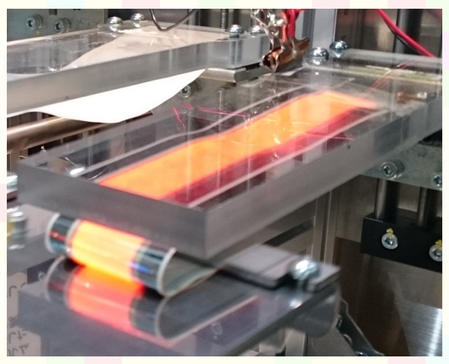


Initial emission (No defect)

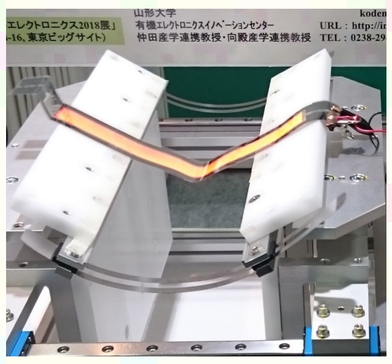
Emission after storage test (Dark spot)

Bending tests

The influences of various bending stress on device characteristics, lifetime, etc. are evaluated using bending equipment.



U-shape sliding



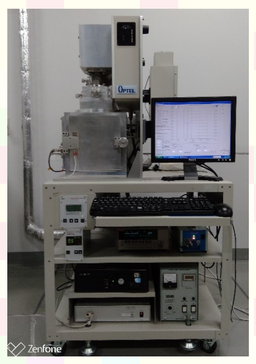
Folding

Both-side bending

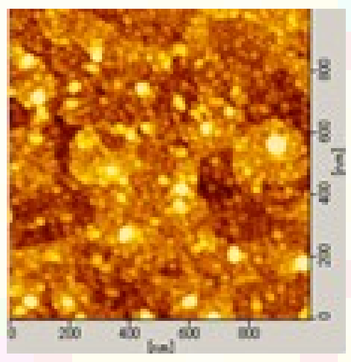
Others

Other evaluations can be used, based on the request from collaborating companies.
(Example)

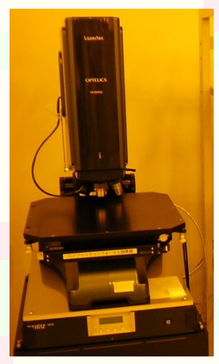
- **Ionization potential**
- **Defect analysis**
- **SEM, AFM**
- **3D profile**



Ionization potential



AFM



Hybrid confocal microscopy

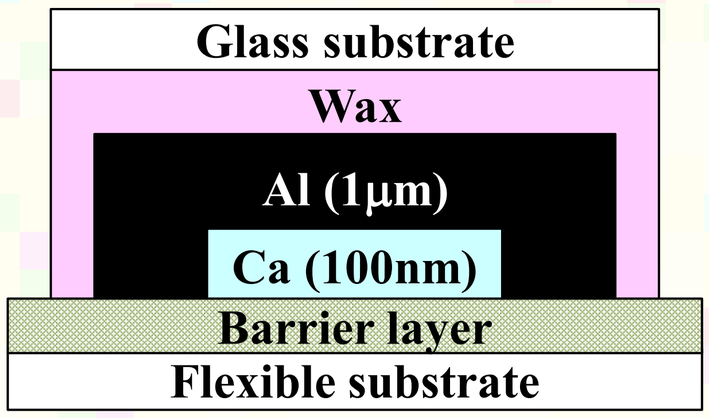
Background technologies

Evaluation of Barrier Properties

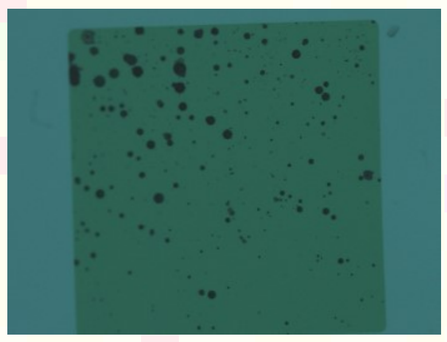
Evaluation of barrier properties is very important in flexible organic electronics technologies. We provide two evaluation methods which are "Calcium corrosion method" and "MA method (Modified differential pressure method with an Attached support)".

Ca corrosion method

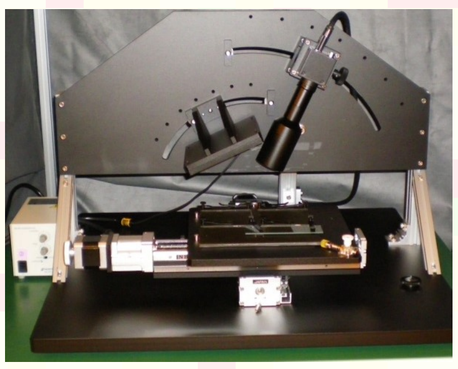
- ✓ **Ca corrosion method evaluates the optical change in Ca reflectivity which changes by the reaction of Ca and H_2O. This method is useful for the evaluation of defects in barrier layer.**
- ✓ **WVTR (Water Vapor Transmission Rate) is calculated from the evaluation results of Ca corrosion method.**



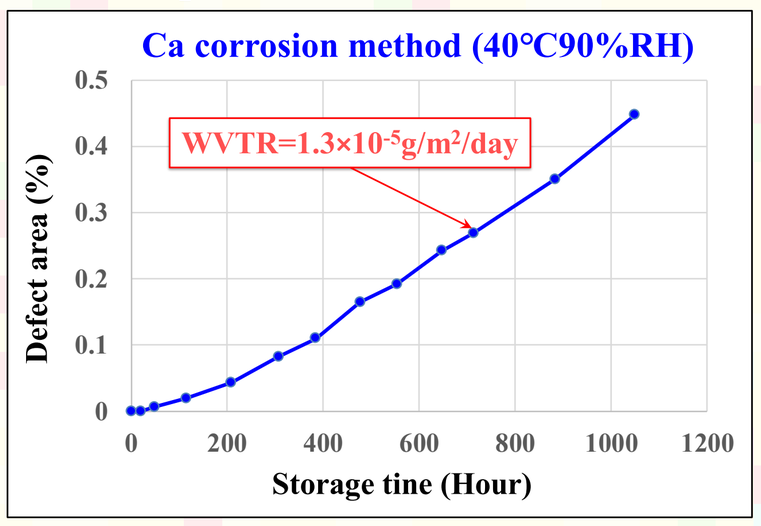
Structure of Ca corrosion device



Microscopic observation of Ca corrosion



Evaluation equipment of Ca corrosion

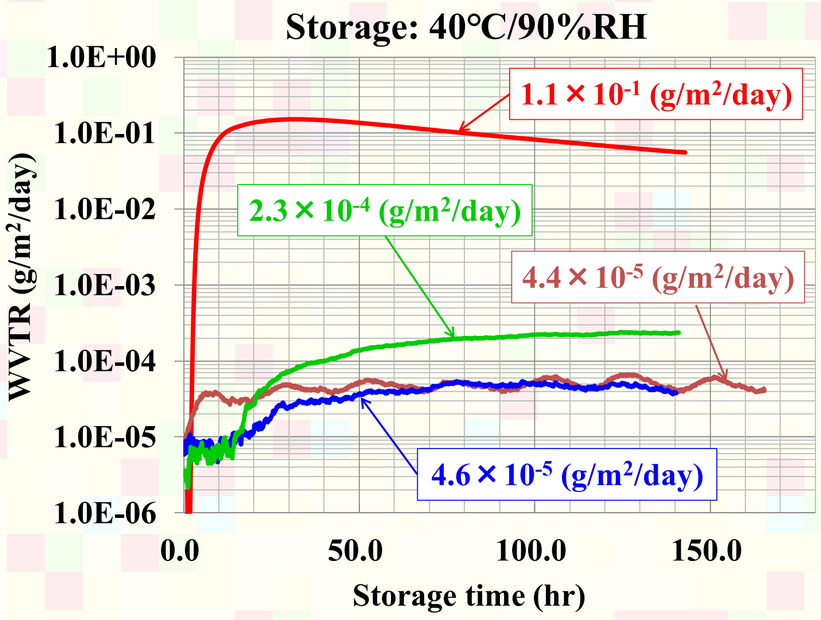


WVTR calculation from Ca corrosion test

MA method

WVTR (Water Vapor Transmission Rate) evaluation (Collaborating with MORESCO)

- ➢ **We provide WVTR (Water Vapor Transmission Rate) evaluation, using the WVTR measurement equipment "Super Detect" of MORESCO.**
- ➢ **The "Super Detect" utilizes the MA method (Modified differential pressure method with an Attached support) developed by the collaboration of MORESCO and AIST (National Institute of Advanced Industrial Science and Technology).**
- ➢ **The MA method reduces measurement time of high gas barrier film such as better than 10^{-4} g/(m^2 day), which are required in flexible OLED, OPV, etc. For example, the "Super Detect" requires only about 20 hours for the WVTR measurement of barrier films with the order of 10^{-5} g/(m^2 day), for which the previous methods require about 100 hours. It should be noticed that the measurement time of the "Super Detect" is only 1/5 of previous methods.**
- ➢ **In addition, the "Super Detect" is able to evaluate wide ranges of WVTR such as 10^{+1}~10^{-7} g/(m^2 day).**
- ➢ **The "Super Detect" with the MA method is able to warrant the WVTR value by the attached compensating unit developed by AIST.**
- ➢ **Moreover, the "Super Detect" is able to evaluate the transmission rate of not only water vapor but also various gasses.**



WVTR equipment (MA method)

INOEL Yamagata University
Innovation Center for Organic Electronics
Research Group for Flexible Technologies (Nakada/Furukawa/Yuki/Koden)
山形大学 Yamagata University

Background technologies

Roll-to-roll (R2R) and Printing Technologies

We provide roll-to-roll (R2R) and printing technologies, aiming at an innovation of productions in flexible organic electronics.

Roll-to-roll (R2R)

Four types of unique roll-to-roll (R2R) equipment are utilized for fabrications of electrodes, barrier layers, organic layers, etc.

- **Substrate width：30cm**
- **Substrate: ultra-thin glass, stainless steel foil, flexible film**

R2R sputtering &CVD (KOBELCO)

R2R screen printing and slit-coating (SERIA)

R2R gravure offset and flexography printing (Komori Machinery / Taiyo Kikai)

R2R wet cleaning (FEBACS)

Printing / Coating

Various printing and coating equipment can be utilized for printing tests and device fabrications.

Screen printing

Flexography and gravure offset printing

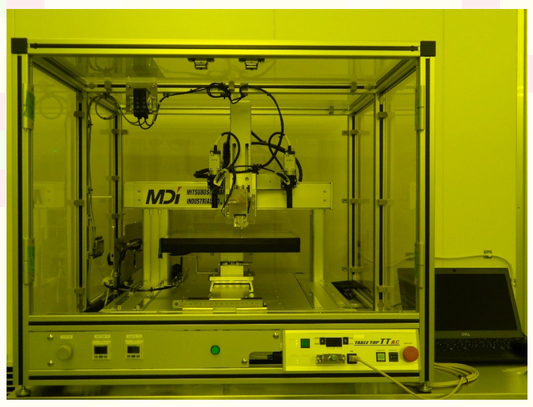
Ink-jet

Spray

Spin-coating

Process technologies

Various equipment for process technologies can be used.



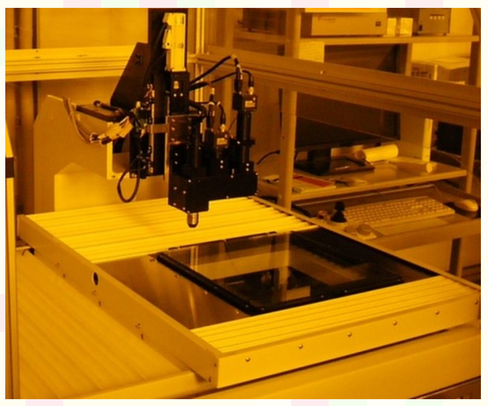
Cutting Machine for Ultra-thin Glass

3D Forming Machine

Evaluation

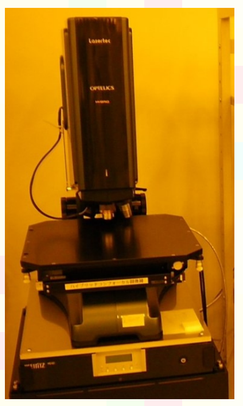
Various evaluation equipment are used for R&D of printing and roll-to-roll (R2R) technologies.

Contact angle measurement



Precise position detector

Viscoelasticity measurement



Hybrid confocal microscopy

INOEL Yamagata University Innovation Center for Organic Electronics

Research Group for Flexible Technologies (Nakada/Furukawa/Yuki/Koden)

山形大学 Yamagata University

Developed technology

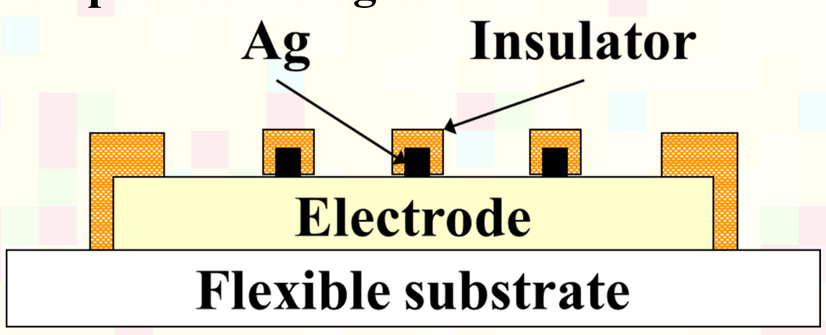
Electrode Fabrication by R2R Technologies with No Photolithography

We develop roll-to-roll (R2R) fabrication technologies of electrodes on flexible substrates by using no photolithographic technique. The developed technologies are applied to flexible OLED devices.

※LAOLA (Large Area Organic Lighting Applications on flexible substrates) project in Yamagata University Flexible Electronics Japan-Germany International Collaborative Practical Utilization Consortium (YU-FIC)

Technological features

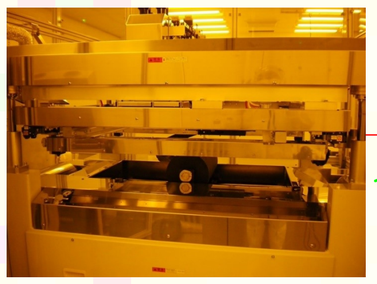
- Roll-to-roll (R2R) fabrication of electrodes on flexible substrates (No Photolithography)
- Flexible OLED devices fabricated by using the developed technologies

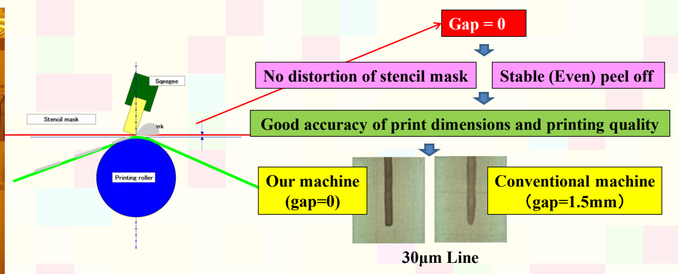


Flexible substrate
↓
R2R sputtering of electrode layer
↓
R2R screen printing of etching paste
↓
R2R wet cleaning for TCO patterning
↓
R2R screen printing of Ag electrode
↓
R2R screen printing of insulator
↓
Cutting

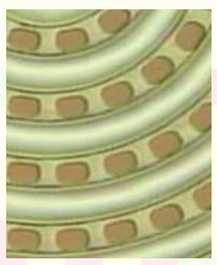
Key technologies

- R2R gap-less screen printing （SERIA ENGINEERING）
  - Improvement of patterning accuracy
- Screen mask （Tokyo Process Service ）
  - Improvement of patterning accuracy
  - protection of contaminations on substrates
- Conducting ink（FUJIKURA KASEI）
  - Reduction in resistivity
  - Reduction of baking temperature
- Insulator ink（FUJIKURA KASEI）
  - Reduction of outgas from insulator for inducing no damage in reliability of OLED device

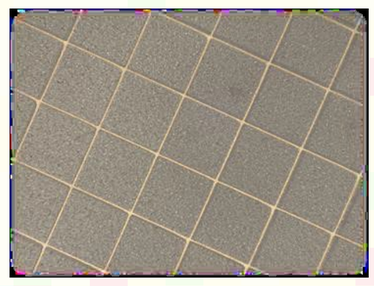




Gap-less screen printing equipment (SERIA ENGINEERING)



Screen mask (Tokyo Process Service)



Conducting ink (FUJIKURA KASEI)

Collaboration SERIA ENGINEERING, Tokyo Process Service, FUJIKURA KASEI

Related program

- Yamagata University Flexible Electronics Japan-Germany International Collaborative Practical Utilization Consortium (YU-FIC) [Oct. 2017～Mar. 2021].
- JST: OPERA Program Grant Number JPMOP1614 [FY2016～FY2020].
- MEXT: Construction Program of Open Innovation Organization [FY2018～FY2022].

Publication

- T. Furukawa, M. Koden, IEICE Trans. Electron, E100-C, 949 (2017). “Novel roll-to-roll deposition and patterning of ITO on ultra-thin glass for flexible OLEDs”
- T. Furukawa, K. Mitsugi, H. Itoh, D. Kobayashi, T. Suzuki, H. Kuroiwa, M. Sakakibara, K. Tanaka, N. Kawamura, M. Koden, IDW’14, FLX3-4L (2014). “Patterned ITO Film by Roll-to-Roll Process on Ultra-thin Glass”
- D. Kobayashi, N. Naoi, T. Suzuki, T. Sasaki, T. Furukawa, IDW'14, FLX3-1 (2014). “Novel Roll-to-Roll Screen Printing Machine for Flexible Devices”
- Yamagata University；”JFlex 2020” (2020), ”Flex Japan 2019” (2019), “LOPEC” (2019).
- SERIA ENGINEERING; “2019 EXPO SERIA” (2019).
- Tokyo Process Service; “2019 FLEX Japan” (2019).
- FUJIKURA KASEI, Nippon Electric Glass, SERIA ENGINEERING; International Workshop on Flexible Electronics and Sensors (2019).

INOEL Yamagata University Innovation Center for Organic Electronics

Research Group for Flexible Technologies (Nakada/Furukawa/Yuki/Koden)

山形大学 Yamagata University

Developed technology

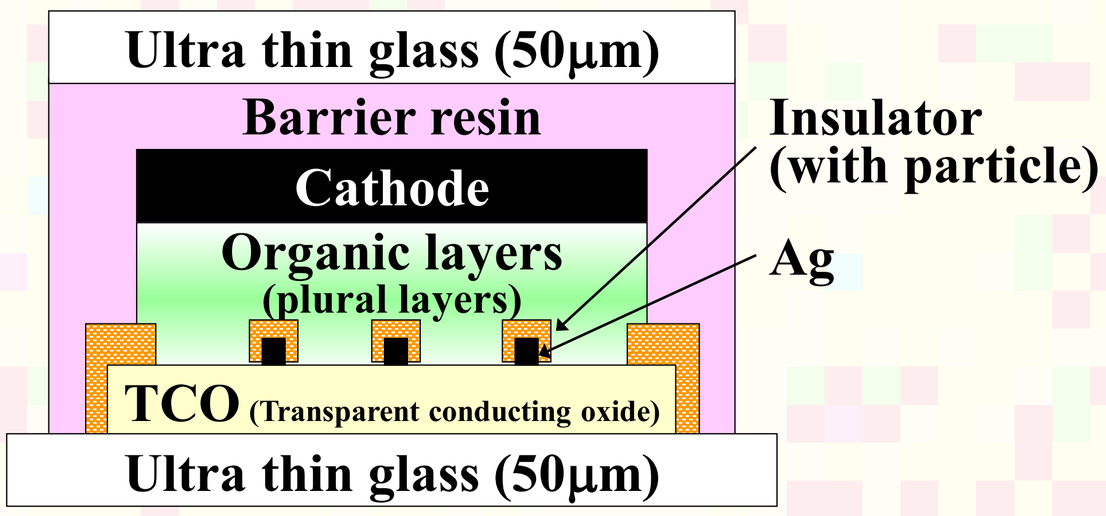
Flexible OLEDs on Ultra-thin Glass

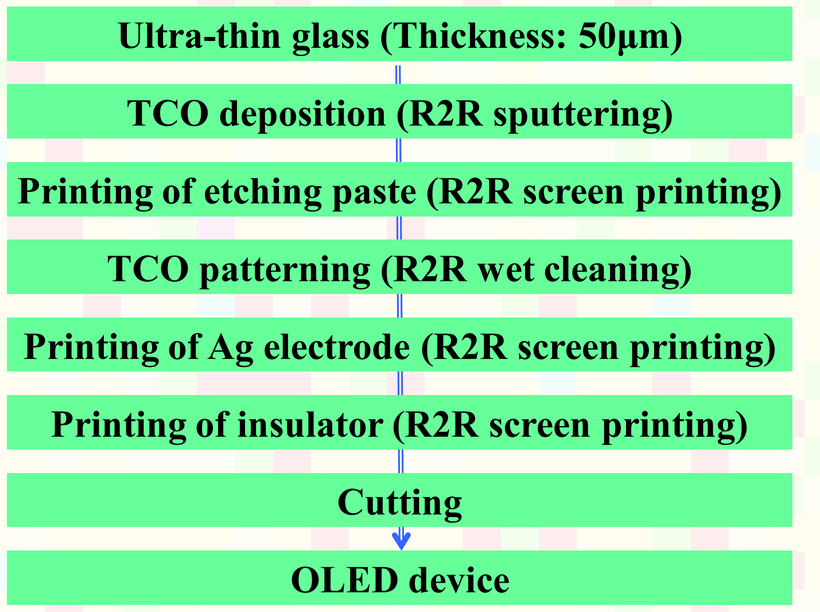
We develop flexible OLED lighting devices on ultra-thin glass with electrodes fabricated by roll-to-roll (R2R) technologies.

※LAOLA (Large Area Organic Lighting Applications on flexible substrates) project in Yamagata University Flexible Electronics Japan-Germany International Collaborative Practical Utilization Consortium (YU-FIC)

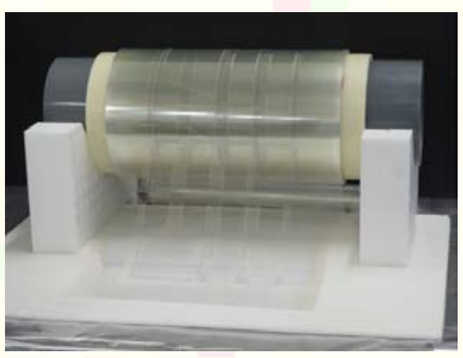
Technological features

- Roll-to-roll (R2R) fabrication of electrodes on ultra-thin glass
- Unique glass cutting technology with no damage

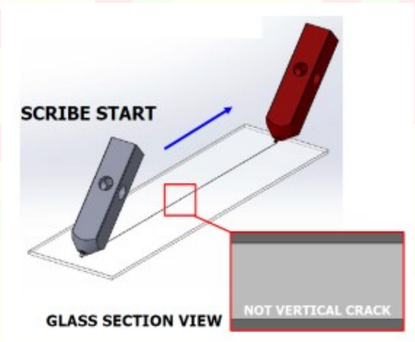




Key technologies

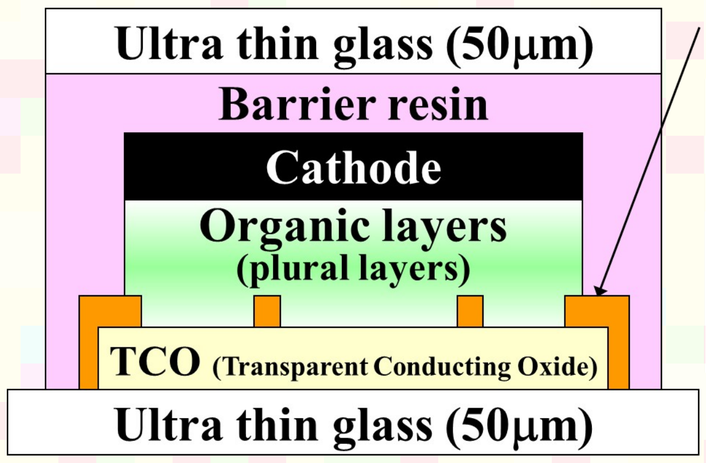


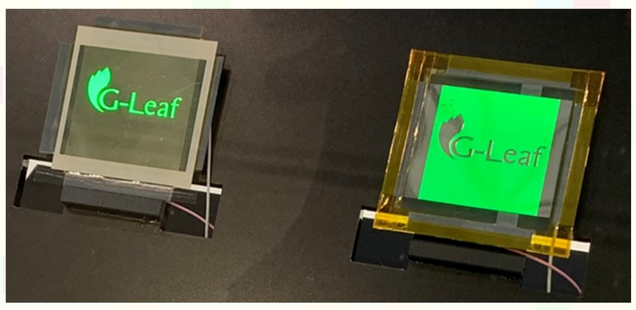
Ultra-thin glass
（Nippon Electric Glass）

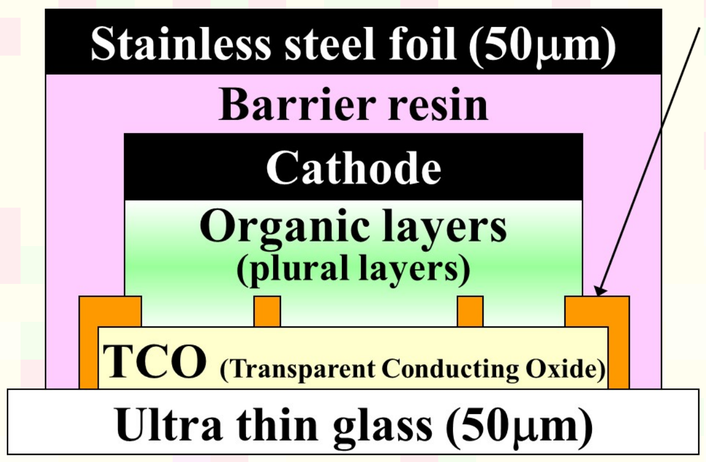


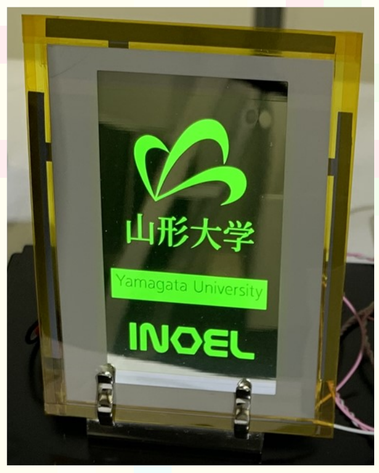
Cutting of substrates with resin
（Mitsuboshi Diamond Industrial）

Prototype OLEDs









Collaboration

Nippon Electric Glass, Mitsuboshi Diamond Industrial

Related program

- Yamagata University Flexible Electronics Japan-Germany International Collaborative Practical Utilization Consortium (YU-FIC) [Oct. 2017～Mar. 2021].
- JST: OPERA Program Grant Number JPMOP1614 [FY2016～FY2020].
- MEXT: Construction Program of Open Innovation Organization [FY2018～FY2022].

Publication

- T. Nakagaki, T. Kawabata, H. Takimoto, T. Furukawa, IDW'19, FLXp1-9L (2019). "Scribing Tool and Cutting Method for Ultra-thin Glass"
- T. Furukawa, M. Koden, IEICE Trans. Electron, E100-C, 949-954 (2017). "Novel roll-to-roll deposition and patterning of ITO on ultra-thin glass for flexible OLEDs"
- T. Furukawa, K. Mitsugi, H. Itoh, D. Kobayashi, T. Suzuki, H. Kuroiwa, M. Sakakibara, K. Tanaka, N. Kawamura, M. Koden, IDW'14, FLX3-4L (2014). "Patterned ITO Film by Roll-to-Roll Process on Ultra-thin Glass"
- Yamagata University；"JFlex 2020 (2020), "Flex Japan 2019" (2019), "LOPEC" (2019), "JFlex 2019" (2019).
- Nippon Electric Glass; "JFlex" (2019, 2020), "FINETECH JAPAN" (2018, 2019).
- Mitsuboshi Diamond Industrial; "FINETECH JAPAN 2019" (2019), "2019 FLEX Japan"(019), "FINETECH JAPAN 2018" (2018).

INOEL Yamagata University Innovation Center for Organic Electronics

Research Group for Flexible Technologies (Nakada/Furukawa/Yuki/Koden)

山形大学 Yamagata University

Developed technology

Flexible OLEDs on Stainless Steel Foil

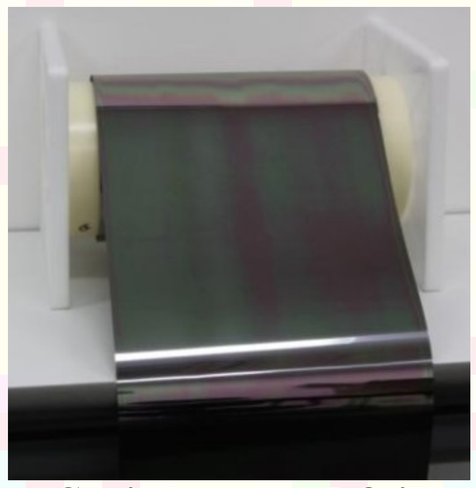
We develop flexible OLED devices on stainless steel foil (thickness: 50μm) of NIPPON STEEL CORPORATION GROUP.

※ YU-FLEC ※LAOLA project in YU-FIC

Technological features

■ **Advantages of stainless steel foils of NIPPON STEEL CORPORATION GROUP**

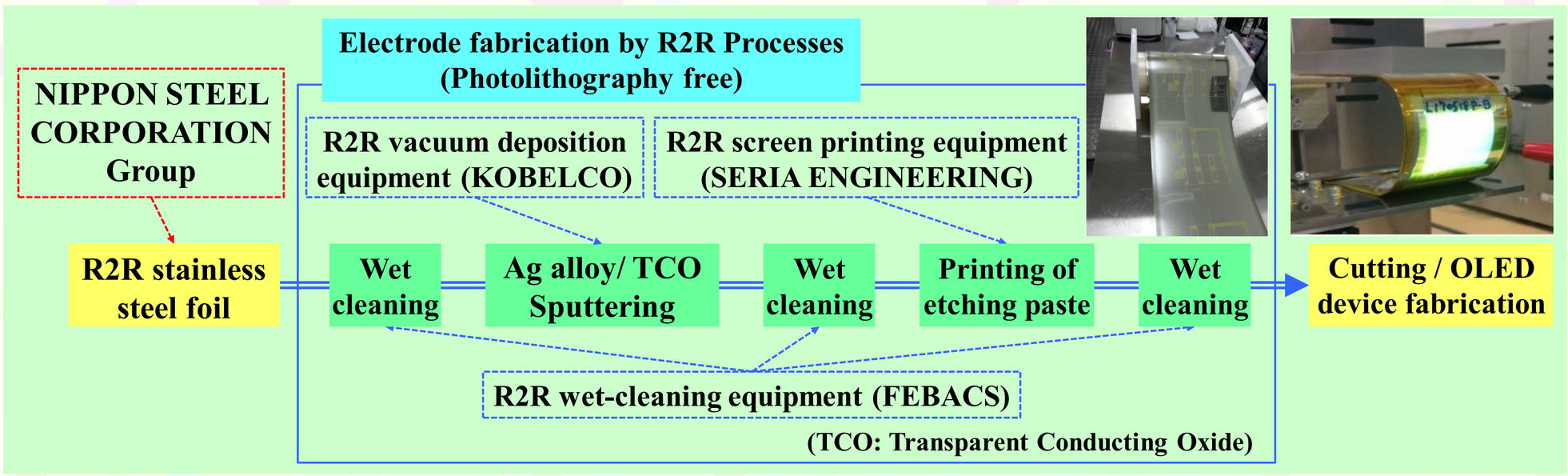
- **Thickness: 50μm**
- **Excellent surface smoothness（Ra～0.6nm）**
- **Excellent temperature and process resistances**
- **High gas barrier ability**

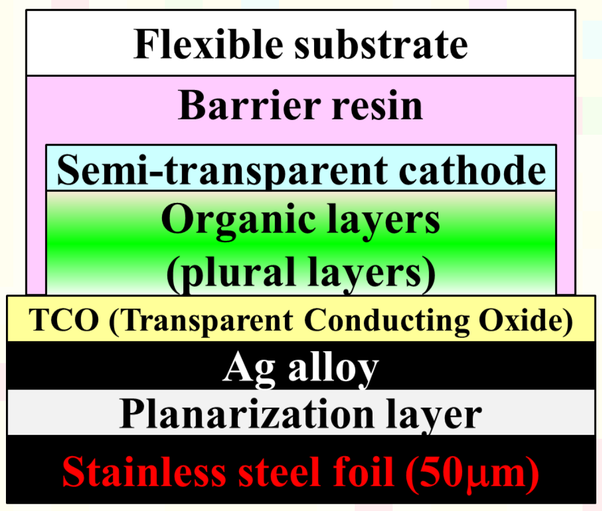


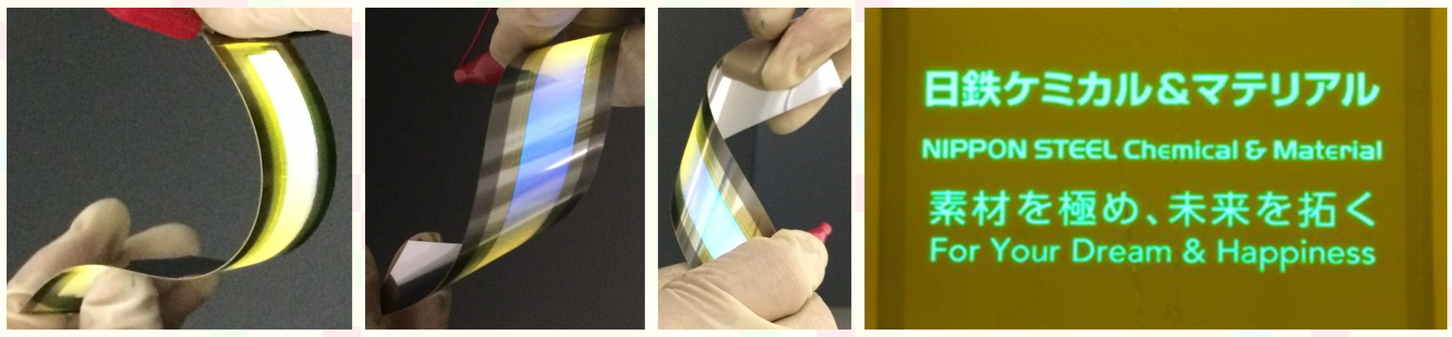
Stainless steel foil

Developed technologies

■ **Flexible OLED on stainless steel foil**
Electrode (reflective anode) is fabricated on stainless steel foil by roll-to-roll (R2R) photolithography-free processes







Flexible OLED lighting prototypes on stainless steel foil of NIPPON STEEL CORPORATION GROUP

Collaboration NIPPON STEEL CORPORATION
NIPPON STEEL Chemical & Material Co., Ltd.

Related program

- **Yamagata University Flexible Electronics Consortium for Academia-Industry Cooperation (YU-FLEC) [Jan. 2018～Mar. 2023].**
- **Yamagata University Flexible Electronics Japan-Germany International Collaborative Practical Utilization Consortium (YU-FIC) [Oct. 2017～Mar. 2021].**
- **MEXT: Construction Program of Open Innovation Organization [FY2018～FY2022].**

Publication

- **Y. Hagiwara, T. Furukawa, T. Yuki, S. Yamaguchi, N. Yamada, J. Nakatsuka, M. Koden, H. Nakada, IDW'17, FLXp1-9L(2017). "Roll-to-Roll Patterning of Reflective Electrode on Planarized Stainless Steel Foil"**
- **M. Koden, T. Furukawa, T. Yuki, H. Kobayashi, H. Nakada, IDW/AD'16, FLX3-1 (2016). "Substrates and Non-ITO Electrodes for Flexible OLEDs"**
- **Y. Hagiwara, H. Itoh, T. Furukawa, H. Kobayashi, S. Yamaguchi, N. Yamada, J. Nakatsuka, M. Koden, H. Nakada, IDW/AD'16, FLXp1-5 (2016). "Roll-to-Roll Processing of Silver/ITO Continuous Deposition on Planarized Stainless Steel Foil"**

INOEL Yamagata University Innovation Center for Organic Electronics

Research Group for Flexible Technologies (Nakada/Furukawa/Yuki/Koden)

山形大学 Yamagata University

Developed technology

Roll-to-Roll (R2R) Fabrication of Barrier Film with Transparent Electrode

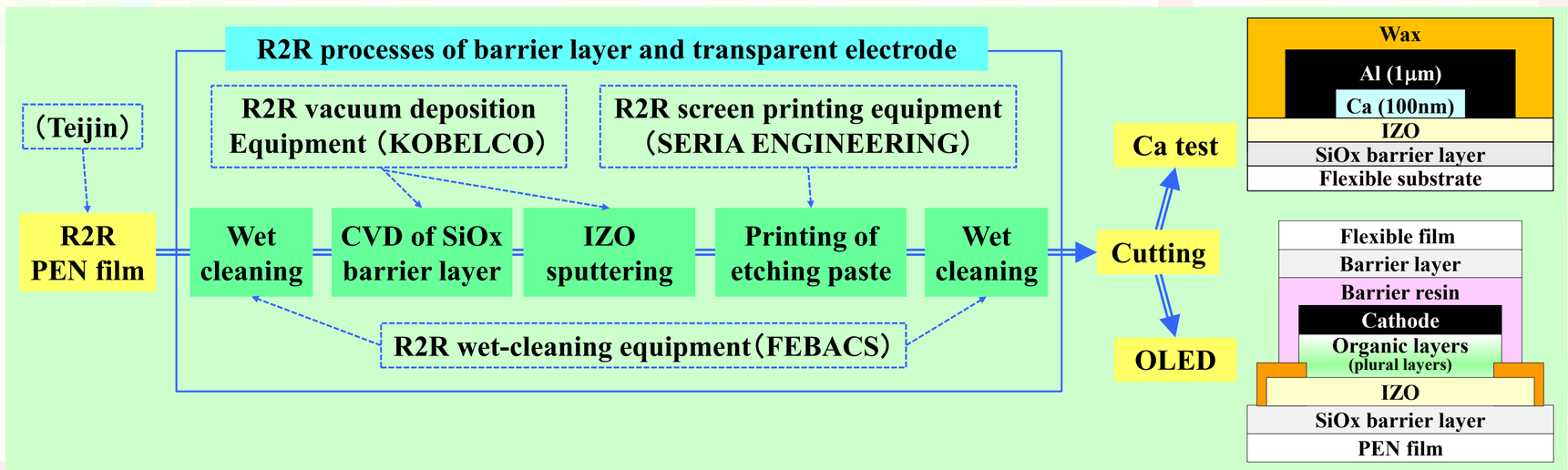
We develop fabrication technologies of gas barrier layer and transparent electrode on flexible film, using roll-to-roll (R2R) PE-CVD (Plasma Enhanced Chemical Vapor Deposition).

Technological features

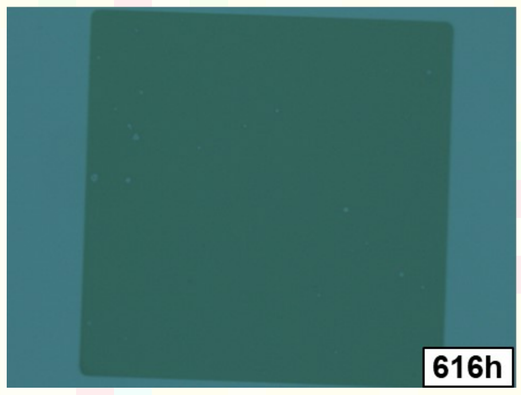
- Roll-to-roll (R2R) PE-CVD deposition of gas barrier layer on flexible films
- High barrier ability with WVTR (Water Vapor Transmission Rate) of the order of 10^{-6}g/m^2/day
- High gas barrier films with transparent electrode

Developed technologies

- Roll-to-roll (R2R) photolithography-free fabrication of barrier layer and transparent electrode on flexible films

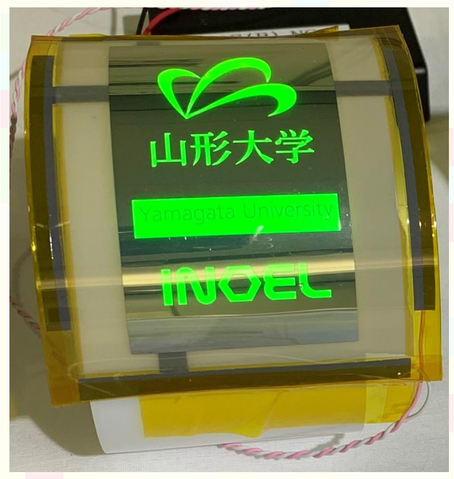


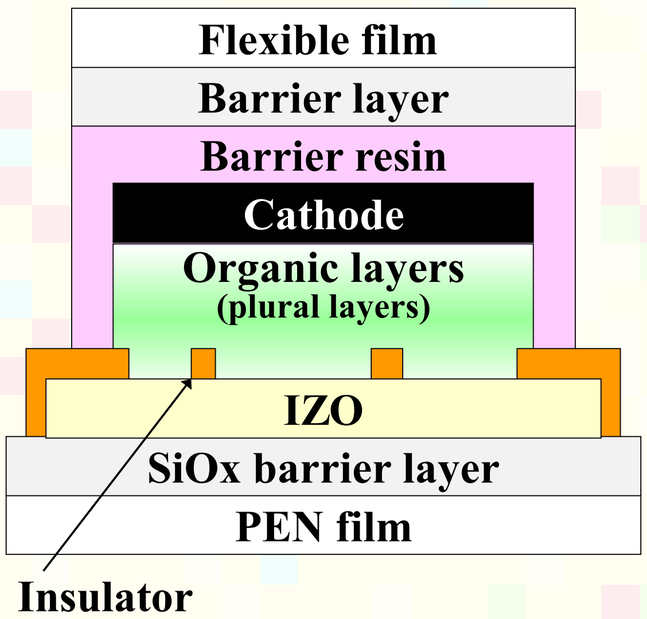
- High gas barrier property (WVTR: 6.3×10^{-6}g/m^2/day)



Ca corrosion device after 616 hours under 40℃/90%RH (Thickness of barrier layer: 720nm)

- Flexible OLED devices





Collaboration TEIJIN LIMITED, Tosoh Corporation

Related program

- Yamagata University Flexible Organic Electronics Practical Key Technology Consortium (YU-FOC) [Apr. 2016～Mar. 2019].
- Yamagata University Flexible Electronics Japan-Germany International Collaborative Practical Utilization Consortium (YU-FIC) [Oct. 2017～Mar. 2021].
- JST: OPERA Program Grant Number JPMOP1614 [FY2016～FY2020].
- MEXT: Construction Program of Open Innovation Organization [FY2018～FY2022].

Publication

- Yamagata University;"Flex Japan 2019" (May 2019 / Tokyo), "LOPEC" (Mar. 2019 / Germany), "JFlex 2019" (Jan. 2019 / Tokyo).
- K. Taira, Taiga Suzuki, W. Konno, H Chiba, H. Itoh, M. Koden, T. Takahashi, T. Furukawa, IDW'18, FLX2-4L (2019). "Development of High Gas Barrier Film Using Novel Precursor by Roll to Roll PECVD"
- T. Suzuki, W. Konno, K. Taira, H Chiba, H. Itoh, M. Koden, T. Takahashi, T. Furukawa, IDW'18, FLXp1-10L (2019). "High Gas Barrier Films with Heterogeneous Multilayer"
- K. Taira, T. Furukawa, N. Kawamura, M. Koden, T. Takahashi, IDW'17, FLXp1-8L (2018). "High gas barrier film for OLED"

INOEL Yamagata University Innovation Center for Organic Electronics

Research Group for Flexible Technologies (Nakada/Furukawa/Yuki/Koden)

山形大学 Yamagata University

Developed technology

Package with OLEDs Fabricated by Printing (IonT)

We develop printing technologies of inexpensive flexible OLED devices for packages, etc., aiming at the application of organic electronics products to advertisement.

※ IonT (Internet on Things - Intelligent OLED-OPV based Signage for interactive Advertisement) project in Yamagata University Flexible Electronics Japan-Germany International Collaborative Practical Utilization Consortium (YU-FIC)

Technological features

- Flexible OLEDs by inexpensive printing
- Application to packages etc.

Collaboration scheme

- Developed by the collaboration led by Yamagata University Flexible Electronics Japan-Germany International Collaborative Practical Utilization Consortium (YU-FIC)

IonT (Internet on Things - Intelligent OLED-OPV based Signage for interactive Advertisement) project by YU-FIC

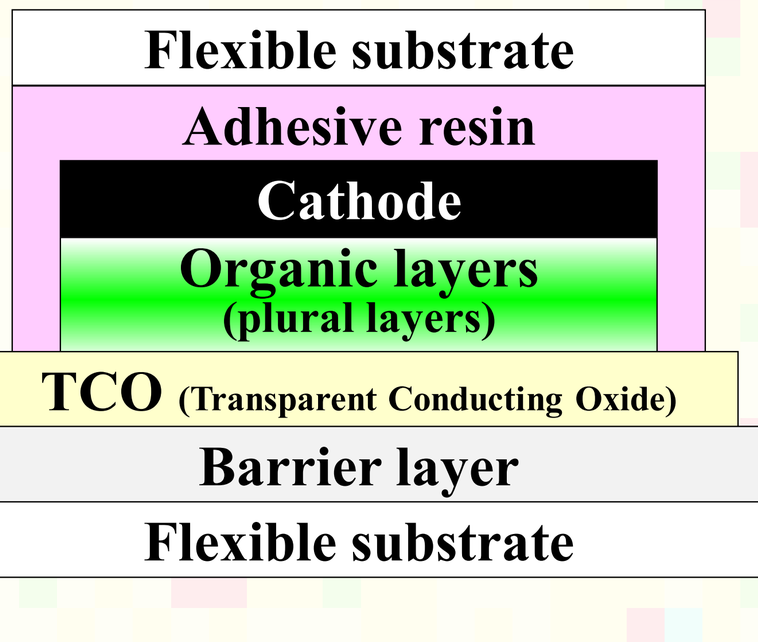
German companies and institutes

Collaboration

Flexible substrate	Anode deposition	Printing of Organic layers	Cathode deposition	Encapsulation	Marketing
Yamagata University		Komori Corporation / Yamagata University			Takeda Printing

Developed technologies

- Flexible OLED prototypes with printing OLED materials



Collaboration KOMORI Corporation / TAKEDA PRINTING CO., LTD.

Related program

- Yamagata University Flexible Electronics Japan-Germany International Collaborative Practical Utilization Consortium (YU-FIC) [Oct. 2017～Mar. 2021].
- MEXT: Construction Program of Open Innovation Organization [FY2018～FY2022].

INOEL Yamagata University Innovation Center for Organic Electronics

Research Group for Flexible Technologies (Nakada/Furukawa/Yuki/Koden)

山形大学 Yamagata University

Developed technology

Free Form Electronics (F2E): Freedom in Design by Thermo-formed Printed Electronics

We develop 3D-molding technologies of flexible substrates with electrodes for developing fabrication processes of 3D-circuit board and their applications.

※ F2E (Free Form Electronics - Freedom in design by thermo-formed printed electronics) project in Yamagata University Flexible Electronics Japan-Germany International Collaborative Practical Utilization Consortium (YU-FIC)

Technological features

- 3D-molding technologies of flexible substrates with electrodes
- Process simplification in fabrication of circuit board by printing technologies

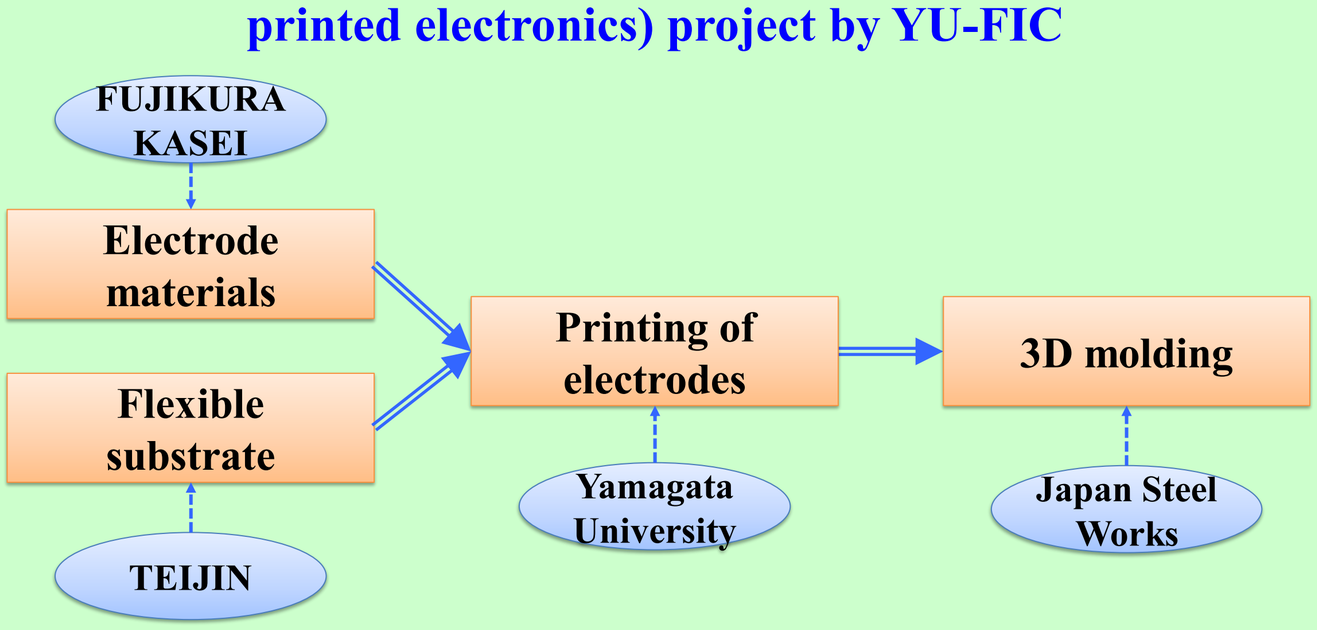
Application areas

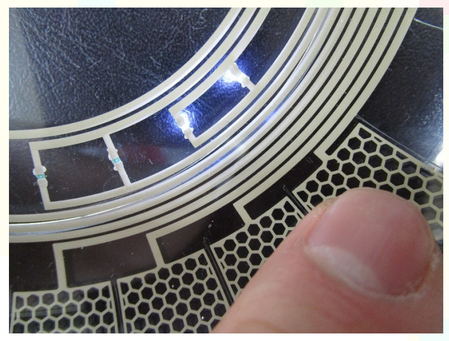
- Automotive interiors (lighting, controller, etc. of instrument panels and consoles)
- Thin IoT devices

Collaboration scheme

- Developed by the collaboration led by Yamagata University Flexible Electronics Japan-Germany International Collaborative Practical Utilization Consortium (YU-FIC)

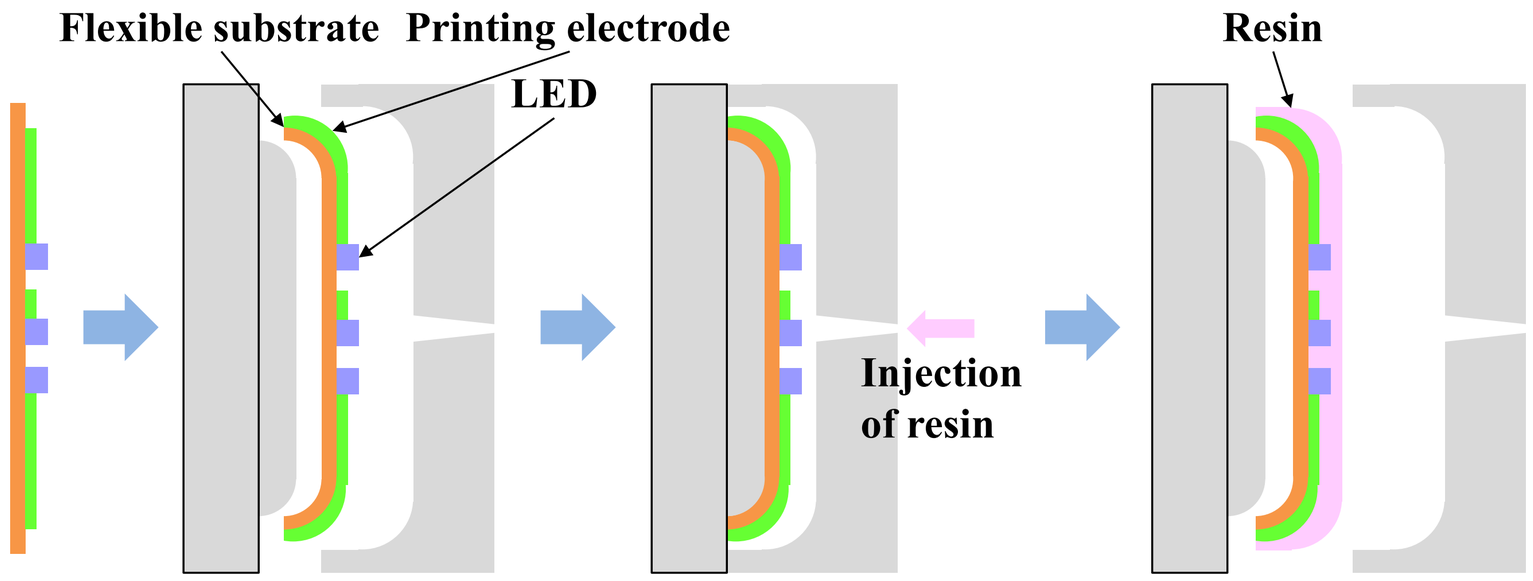
F2E (Free Form Electronics - Freedom in design by thermo-formed printed electronics) project by YU-FIC





Developed technologies

■ 3D-shaped prototype with touch screen and LEDs



Collaboration

The Japan Steel Works, LTD. / TEIJIN LIMITED / FUJIKURA KASEI CO., LTD.

Related program

- Yamagata University Flexible Electronics Japan-Germany International Collaborative Practical Utilization Consortium (YU-FIC) [Oct. 2017～Mar. 2021].
- MEXT: Construction Program of Open Innovation Organization [FY2018～FY2022].

INOEL Yamagata University
Innovation Center for Organic Electronics
Research Group for Flexible Technologies (Nakada/Furukawa/Yuki/Koden)
山形大学 Yamagata University

Developed technology

TFE (Thin Film Encapsulation) Technologies for OLEDs

We develop TFE (Thin Film Encapsulation) technologies for OLED devices, using organic resins developed by TOYO INK SC HOLDINGS.

Technological features

■ **Advantages of "Non-solvent UV-IJ resin ink" developed by TOYO INK SC HOLDINGS"**
- To support SiNx barrier layer
- UV cure type (non-solvent)
- Applicable to ink-jet

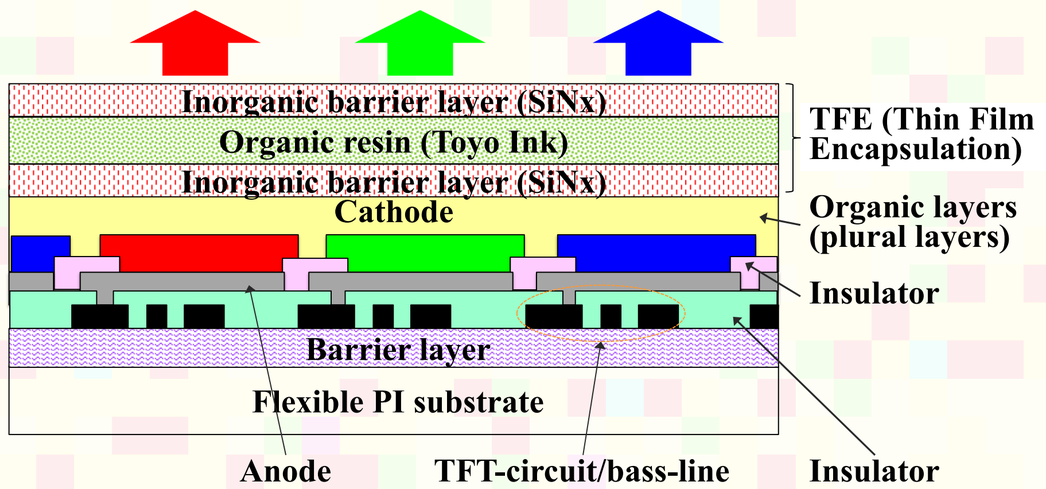
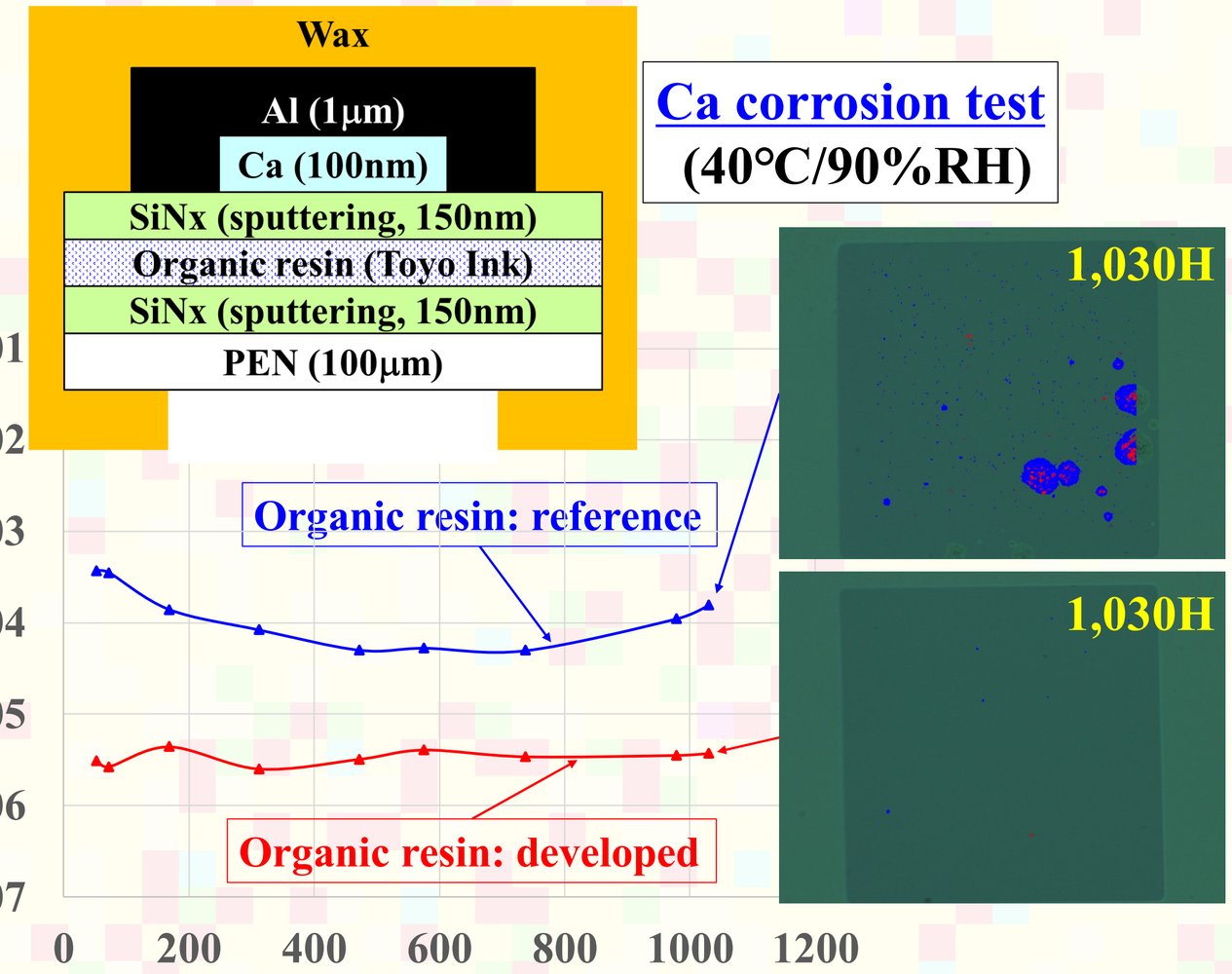


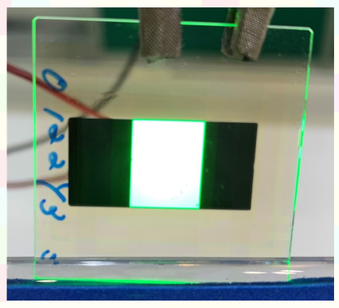
Image of OLED with TFE

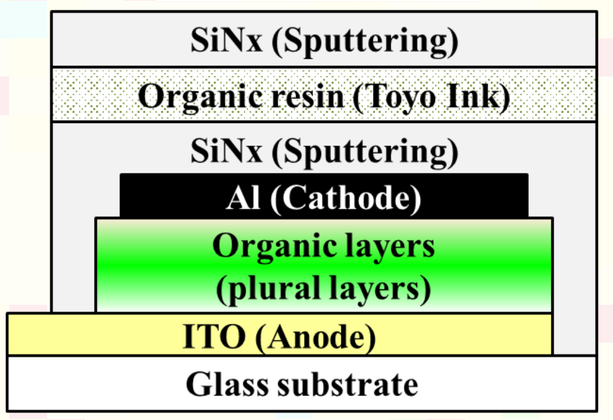
Developed technologies

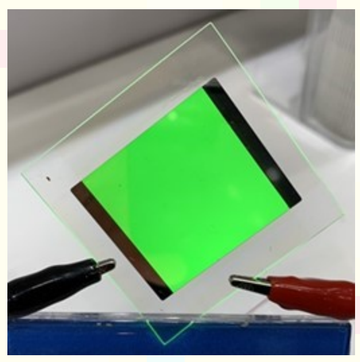
■ **TFE structure with high gas barrier property**
- TEF with "Non-solvent UV-IJ resin ink" developed by TOYO INK SC HOLDINGS
- No actual damage after storage test of 1,000 hours under 40℃/90%RH
- WVTR (Water Vapor Transmission Rate): order of 10^{-6}g/m^2/day (40℃/90%RH)

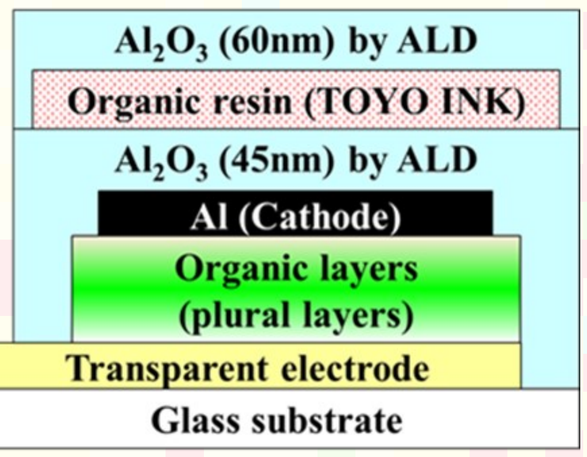


■ **OLED device with the developed TFE structure**









Collaboration

TOYO INK SC HOLDINGS CO., LTD.

Related program

- Yamagata University Flexible Electronics Consortium for Academia-Industry Cooperation (YU-FLEC) [Jan. 2018～Mar. 2023].
- MEXT: Construction Program of Open Innovation Organization [FY2018～FY2022].

Publication / Commercialization

- Yamagata University；"JFlex2020" (Jan. 2020 / Tokyo); "JFlex2019" (Jan. 2019 / Tokyo).
- The developed results have been applied to LIORESIT™ NSP 800 (UV Curing/ IJ printing) of TOYOCHEM CO., LTD., is a wholly owned subsidiary company of Toyo Ink SC Holdings Co., Ltd.

INOEL Yamagata University Innovation Center for Organic Electronics

Research Group for Flexible Technologies (Nakada/Furukawa/Yuki/Koden)

山形大学 Yamagata University

Developed technology

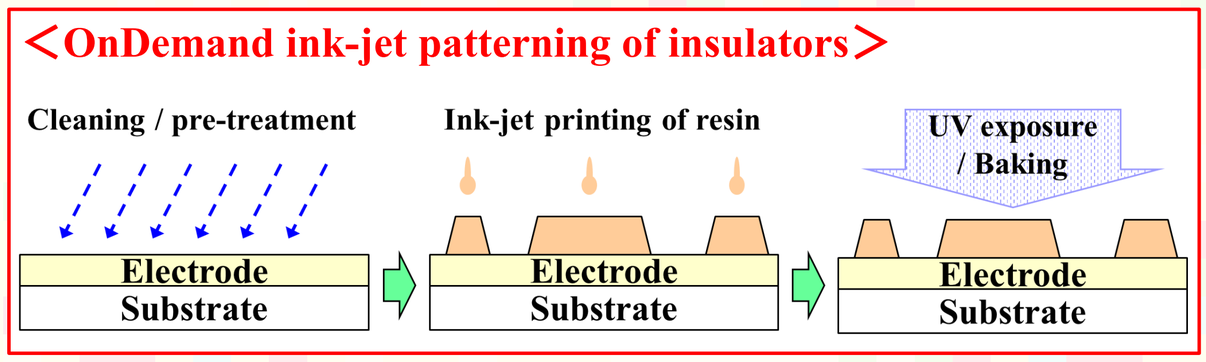
OnDemand Patterning of OLEDs by Ink-jet Printed Insulators

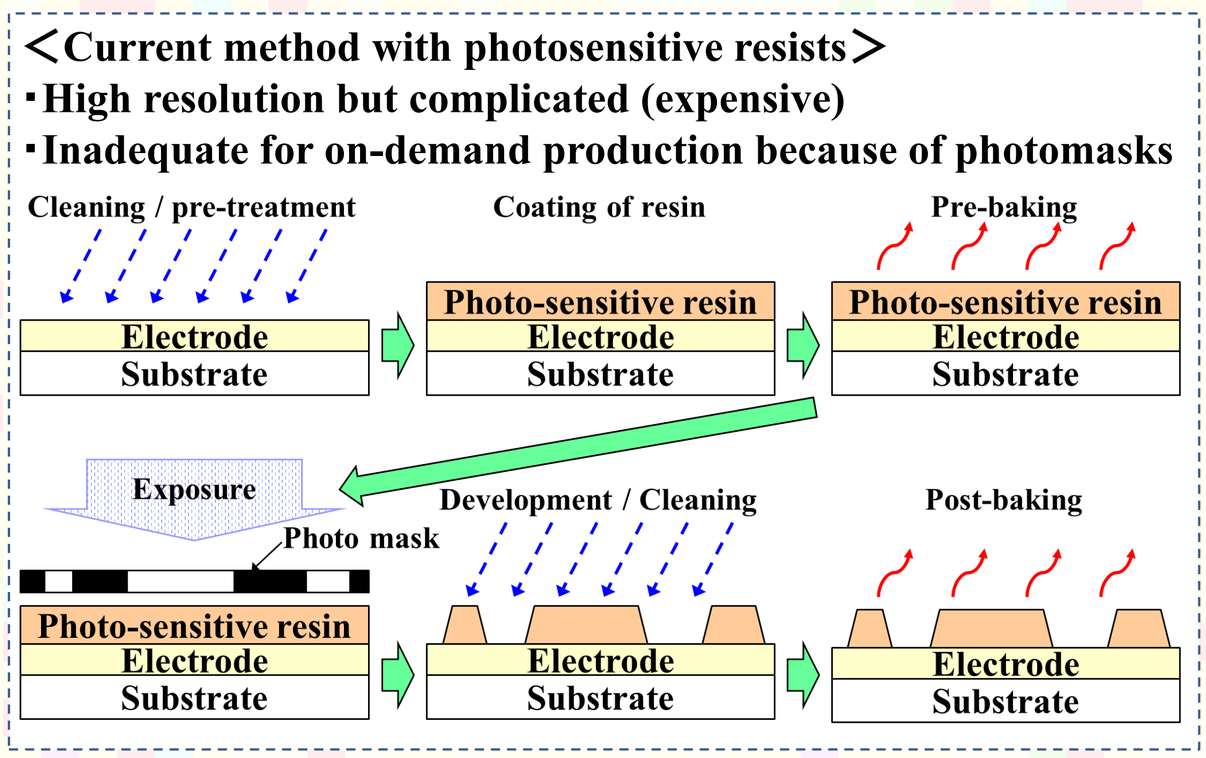
OnDemand patterning of OLEDs was developed by on-demand pattens of insulators fabricated by ink-jet printing. The developed technology can be applied to small lot OLED productions with various designs, inducing novel applications.

Technological features

- **Ink-jet printing of insulators**
  - simple and inexpensive processes
  - On-Demand design (small lot with various designs)
  - Eco-friendly (small volume of waste liquid)
  - Suppression of contamination (Non-contact between substrates and masks)
- **LIORESIT™ NSP 800 of TOYOCHEM CO., LTD.**
  - UV curing transparent insulation material
  - Printable with IJ printer
  - Curable with 365～395nm UV light
  - No solvent included

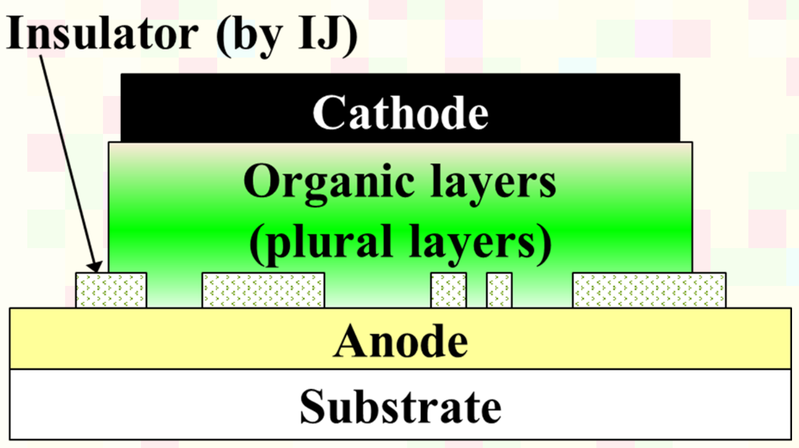
[*] TOYOCHEM CO., LTD. is a wholly owned subsidiary company of Toyo Ink SC Holdings Co., Ltd.

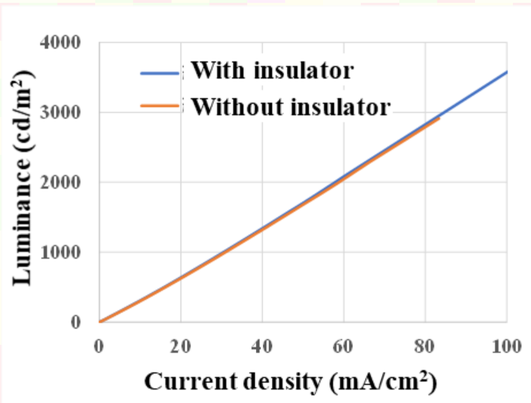


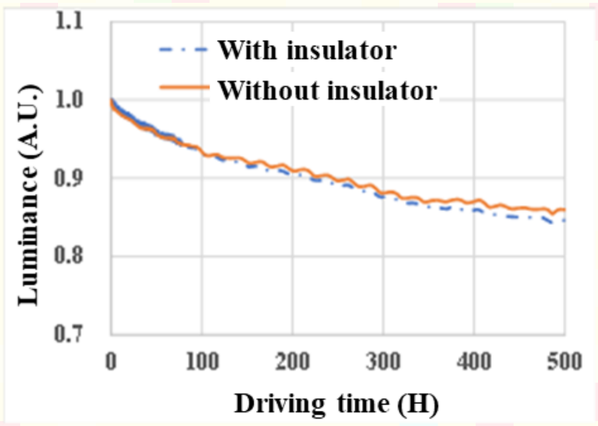


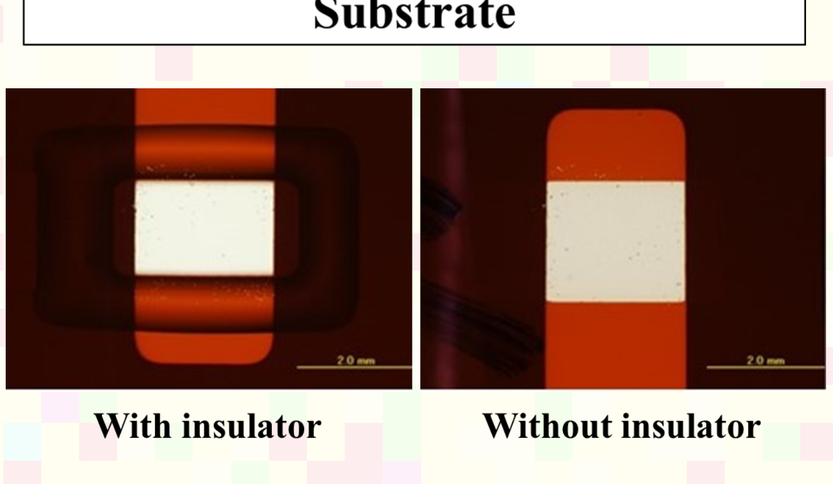
Developed technologies

- **OLED devices with On-Demand patterns of insulators printed by ink-jet**
  - Uniform emission including with edges of insulators
  - Comparable characteristics and lifetime with OLEDs without the insulators.



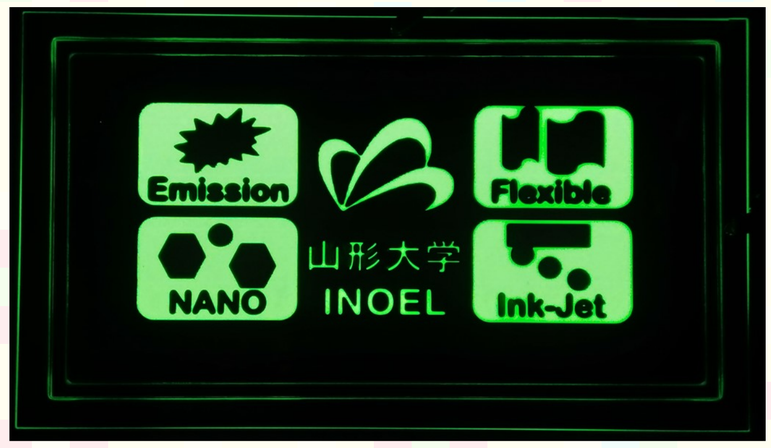






With insulator Without insulator

Substrate size：50mm × 50mm



Substrate size：60mm × 100mm

Collaboration TOYO INK SC HOLDINGS CO., LTD.

Related program

- Yamagata University Flexible Electronics Consortium for Academia-Industry Cooperation (YU-FLEC) [Jan. 2018～Mar. 2023].
- MEXT: Construction Program of Open Innovation Organization [FY2018～FY2022].

Publication

- M. Sugimoto, Y. Fukuchi, H. Tsuruta, M. Koden, H. Nakada, T. Yuki, The 31th Meeting of Japan OLED Forum, S7-3 (2020).

INOEL Yamagata University Innovation Center for Organic Electronics

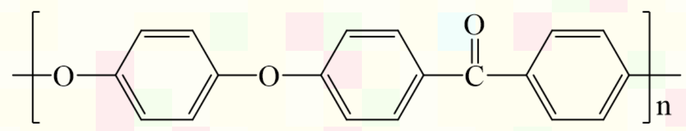
Research Group for Flexible Technologies (Nakada/Furukawa/Yuki/Koden)

山形大学 Yamagata University

Developed technology

High Temperature Tolerant Barrier Films for Flexible OLEDs

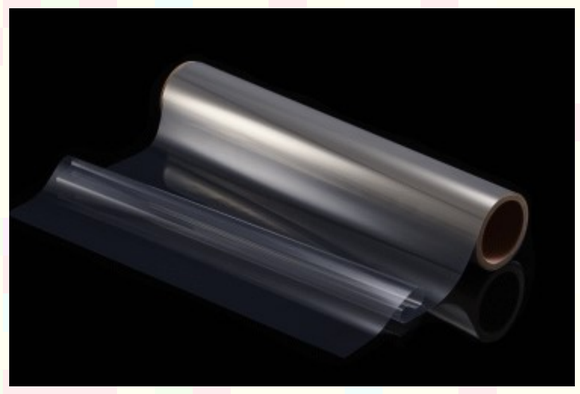
OLED fabrication often requires high temperature processes (higher than 200℃). From this point of view, we develop high temperature tolerant barrier films for flexible OLEDs, using EXPEEK® film developed by KURABO.



Fundamental moiety of PEEK

Technological features

- Advantages of high temperature tolerant film EXPEEK (KURABO INDUSTRIES LTD.)
  - Biaxially stretched PEEK (polyetheretherketone) film
  - Similar temperature tolerance to polyimide (Tg：320℃)
  - Excellent solvent tolerance
  - Excellent transparency
  - Low thermal shrinkage
- Application of EXPEEK with gas barrier layer to flexible OLED devices

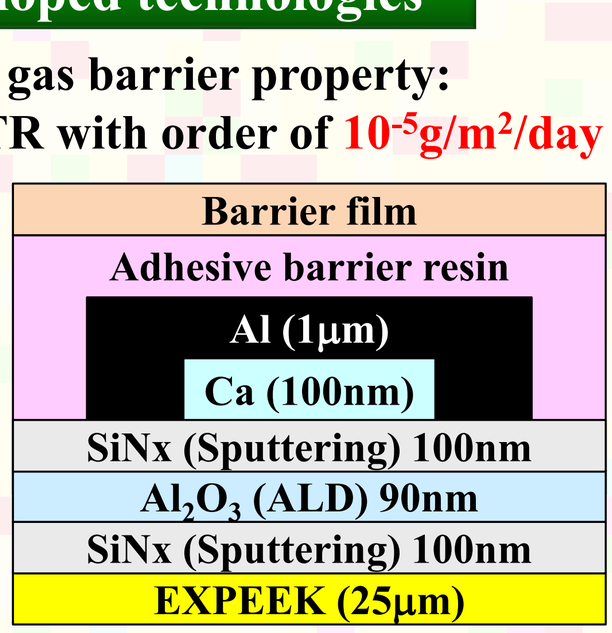


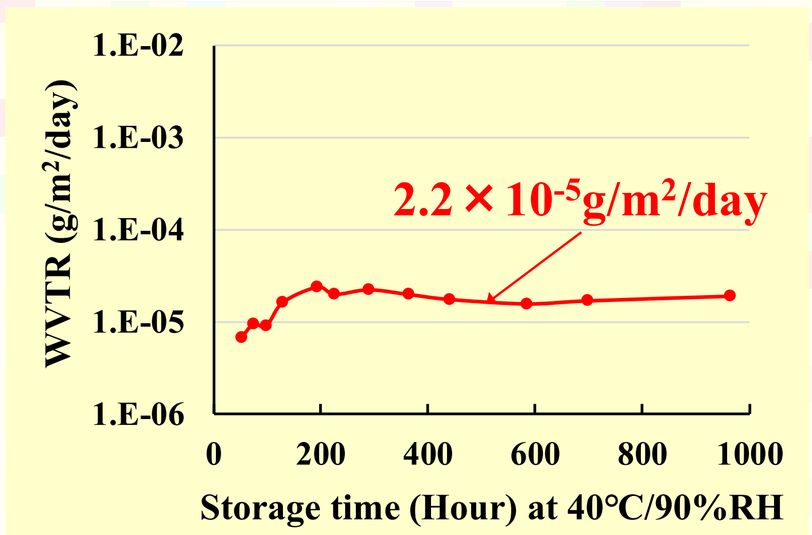
EXPEEK
(KURABO INDUSTRIES)

Developed technologies

- High gas barrier property:

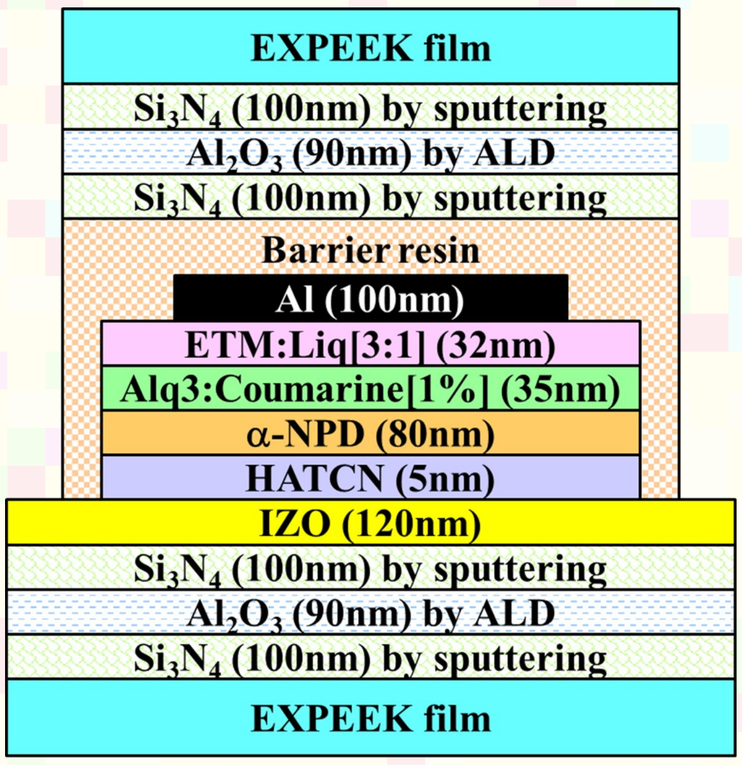
WVTR with order of 10^{-5}g/m^2/day

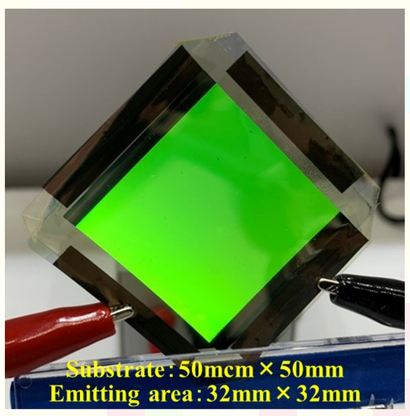




WVTR (Water Vapor Transmission Rate) measurement by Ca corrosion method

- Flexible OLED devices





"JFlex2020"
(Jan. 2020 / Tokyo)

Collaboration KURABO INDUSTRIES LTD.

Related program

- Yamagata University Flexible Electronics Consortium for Academia-Industry Cooperation (YU-FLEC) [Jan. 2018～Mar. 2023].
- MEXT: Construction Program of Open Innovation Organization [FY2018～FY2022].

Publication

- T. Yuki, T. Nishikawa, M. Sugimoto, H. Nakada, M. Koden, IDW'20, FLX2-3 (2020). "High Temperature Tolerant Barrier Film with Stacking Barrier Layers by Sputtering and ALD"
- Yamagata University；"JFlex2020" (Jan. 2020 / Tokyo); "JFlex2019" (Jan. 2019 / Tokyo).
- KURABO; "7th Fine Plastic Exhibition" (Dec. 2018 / Tokyo), "SEMICON Japan 2018" (Dec. 2018 / Tokyo).

INOEL Yamagata University Innovation Center for Organic Electronics

Research Group for Flexible Technologies (Nakada/Furukawa/Yuki/Koden)

山形大学 Yamagata University

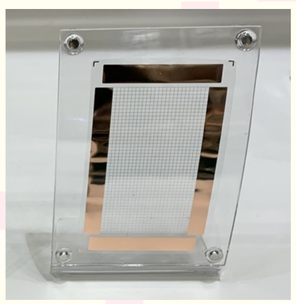
Developed technology

Non-ITO Transparent Electrode with Implanted Metal-mesh Structure

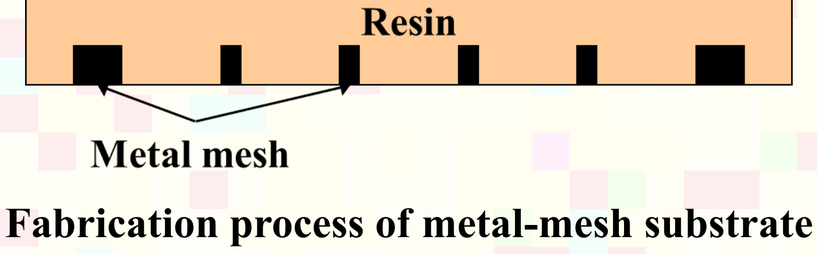
ITO (Indium Tin Oxide), which is the most common transparent electrode in LCDs and OLEDs, has issues in cost, productivity, etc.
We develop OLED devices using a non-ITO transparent electrode with novel implanted metal-mesh structure fabricated by Toyo Aluminium.

Technological features

■ **Non-ITO transparent electrode with implanted metal-mesh structure fabricated by Toyo Aluminium K.K.**
- **High conductivity led by Al-mesh or Cu-mesh**
- **Smooth surface due to the implanted metal-mesh electrode into resin**
- **Applicable to OLED, OPV, etc.**
- **Applicable to flexible devices**



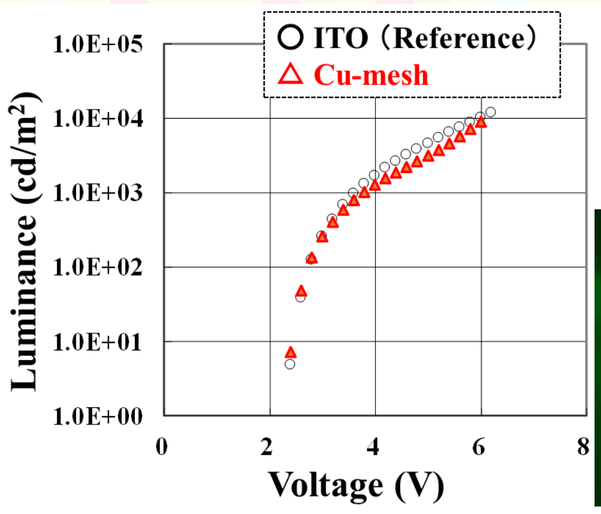
	Sheet resistance
ITO（on glass）	～10Ω/□
ITO（on film）	～40Ω/□
Al mesh (thickness: 15μm)	0.65mΩ/□
Cu mesh (thickness: 15μm)	0.026mΩ/□

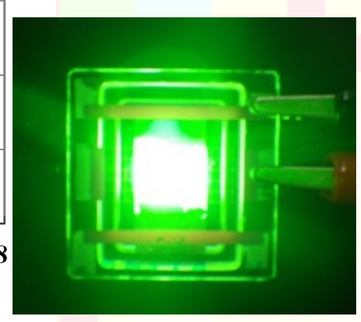


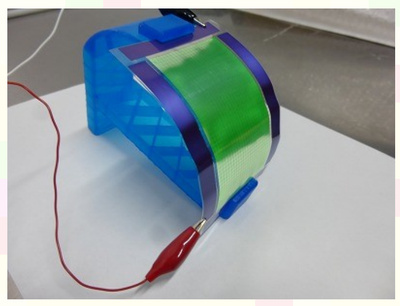
Fabrication process of metal-mesh substrate

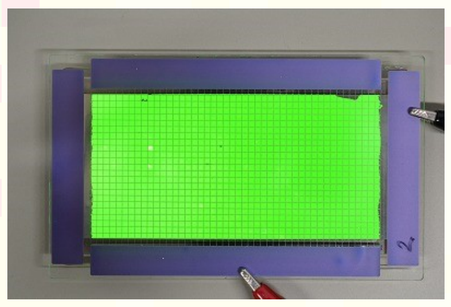
Developed technologies

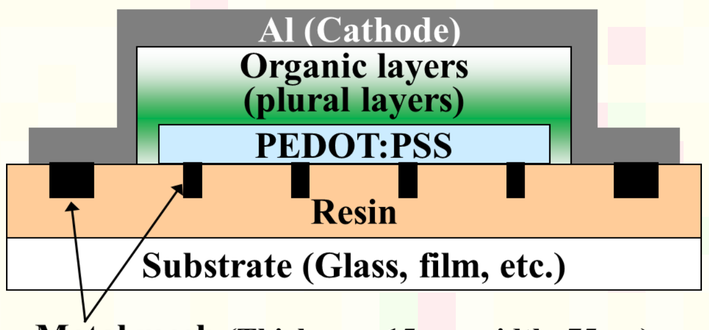
■ **OLED devices using non-ITO transparent electrode with implanted metal-mesh electrode fabricated by Toyo Aluminium K.K.**
- **Comparative performance with normal ITO electrode**











Metal mesh (Thickness: 15μm, width: 75μm)

Collaboration Toyo Aluminium K.K., Prof. Takeshi Sano (INOEL, Yamagata University)

Related program

- Yamagata University Flexible Electronics Consortium for Academia-Industry Cooperation (YU-FLEC) [Jan. 2018～Mar. 2023].
- JST: OPERA Program Grant Number JPMOP1844 [FY2018～FY2022].
- MEXT: Construction Program of Open Innovation Organization [FY2018～FY2022].

Publication

- M. Koden, N. Kawamura, T. Yuki, H. Nakada, R. Waguri, K. Den, R. Nakao, H. Minamiyama, The 31th Meeting of Japan OLED Forum, S7-2 (2020).
- R. Waguri, K. Den, R. Nakao, H. Minamiyama, MES2020, 1B1-2 (2020).
- Yamagata University; “JFlex2020” (Jan. 2020 / Tokyo), “TCTJAPAN” (Jan. 2020 / Tokyo, “JFlex2019” (Jan. 2019 / Tokyo).
- Toyo Aluminium; Japan Chemical Daily (20 Jan. 2020), Japan Metal Daily (18 Mar. 2020).
- R. Waguri, Toyal Technical Report (2019).
- Toyo Aluminium; “INTERNEPCON Japan” (Jan. 2020, Jan. 2019 / Tokyo).

INOEL Yamagata University Innovation Center for Organic Electronics

Research Group for Flexible Technologies (Nakada/Furukawa/Yuki/Koden)

山形大学 Yamagata University

Developed technology

Printed Flexible Organic Photovoltaic (OPV) Fabricated by Roll-to-roll Processes

By the collaboration with MORESCO Corporation and ideal star inc., we developed a roll-to-roll (R2R) process technology for printing-type flexible Organic Photovoltaics (OPVs), which are being developed by MORESCO Corporation and ideal star inc. The develop devices are being evaluated by the verification test of the technology.

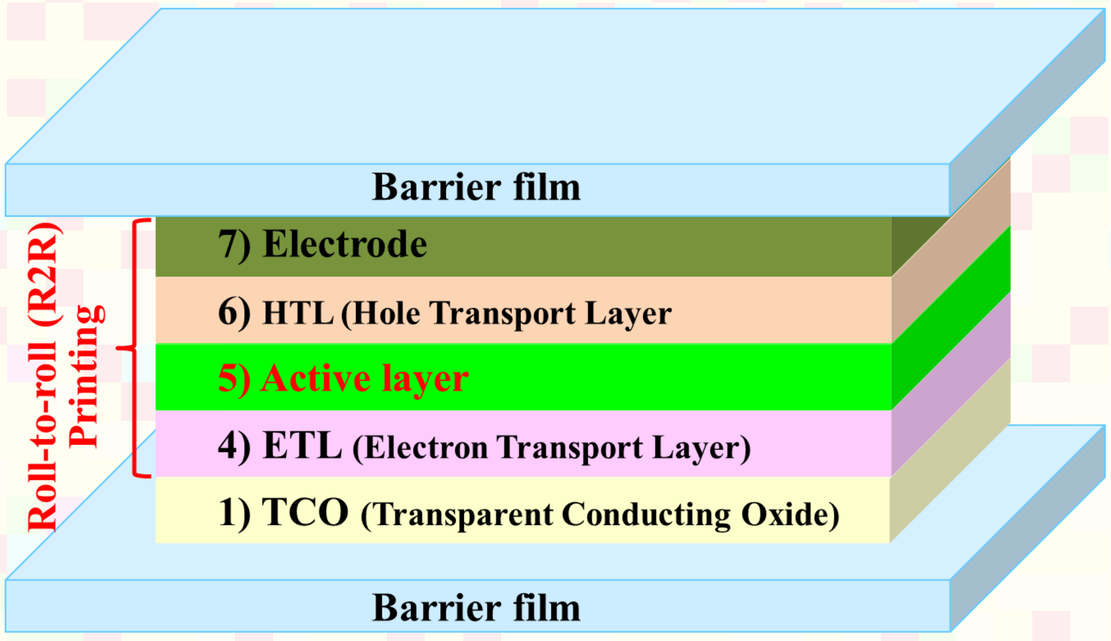
The printed flexible OPV is expected to be inexpensive compared with silicon-based current PV and to produce clean energy because of the drastic reduction of greenhouse gas generated during production to discard.

Features of flexible OPV

- ■can be applied to windows etc. due to the transparent feature.
- ■thin, light weight and un-breakable due to flexible and film
- ■applied to various places such as windows, walls, etc. by double-sided tape etc.

Technological features

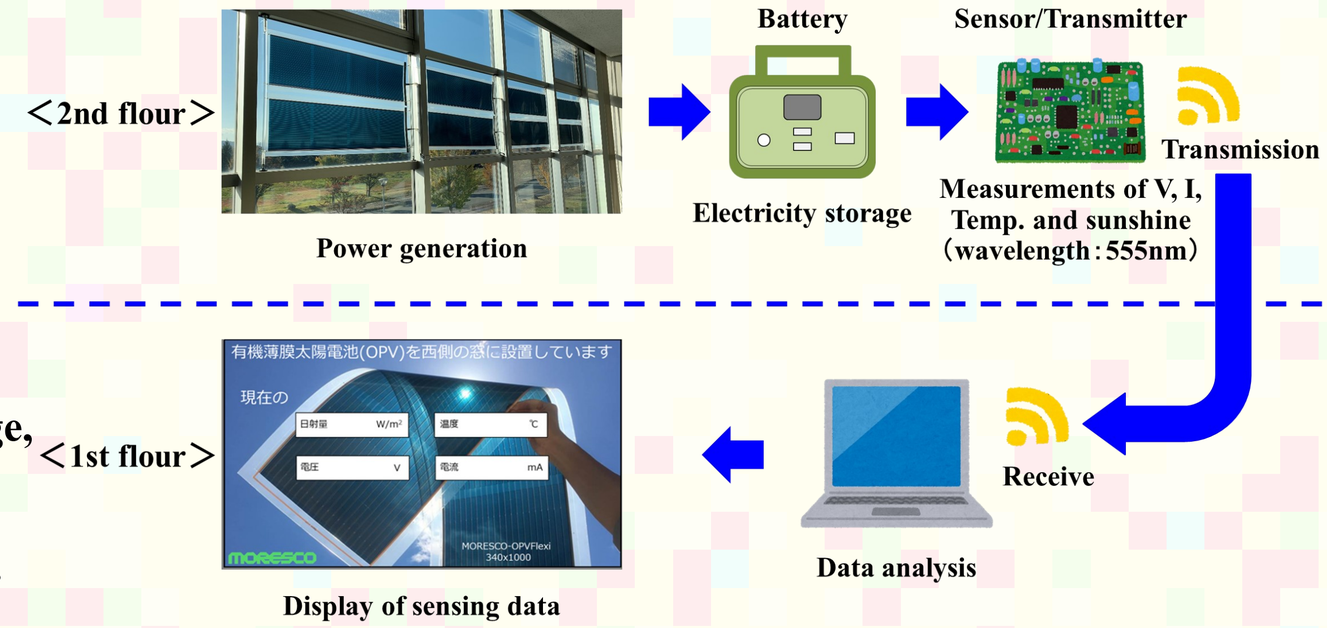
- ■Fabricated by roll-to-roll (R2R) printing
- ■Width:30cm、Length>1m
- ■Fabrication processes
  - 1) Transparent electrode(TCO) deposition
  - 2) TCO patterning
  - 3) Cleaning of substrate
  - 4) Printing of ETL（R2R）
  - 5) Printing of active layer（R2R）
  - 6) Printing of HTL（R2R）
  - 7) Printing of electrode（R2R）
  - 8) Current collection
  - 9) Encapsulation



Structure of flexible OPV

Developed technologies

- ■ Roll-to-roll (R2R) printing technologies of flexible OPV
- ■ Verification test:
  - 1) Laminate flexible OPVs on windows of 2nd flour
  - 2) Measure and transmit the data of voltage, current, temperature and sunshine by using the generated power.
  - 3) Display the measured data on a monitor of 1st flour.



Verification test at INOEL of Yamagata University

Collaboration

MORESCO Corporation / ideal star inc.

Related program

- JST: OPERA Program Grant Number JPMOP1614 [FY2016～FY2020].
- MEXT: Construction Program of Open Innovation Organization [FY2018～FY2022].

Publication

- Yamagata University； Press Release 2019.11.6.
- MORESCO； Press Release 2019.11.6.

INOEL Yamagata University Innovation Center for Organic Electronics

Research Group for Flexible Technologies (Nakada/Furukawa/Yuki/Koden)

山形大学 Yamagata University

Developed technology

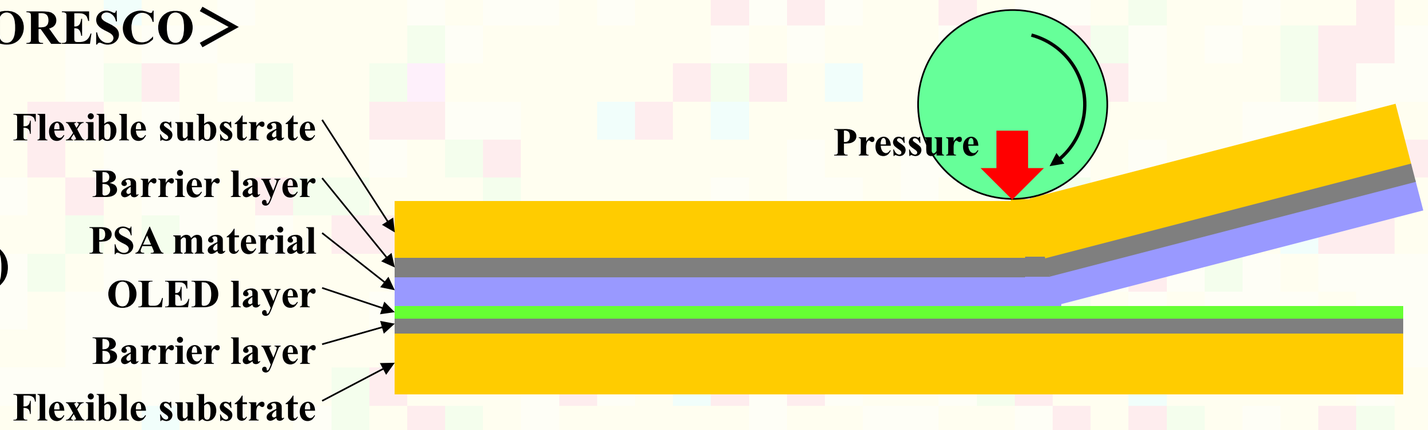
PSA Encapsulating Technologies for OLEDs

We collaborate with MORESCO Corporation, aiming at the development of flexible OLED devices with their PSA (Pressure Sensitive Adhesive) film.

Technological features

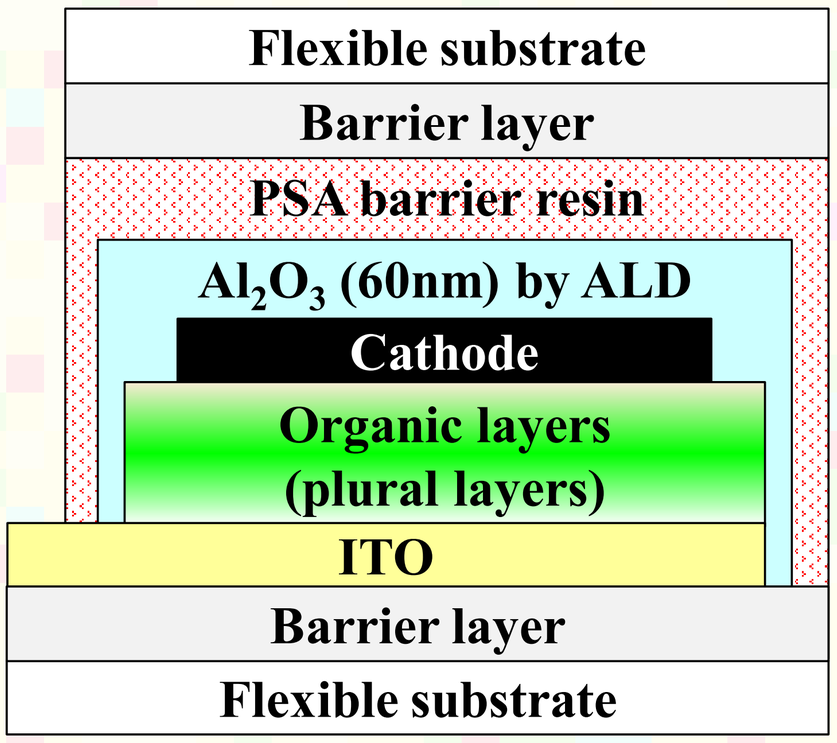
＜Unique features of PSA film of MORESCO＞

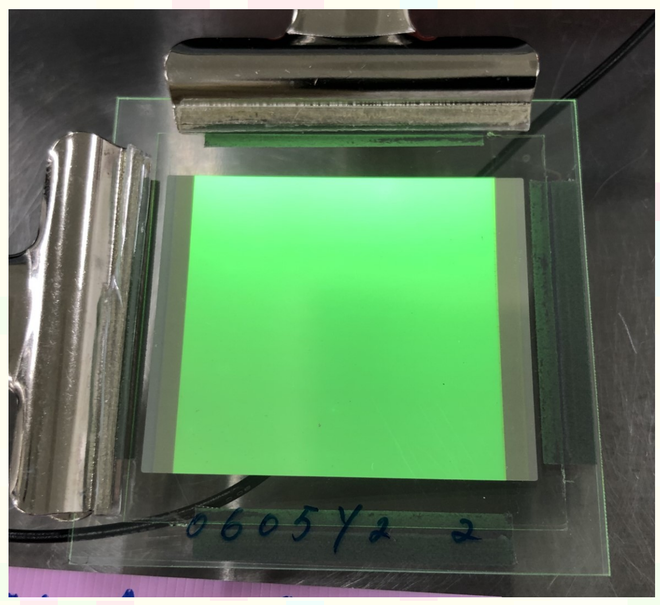
- Hot-melt type
- Simple encapsulation process
- Excellent flexibility
- Excellent adhesion (barrier layer)
- High gas barrier
- Solvent free

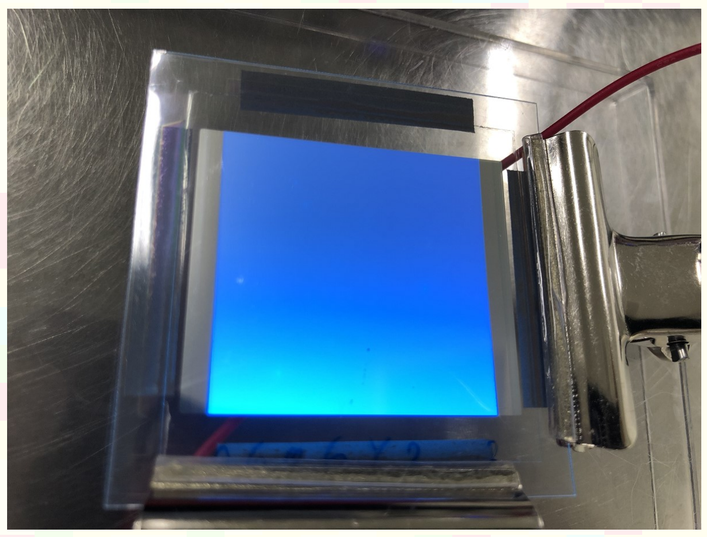


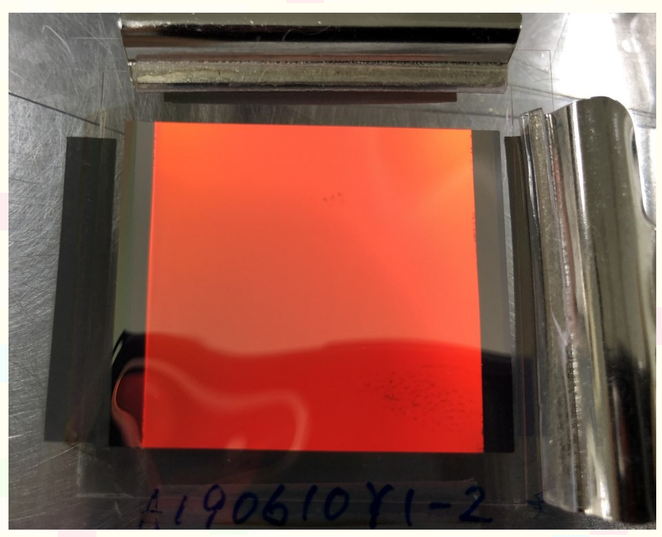
Developed technologies

- Flexible OLED devices with PSA encapsulation









Collaboration **MORESCO Corporation**

Related program

- Yamagata University Flexible Electronics Consortium for Academia-Industry Cooperation (YU-FLEC) [Jan. 2018～Mar. 2023].
- JST: OPERA Program Grant Number JPMOP1614 [FY2016～FY2020].
- MEXT: Construction Program of Open Innovation Organization [FY2018～FY2022].

INOEL Yamagata University
Innovation Center for Organic Electronics

Research Group for Flexible Technologies (Nakada/Furukawa/Yuki/Koden)

山形大学 Yamagata University

Developed technology

Barrier layer by ALD (Atomic Layer Deposition)

ALD (Atomic Layer Deposition) can fabricate barrier layers with excellent surface coverage and can be applied flexible electronics devices.
We provide high gas barrier layers using ALD method for applying various collaborations on flexible organic electronics.

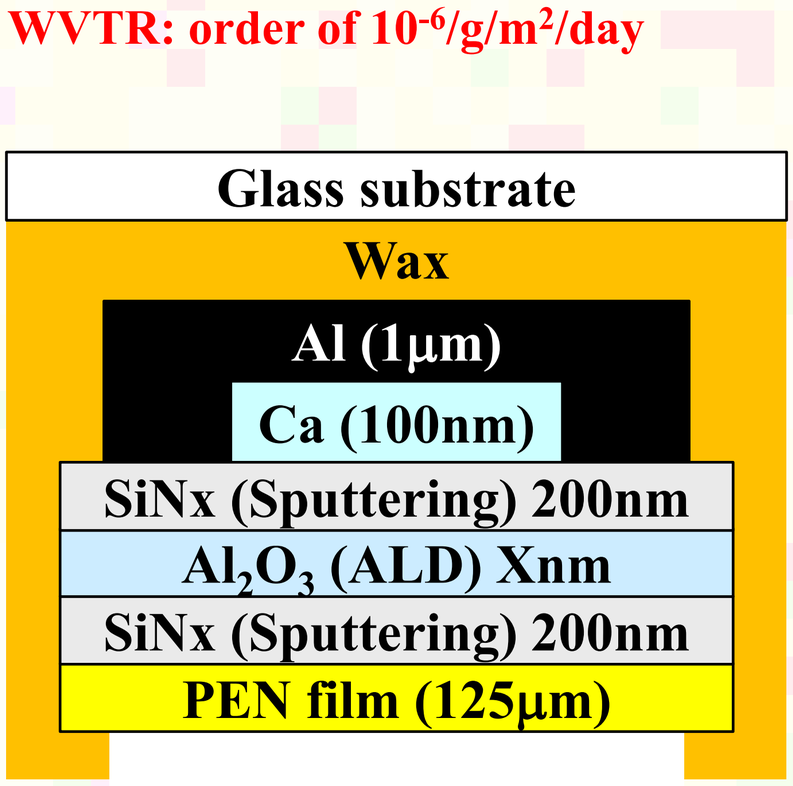
Technological features

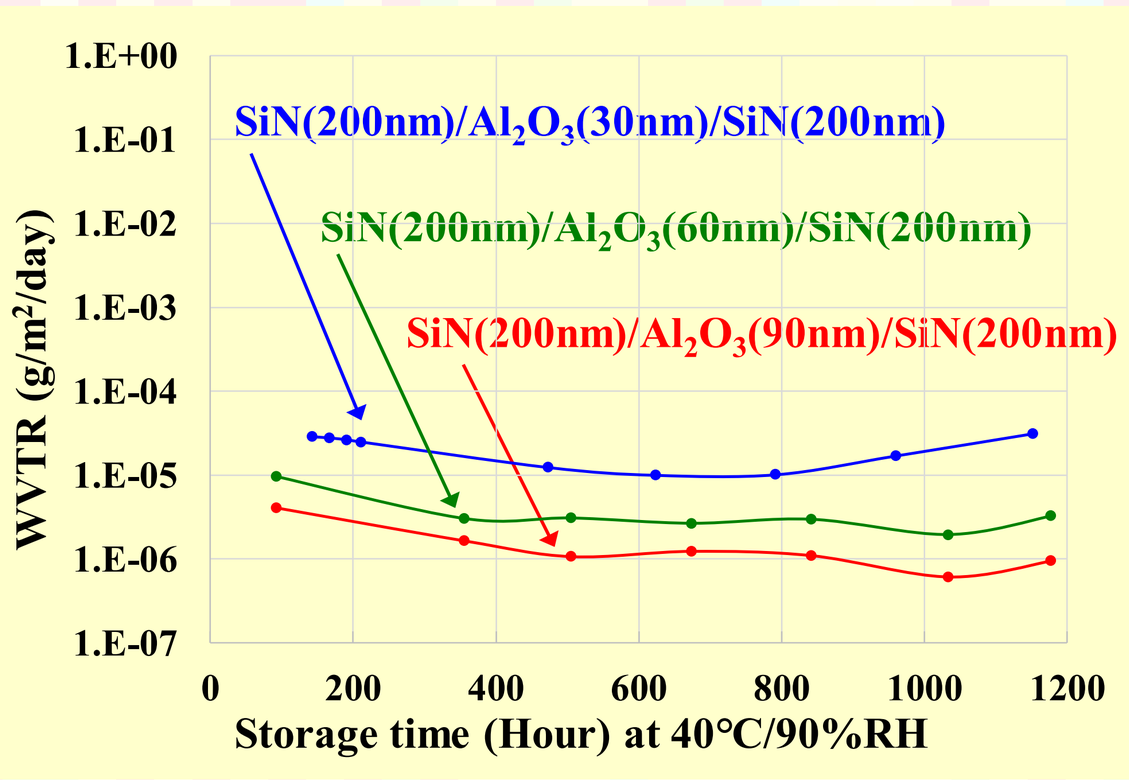
- Excellent surface coverage by ALD
- High gas barrier property by multi-layer structure with SiNx.
  WVTR: order of 10^{-6}/g/m^2/day
  (WVTR: Water Vapor Transmission Rate)
- Equipment：ALD of SUGA CO., Ltd.
  (Maximum substrate size: 10cm × 10cm)

ALD equipment (SUGA CO., Ltd.)

Developed technologies

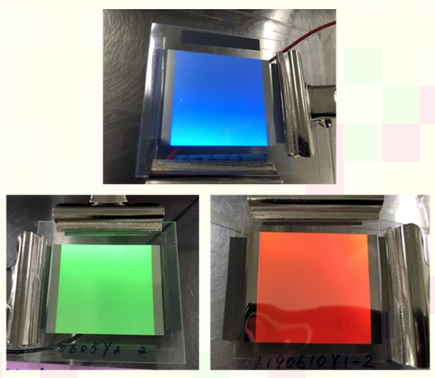
- Multi-layered barrier with Al_2O_3(ALD) and SiNx (Sputtering) layers
  WVTR: order of 10^{-6}/g/m^2/day

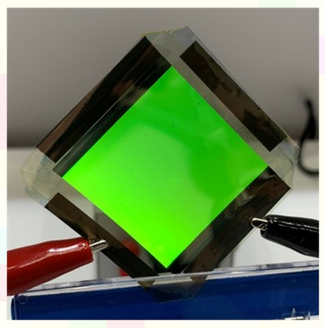


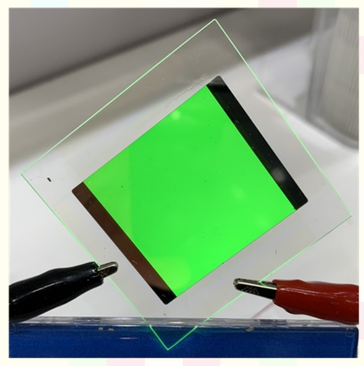


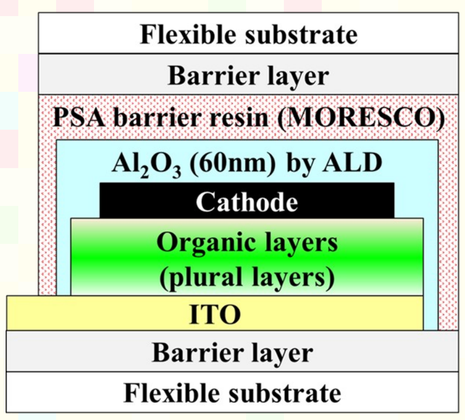
WVTR (Water Vapor Transmission Rate) measurement by Ca corrosion method

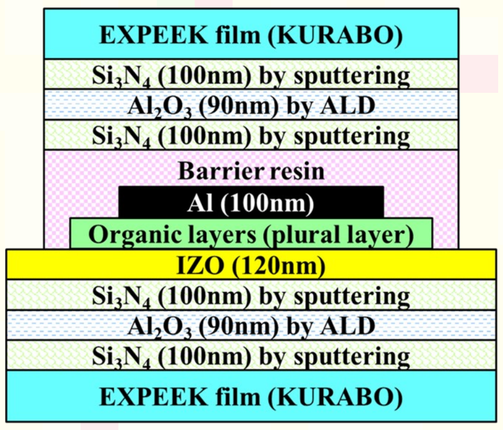
- OLED devices with Al_2O_3 layers deposited by ALD

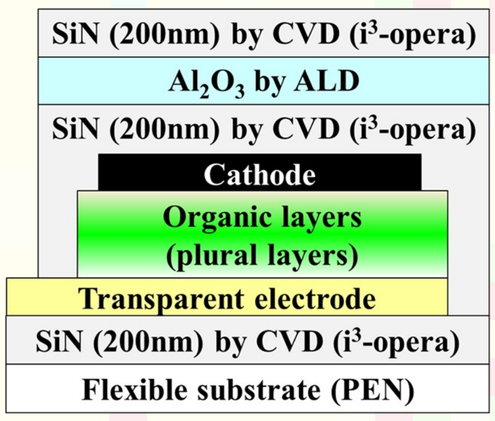


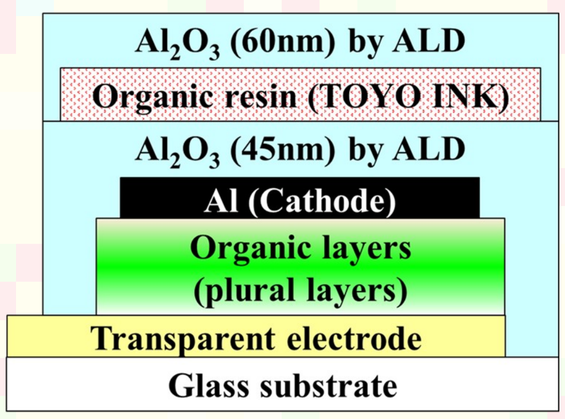












Related program

- Yamagata University Flexible Electronics Consortium for Academia-Industry Cooperation (YU-FLEC) [Jan. 2018～Mar. 2023].
- MEXT: Construction Program of Open Innovation Organization [FY2018～FY2022].

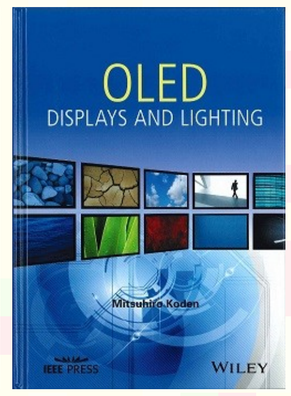
Topics / Publications

Award

- H. Nakada, M. Koden, "Award from Minister of State for Science and Technology Policy", Cabinet Office, Government of Japan, (2017).

Book

- M. Koden, "OLED Displays and Lighting" (Wiley, IEEE Press) (2017).



Paper

- T. Furukawa, M. Koden, IEICE Trans. Electron, E100-C, 949-954 (2017).
  "Novel roll-to-roll deposition and patterning of ITO on ultra-thin glass for flexible OLEDs"

International Conference

- T. Yuki, T. Nishikawa, M. Sugimoto, H. Nakada, M. Koden, IDW'20, FLX2-3 (2020).
  "High Temperature Tolerant Barrier Film with Stacking Barrier Layers by Sputtering and ALD"
- Y. Kawamura, T. Takahashi, K. Wakabayashi, H. Hirose, Y. Azakami, H. Itoh, T. Furukawa, IDW'20, FLX3-04L (2020).
  "Effect of Pressure Forming Conditions on PC Sheet integrating Electric Wiring for 3D Electronics Technology"
- T. Nakagaki, T. Kawabata, H. Takimoto, T. Furukawa, IDW'19, FLXp1-9L (2019).
  "Scribing Tool and Cutting Method for Ultra-thin Glass"
- K. Taira, Taiga Suzuki, W. Konno, H Chiba, H. Itoh, M. Koden, T. Takahashi, T. Furukawa, IDW'18, FLX2-4L (2018).
  "Development of High Gas Barrier Film Using Novel Precursor by Roll to Roll PECVD"
- T. Furukawa, Advanced Materials-2018（WCAM2018） (2018). [Invited]
  "Substrates for Organic Electronics - Ultra-thin Glass, Stainless Steel Foil and High Gas Barrier Plastic Film"
- M. Koden, T. Furukawa, T. Yuki, H. Nakada, LS16 (2018). [Invited]
  "Roll-to-roll and printing technologies for electrodes of flexible OLED lighting"
- T. Furukawa, N. Kawamura, T. Noda, Y. Hasegawa, D. Kobayashi, M. Koden, IDW'17, FLX6-2 (2017).
  "Novel Roll-to-Roll Fabrication Processes of Transparent Electrodes on Ultra-Thin Glass"
- T. Furukawa, N. Kawamura, M. Koden, H. Itoh, H. Kuroiwa, K. Nagai, LOPEC (2017).
  "Gas barrier film for OLED devices"
- M. Koden, T. Furukawa, T. Yuki, H. Kobayashi, H. Nakada, IDW/AD'16, FLX3-1 (2016). [Invited]
  "Substrates and Non-ITO Electrodes for Flexible OLEDs"
- T. Furukawa, IWFPE2016 (2016). [Invited]
  "Flexible Substrates and Printed Transparent Electrode for OLED Lighting"
- T. Furukawa, N. Kawamura, H. Nakada, M. Koden, The International Conference on Flexible and Printed Electronics (ICFPE 2016), O15-6 (2016). "Novel ITO fabrication processes on ultra-thin glass"

Exhibitions

- "JFlex" (Jan. 2019, Jan. 2020).
- "Printable Electronics"（2014, 2015, 2015, 2016, 2017, 2018）.
- "LOPEC"（2018, 2019 / Germany）.
- "Flex Japan 2019"（May 2019）.
- "LED & OLED EXPO 2017"（Jun. 2017 / Korea）.
- "G7 Exhibition" (May 2016).
- "International Photonics Exhibition 2015"（Oct. 2015 / Korea）.

Printable Electronics 2017 Award

JFlex Award (2019, 2020)

"International Photonics Exhibition 2015" (October 2015, Korea)

"JFlex 2020" (Jan. 2020, Tokyo)

"LOPEC" (Mar. 2019, Germany)

"Flex Japan 2019" (May 2019, Tokyo)

Research Group for Flexible Technologies (Nakada/Furukawa/Yuki/Koden)

Main Members

Professor, Deputy Director
Hitoshi Nakada
nakada@yz.yamagata-u.ac.jp
Field: Organic electronics devices

1981 Graduated at Tohoku University
1981～2013 Pioneer Corporation
1988～ R&D of OLED display and OLED lighting
2013～ INOEL, Yamagata University (current position)

(Award)
- Award from Minister of State for Science and Technology Policy", Cabinet Office, Government of Japan (2017).
- Optoelectronics Industry and Technology Development Association, 19th Kenjiro-Sakurai Memorial Award (2003).
- 47th Okochi Memorial Award (2000).

(Development)
- World's first OLED product (passive-matrix OLED display) (1997).
- World's first phosphorescent OLED product (2003).
- Passive-matrix full-color flexible OLED display prototype (2003).

Professor
Dr. Mitsuhiro Koden
koden@yz.yamagata-u.ac.jp
Field: LCD, OLED, Chemistry

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)

(Award)
- Award from Minister of State for Science and Technology Policy", Cabinet Office, Government of Japan (2017).
- Award from The Japanese Liquid Crystal Society (2005).

(Development)
- 17" Ferroelectric liquid crystal display (FLCD) prototype (1999).
- 3.6" Polymer OLED display prototype fabricated by ink-jet (2006).

(Book)
- M. Koden, "OLED Displays and Lighting" (Wiley; IEEE Press) (2017).
- K. Takatoh, M. Hasegawa, M. Koden, N. Itoh, R. Hasegawa, M. Sakamoto, "Alignment Technologies and Applications of Liquid Crystal Devices" Taylor & Francis (2005).

Associate Professor
Tadahiro Furukawa
ta-furukawa@yz.yamagata-u.ac.jp
Field: Fine patterning technology, Printing, Roll-to-roll technology

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
2011～ INOEL, Yamagata University (current position)

(Papers)
- T. Furukawa *et al*, IEICE Trans. Electron, E100-C, 949-954 (2017).

(International conference)
- T. Furukawa, M. Koden, ICDT2019 (2019).
- T. Furukawa, WCAM2018 (2018). [China, Invited]
- T. Furukawa *et al*., IDW'17, FLX6-2 (2017).
- T. Furukawa, LED & OLED EXPO 2017 (2017). [Korea]
- T. Furukawa *et al*., LOPEC (2017). [Germany]
- T. Furukawa *et al*., IDW/AD'16, FLX3-3 (2016).
- T. Furukawa, IWFPE2016 (2016). [Korea, Invited]
- T. Furukawa *et al*., ICFPE 2016, O15-6 (2016).

Associate Professor
Dr. Toshinao Yuki
t-yuki@yz.yamagata-u.ac.jp
Field: OLED (Display, Lighting, Device) Polymer materials

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)

(Award)
- The 4th Japan OLED Forum Outstanding Achievement Awards (2011).

(Development)
- World's first phosphorescent OLED product (2003).
- World's first large size tiling OLED display product (2010).
- World's first color-tunable OLED lighting product (2013).

Project Scientist
Miho Sugimoto
m-sugimoto@yz.yamagata-u.ac.jp

1999 Graduated at Keio University (Master deg.)
1999～2004 Murata Manufacturing Co., Ltd.
2005～2019 Tohoku Pioneer Corporation
2019～ INOEL, Yamagata University (current position)
(Skills)
Film OLED, Encapsulation, Electrode, Equipment, etc.

Project Scientist
Norifumi Kawamura
n-kawamura@yz.yamagata-u.ac.jp

2001 Graduated at Yamagata University (Master deg.)
2001～2007 IMES Co., LTD
2007～2013 ROHM Co., Ltd. / Lumiotec Inc.
2013～ INOEL, Yamagata University (current position)
(Skills)
OLEDs (Device, process, Evaluation)

Project Scientist
Masanori Abe
m-abe@yz.yamagata-u.ac.jp

1990～2013 Tohoku Pioneer Corporation
2013～ INOEL, Yamagata University (current position)
(Skills)
Printing (Screen printing, etc.), Roll-to-roll (R2R), OLEDs, Encapsulation, Equipment, etc.

Decemver 2020
Research Group for Flexible Technologies
(Nakada/Furukawa/Yuki/Koden Group)
Innovation Center for Organic Electronics (INOEL)
Yamagata University
1-808-48 Arcadia, Yonezawa, Yamagata 992-0119, Japan
TEL +81-238-29-0575
E-mail: nakada@yz.yamagata-u.ac.jp
E-mail: koden@yz.yamagata-u.ac.jp
URL: https://inoel.yz.yamagata-u.ac.jp/F-consortium/home-e.html