山形大学 YAMAGATA UNIVERSITY

CEATEC 2021 (October 2021)

Flexible Organic Electronics Technologies (OLED, OPV, etc.)

We have various technologies and equipment for fabricating flexible organic electronics devices (OLEDs, OPV, etc.).

Using these technologies, we collaborate with industrial companies, aiming at practical developments for actual products.

This material reviews our technologies and equipment for flexible organic electronics devices (OLEDs, OPV, etc.).

Yamagata University
Innovation Center for Organic Electronics (INOEL)
Research Group for Flexible Technologies (Nakada/Furukawa/Yuki/Koden)
http://inoel.yz.yamagata-u.ac.jp/F-consortium/home.html

(Contact) Prof. H. Nakada nakada@yz.yamagata-u.ac.jp
Prof. M. Koden koden@yz.yamagata-u.ac.jp

Technologies and equipment

OLED (Organic Light Emitting Diode) fabrication

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 structure

Various types of OLED devices can be fabricated.

- Bottom emitting OLED
- Top-emitting OLED
- Transparent OLED (Both side emitting)
- Multi-photon
- White emitting

Processes for organic layers

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

Vacuum deposition

Ink-jet

Spin-coat

Spray

Wet cleaning

Plasma cleaner

OPV (Organic Photovoltaic) fabrication

Materials

Various types of OPV materials shown below can be applied to OPV devices.

- Vacuum deposition materials
- Solution materials
- Quantum dot (QD) materials

Device structure

Two types of OPV devices can be fabricated.

- Normal structure
- Inverted structure

Processes for organic layers

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

Vacuum deposition

Ink-jet

Spin-coat

Spray

Wet cleaning

Plasma cleaner

Barrier Layer and Encapsulation

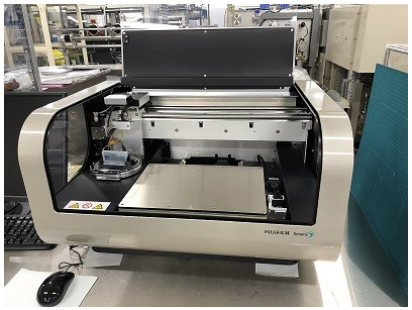
Barrier Layer

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

R2R sputtering and CVD

ALD
（Atomic Layer Deposition）

Sputterig

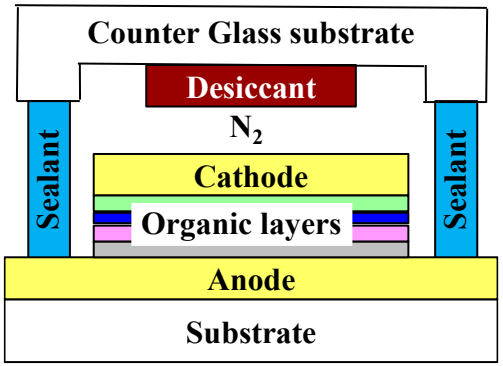


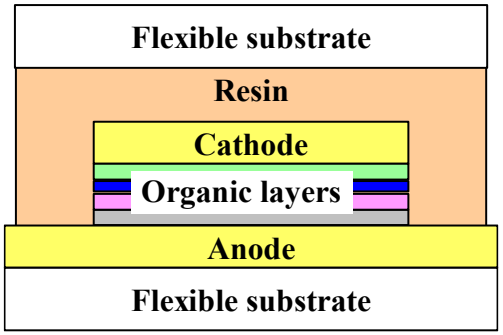
Ink-jet

Encapsulation

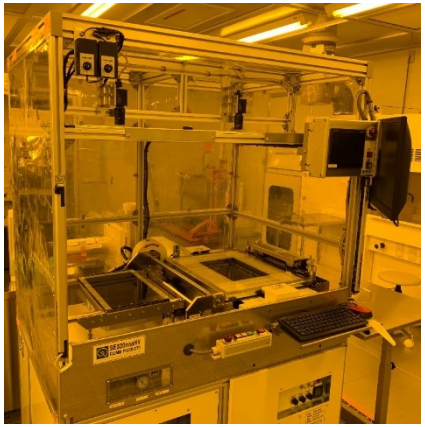
Various encapsulating technologies are applied.

- Common encapsulation with desiccant
- Flexible all-solid type encapsulation





Sheet-type lamination

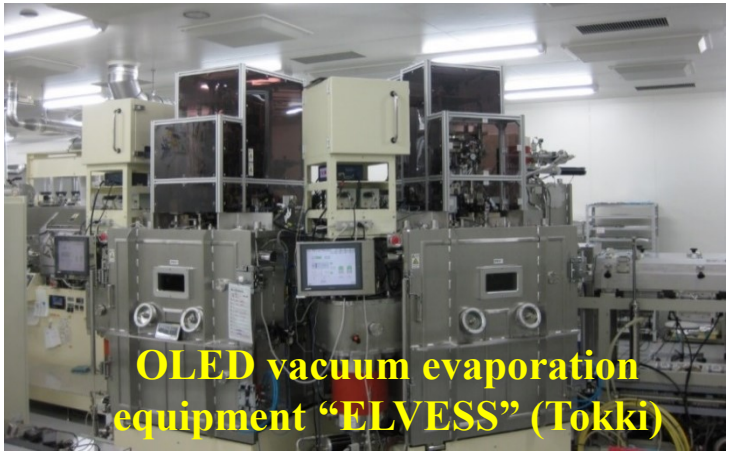


Roll-type lamination

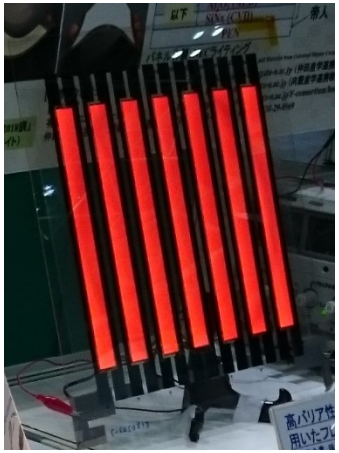
有機EL（OLED），有機薄膜太陽電池（OPV）試作

大面積有機EL

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



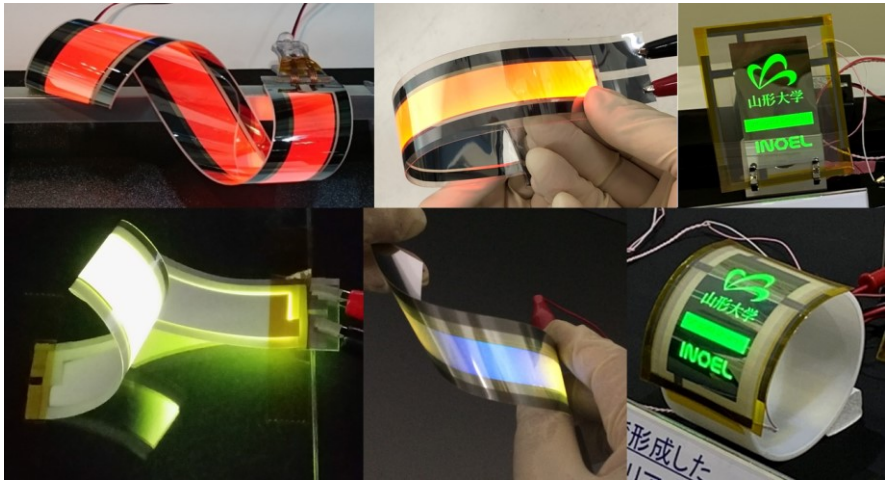
OLED vacuum evaporation equipment “ELVESS” (Tokki)



OLED on 30×30cm glass substrate

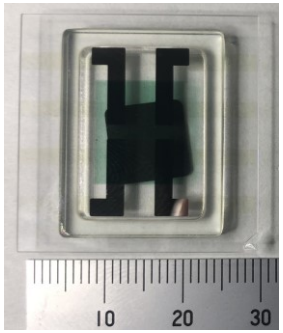
フレキシブル有機EL

Flexible OLED devices with various designs can be fabricated.



有機膜膜太陽電池

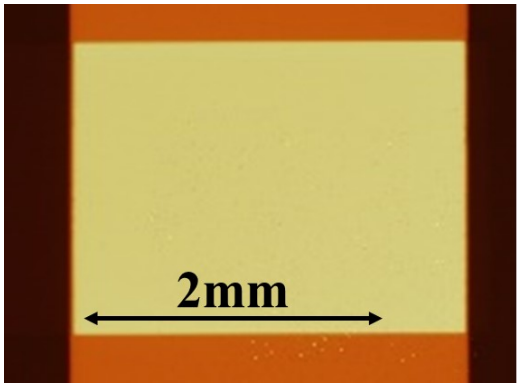
OPV devices can be fabricated.



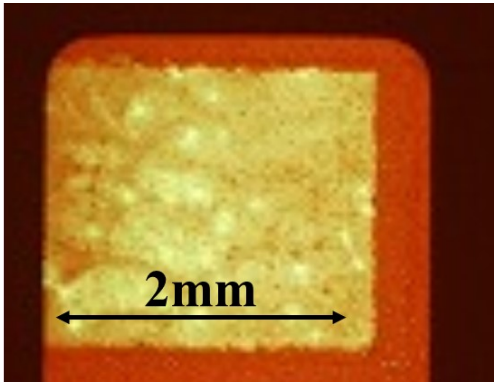
Evaluation of OLED Materials and Devices

Emission uniformity

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



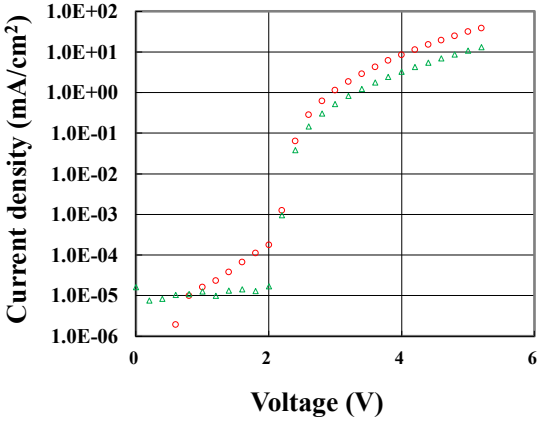
Uniform emission



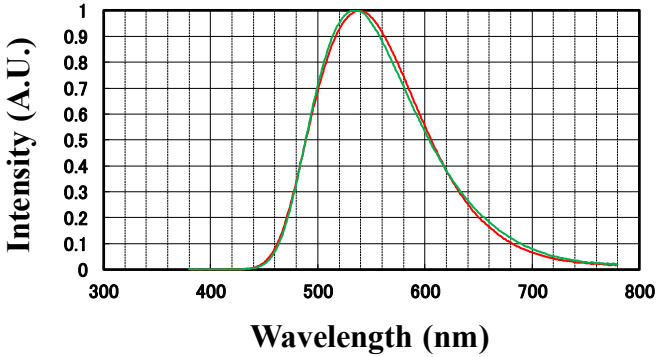
Non-uniform emission with defects

Device characteristics

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



I-V characteristics

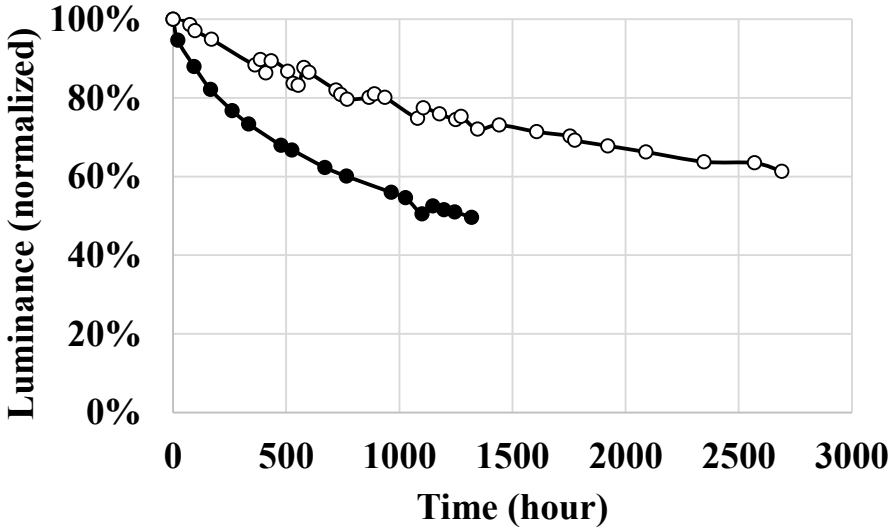


Emission spectrum

Lifetimes of OLED devies

Driving lifetime

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

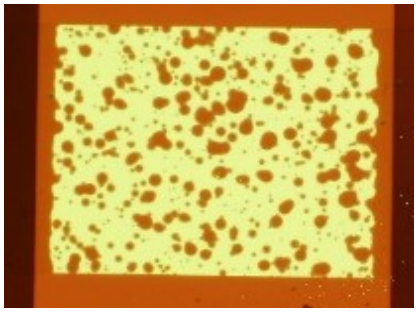


Driving lifetime

Storage lifetime

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

Initial emission (No decfect)

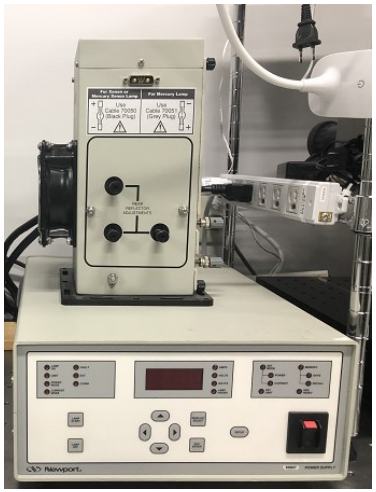


Emission after storage test (Dark spot)

Evaluation of OPV

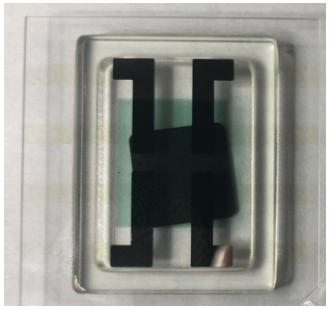
Equipment

Solar simulator
Newport MODEL 66902

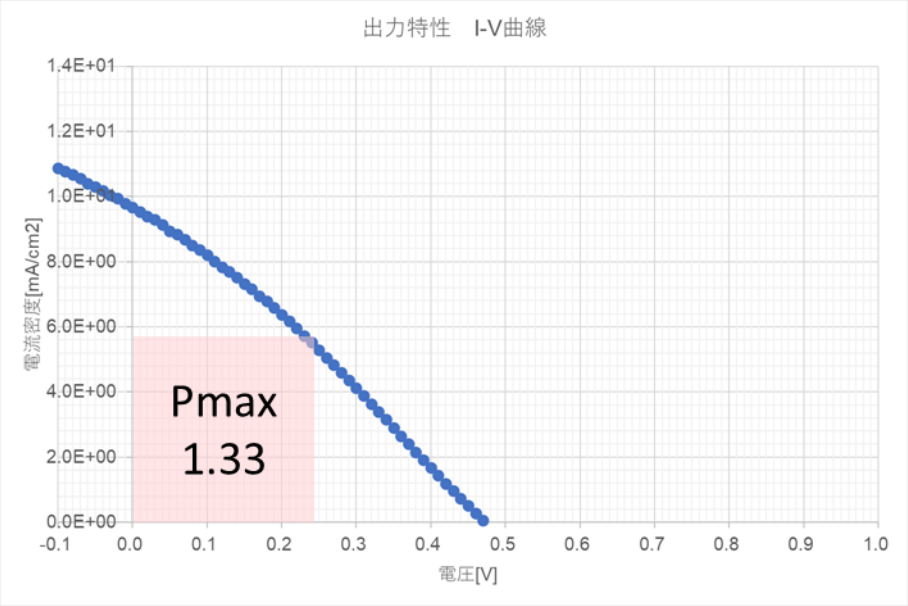


1SUN(1000W/m^2)
AM1.5 room temp.
About 100,000 LUX

OPV device



OPV characteristics



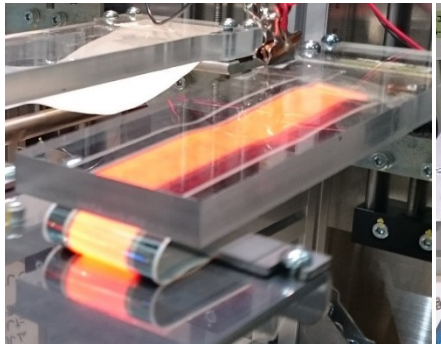
Other evaluaitons

Bending tests

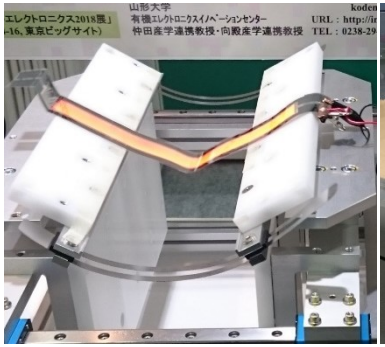
The influences of various bending stress on device characteristics, barrier properties, etc. are evaluated using three types of bending equipment.

Analysis

Other evaluations can be used, based on the request from collaborating companies.
(Example)
- Ionization potential
- Defect analysis
- SEM, AFM
- 3D profile



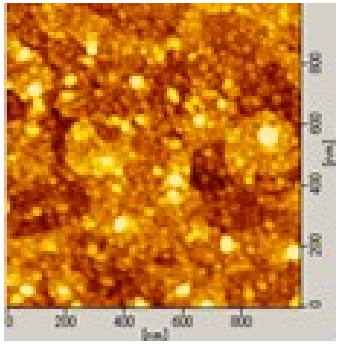
U-shape sliding



Folding

Both-side bending

Ionization potential



AFM

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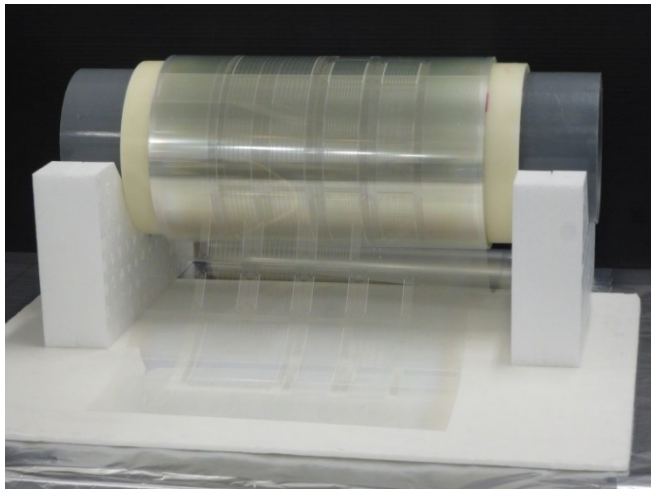
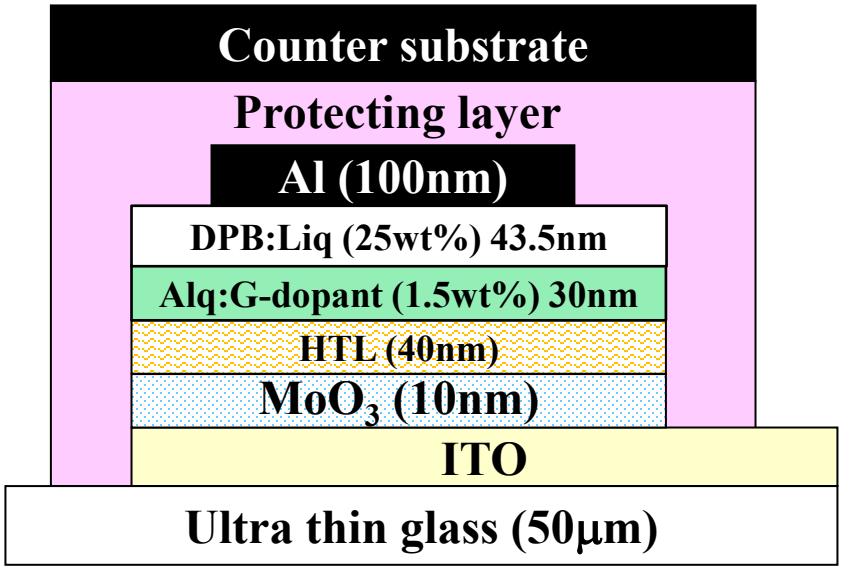
Fabricated flexible organic electronics devices (OLED and OPV)

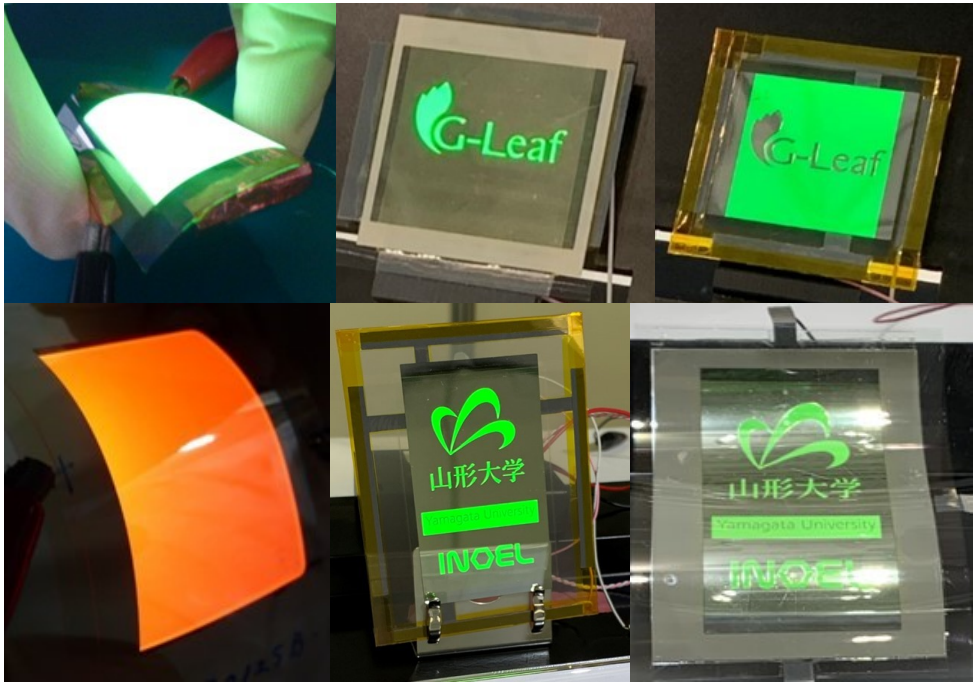
Flexible OLEDs on ultra-thin glass



Ultra-thin glass with bottom electrodes



Devise structure

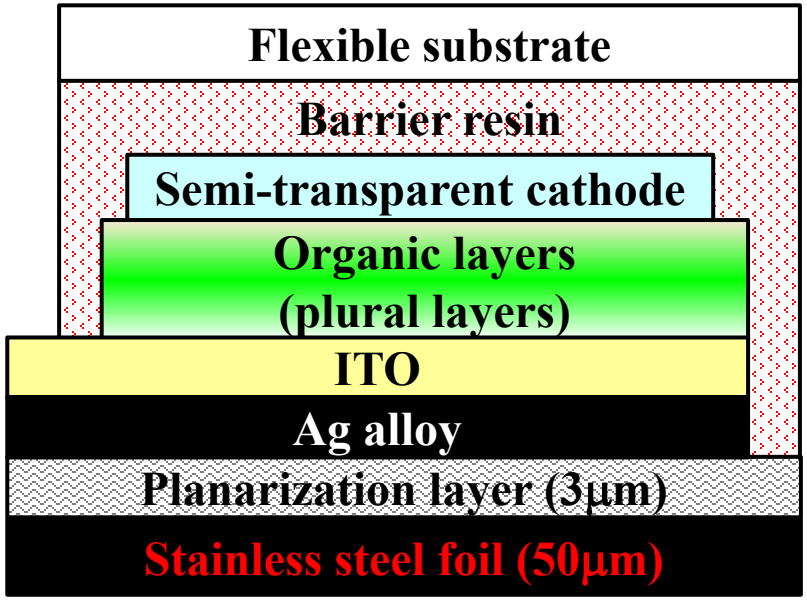


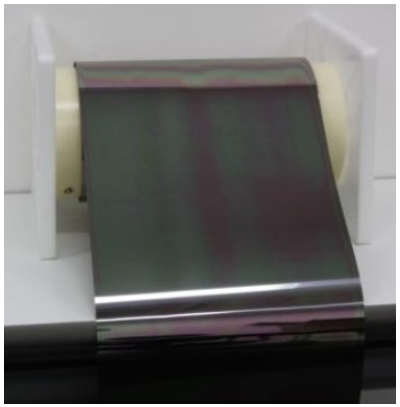
Collaboration Nippon Electric Glass, etc.

Pubrication

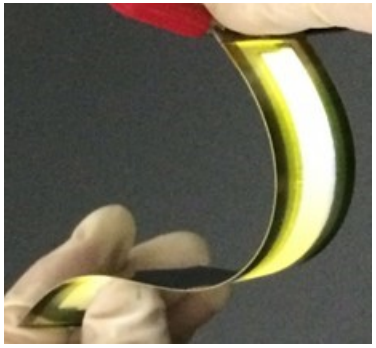
- T. Furukawa, M. Koden, IEICE Trans. Electron, E100-C, 949 (2017).
- T. Nakagaki, T. Kawabata, H. Takimoto, T. Furukawa, IDW'19, FLXp1-9L (2019).
- T. Furukawa, N. Kawamura, T. Noda, Y. Hasegawa, D. Kobayashi, M. Koden, IDW'17,FLX6-2 (2017).

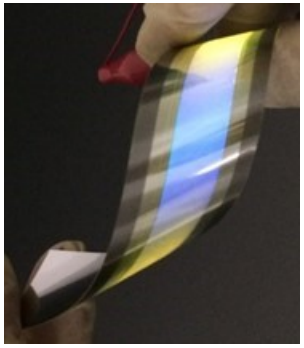
Flexible OLEDs on stainless steel foil





Stainless steel foil of NIPPON STEEL CORPORATION GROUP





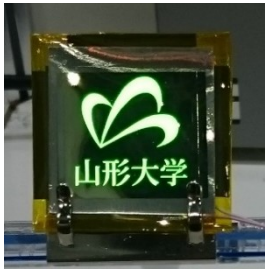
Collaroration

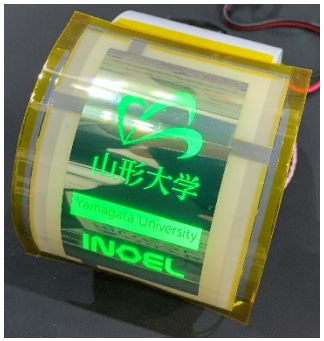
NIPPON STEEL CORPORATION
NIPPON STEEL Chemical & Material Co., Ltd.

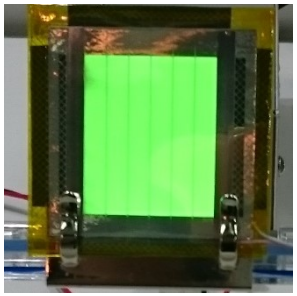
Publication

- Y. Hagiwara, T. Furukawa, T. Yuki, S. Yamaguchi, N. Yamada, J. Nakatsuka, M. Koden, H. Nakada, IDW'17, FLXp1-9L (2017).
- M. Koden, T. Furukawa, T. Yuki, H. Kobayashi, H. Nakada, IDW/AD'16, FLX3-1 (2016).

Flexible OLEDs on barrier film

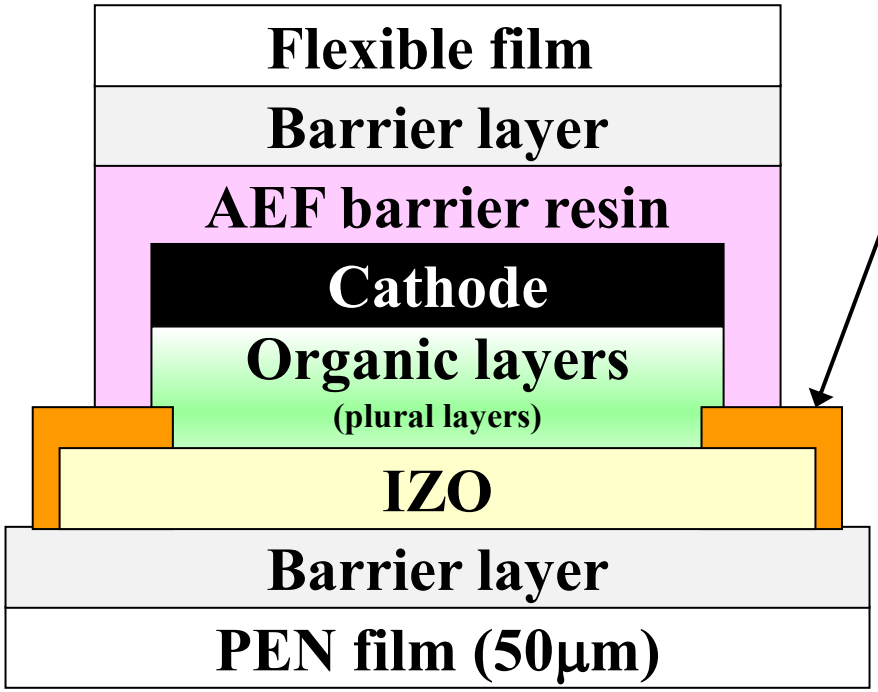


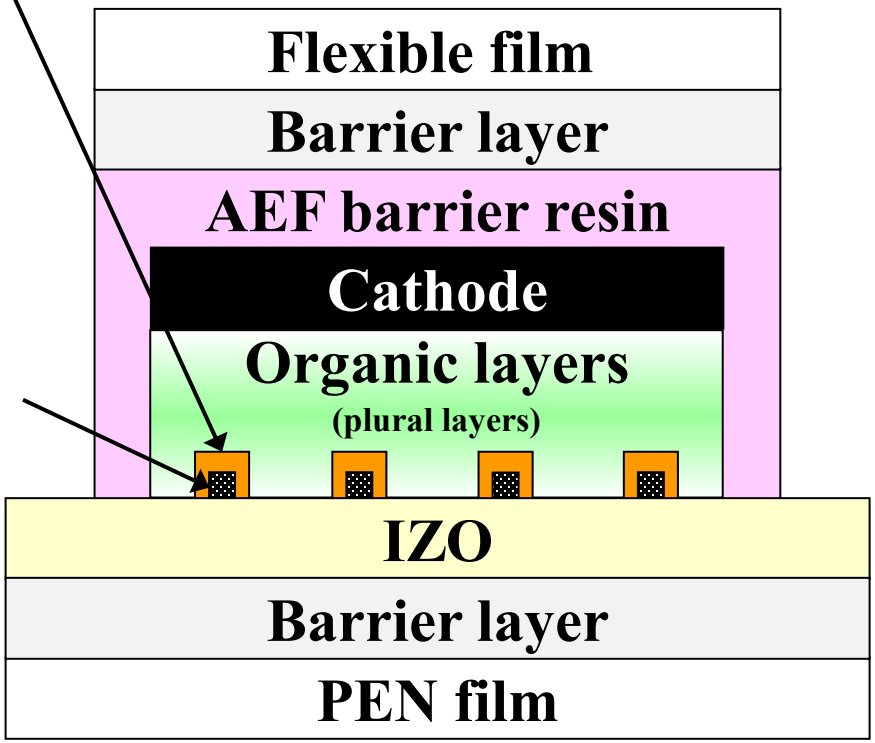




Insulator
(with particles)

Ag



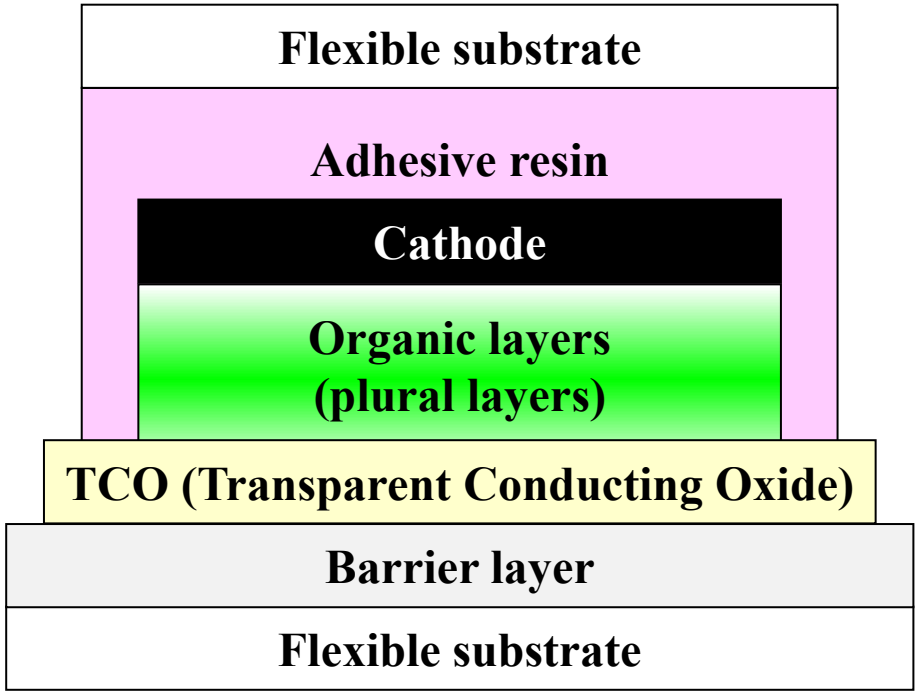


Collaroration TEIJIN LIMITED, etc.

Publication

- K. Taira, Taiga Suzuki, W. Konno, H Chiba, H. Itoh, M. Koden, T. Takahashi, T. Furukawa, IDW'18, FLX2-4L (2018).

Concept samples using flexible OLED device

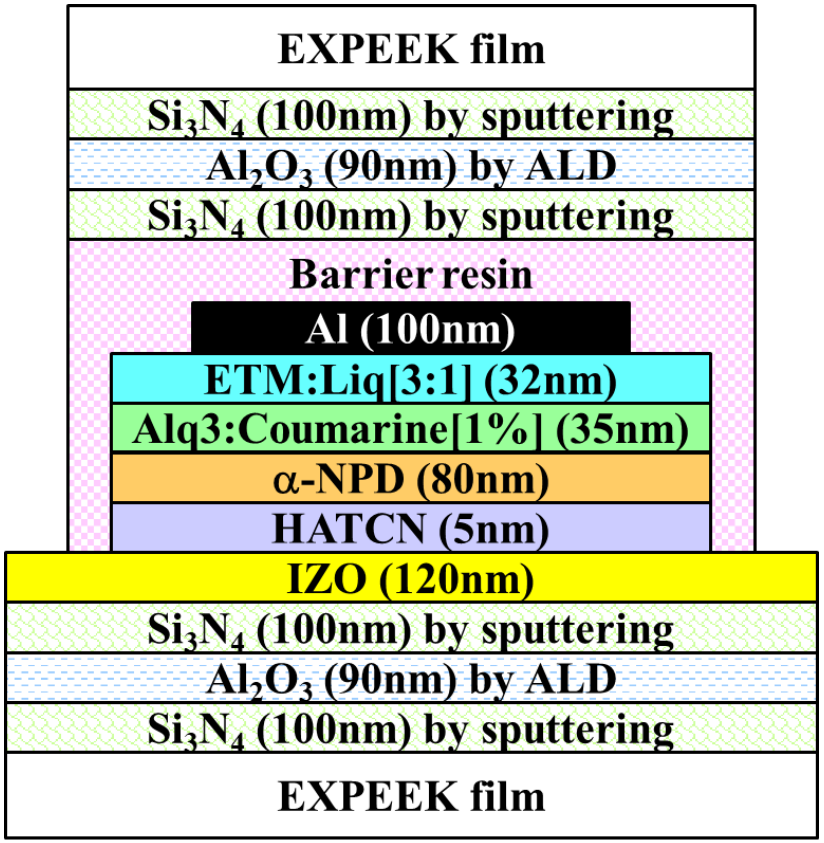


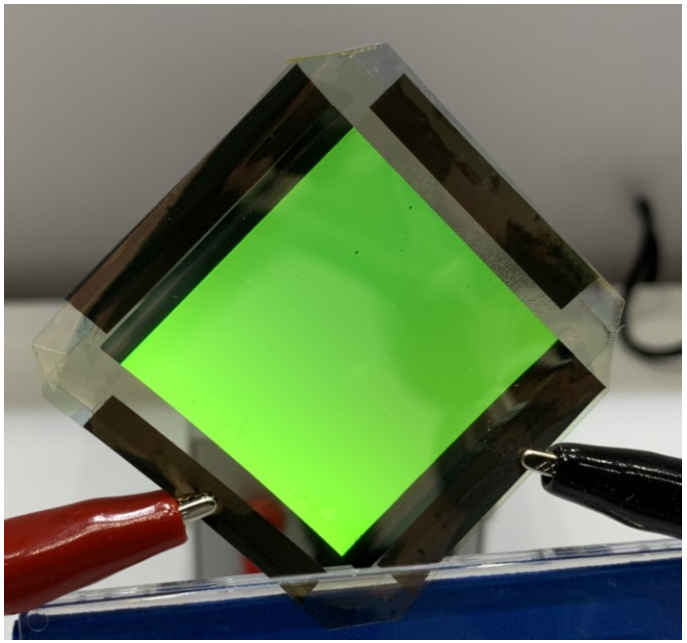
Collaroration KOMORI Corporation / TAKEDA PRINTING CO., LTD.

Publication

- Yamagata University；“JFlex2020” (Jan. 2020 / Tokyo).

Flexible OLEDs on EXPEEK® barrier film





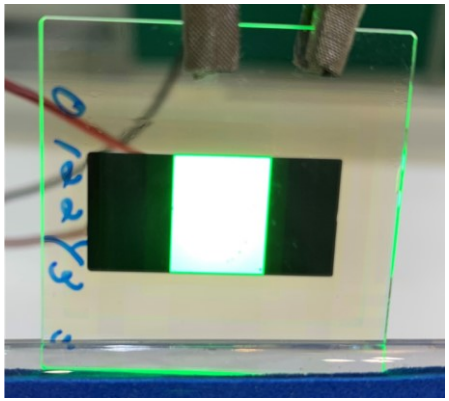
Device size: 50 × 50mm
Emission area: 32 × 32mm

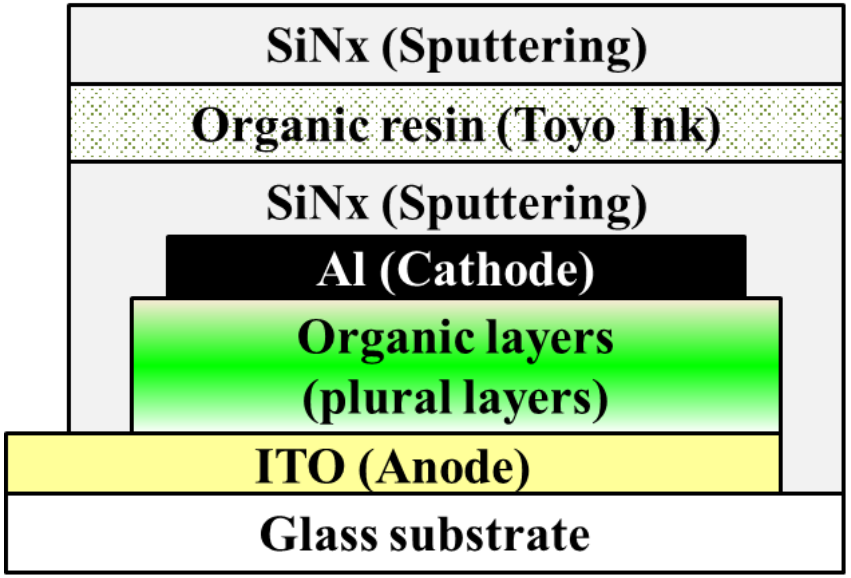
Collaroration KURABO INDUSTRIES LTD.

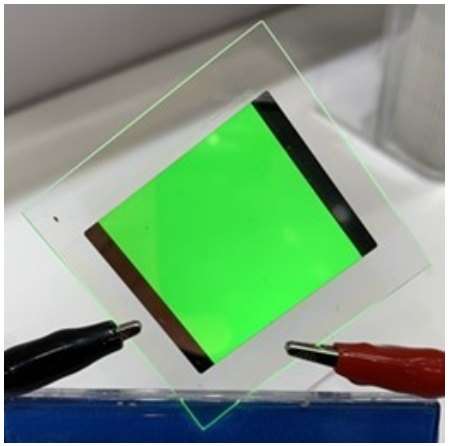
Publication

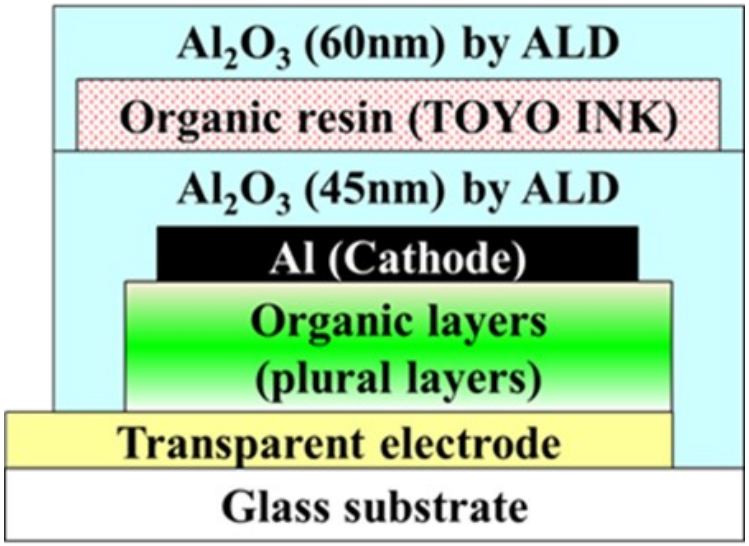
- T. Yuki, T. Nishikawa, M. Sugimoto, H. Nakada, M. Koden, IDW'20, FLX2-3 (2020).
- Yamagata University; "JFlex2020" (Jan. 2020 / Tokyo); "JFlex2019" (Jan. 2019 / Tokyo).
- KURABO; "7th Fine Plastic Exhibition" (Dec. 2018 / Tokyo), "SEMICON Japan 2018" (Dec. 2018 / Tokyo).

Flexible OLEDs with TFEL







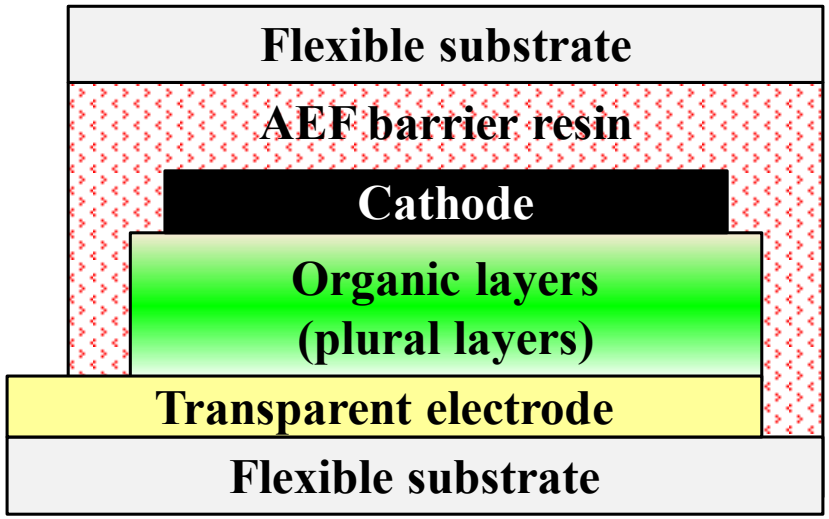


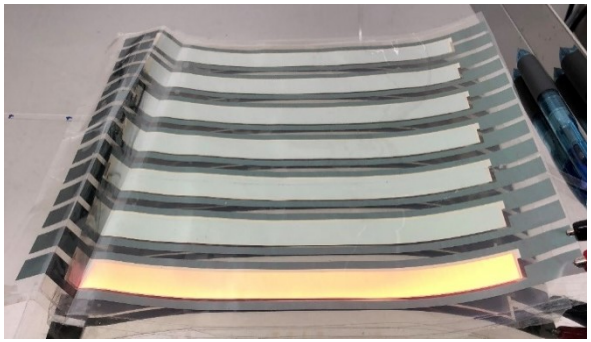
Collaroration TOYO INK SC HOLDINGS CO., LTD.

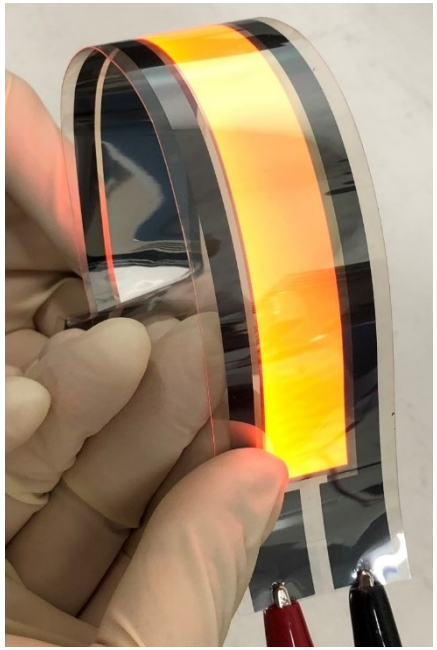
Publication

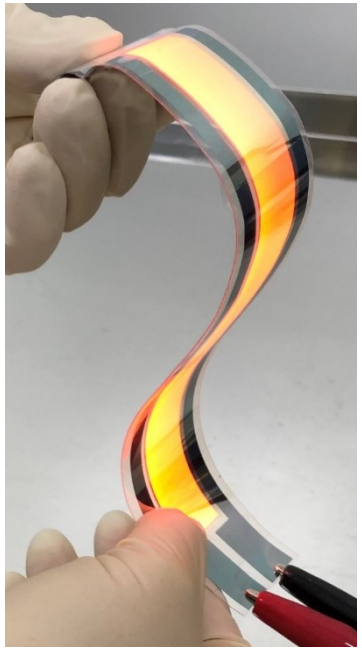
- Yamagata University；“JFlex2020” (Jan. 2020 / Tokyo); “JFlex2019” (Jan. 2019 / Tokyo).

Flexible OLEDs with laminating encapsulation









Exhibited in "Printable Electronics 2018" exhibition (Feb. 2018, Tokyo)

Collaroration

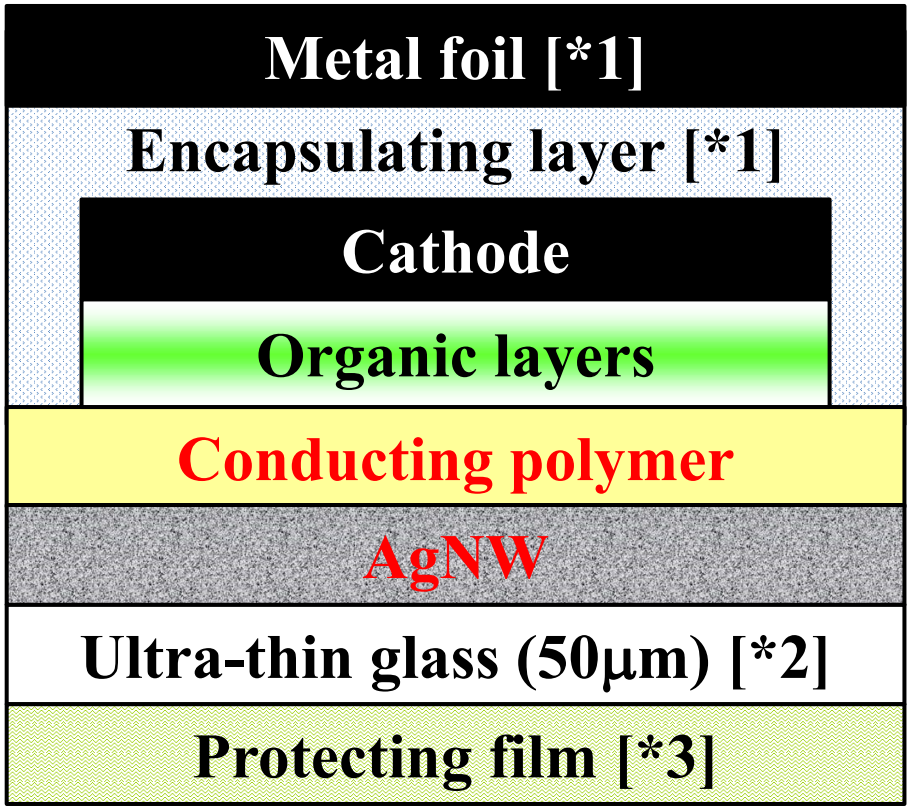
Ajinomoto Co., Inc. /
Ajinomoto Fine-Techno Co., Inc.

Publication

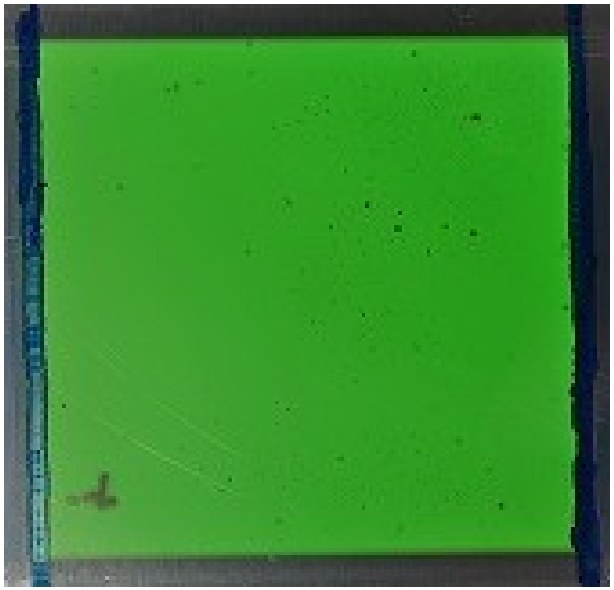
- Yamagata University;
  "JFlex2019" (Jan. 2019 / Tokyo).

Flexible OLED with transparent electrode of Ag nanowire and conducting polymer

Flexible OLED without ITO was successfully fabricated.



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



Panel size: 50mm x 50mm
Emission area: 32mm x 32mm

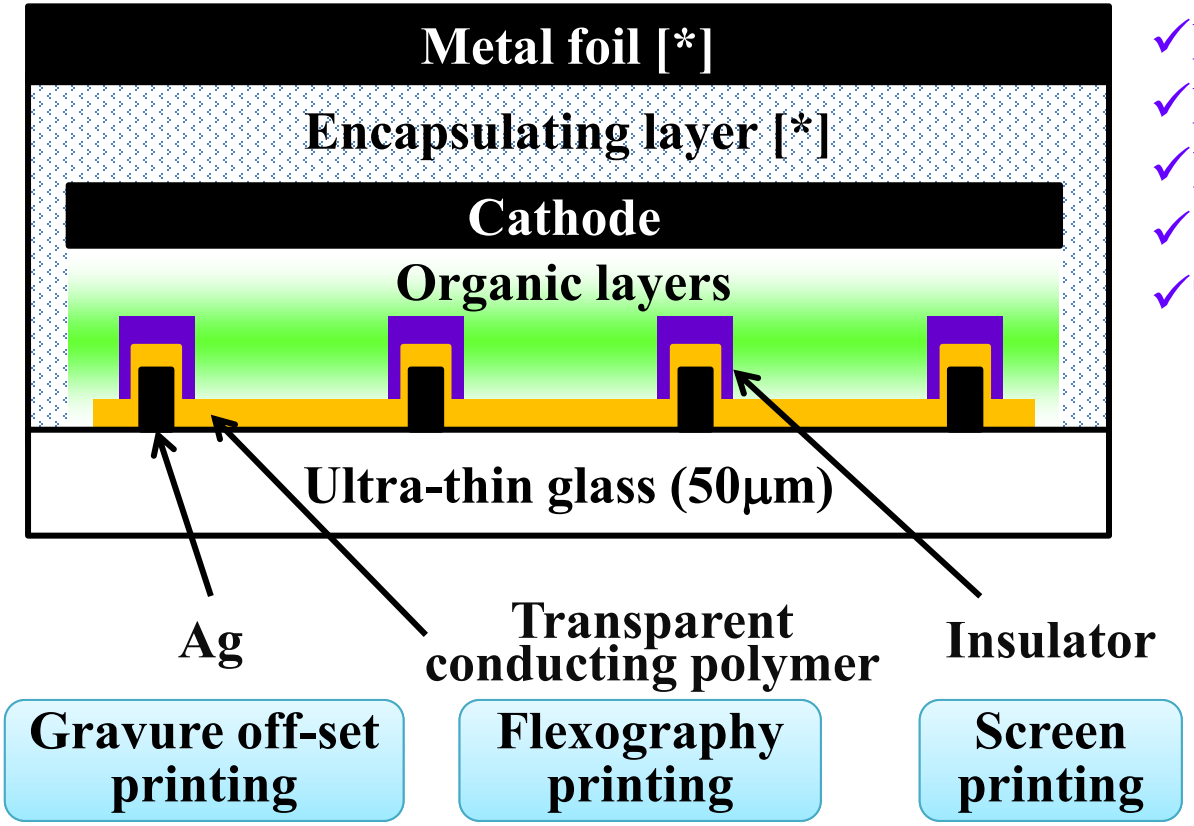
Publication

- M. Koden, T. Furukawa, T. Yuki, H. Kobayashi, H. Nakada, IDW/AD'16, FLX3-1 (2016).

Flexible OLEDs with printing non-ITO electrode

Flexible OLED without ITO was successfully fabricated.

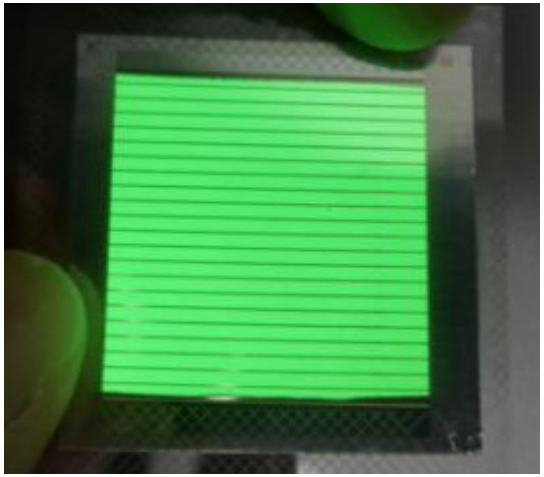
- ✓Substrate size : 50mm X 50mm
- ✓Emission aria : 32mm X 32mm



Collaboration by:

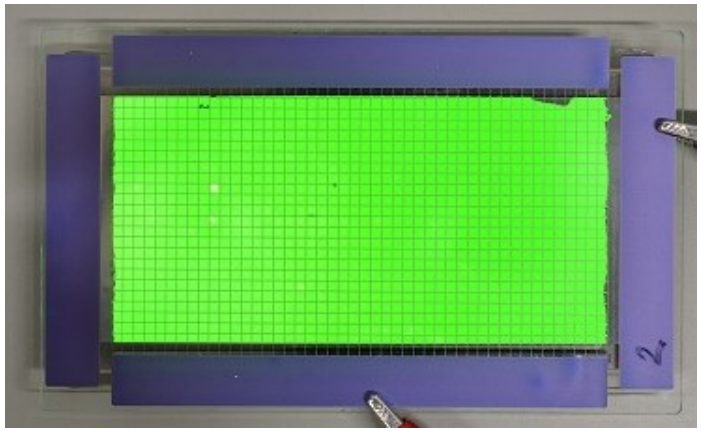
- ✓Yamagata University
- ✓Dai Nippon Printing
- ✓DIC
- ✓Komori Machinery
- ✓SERIA
- ✓Taiyo Kikai

[*] supplied from Ajinomoto Fine-Techno

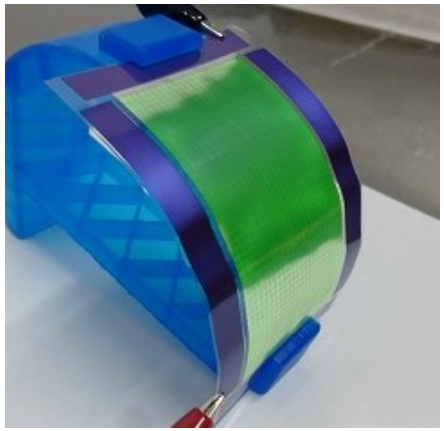


T. Furukawa, N. Kawamura, M. Sakakibara, M. Koden, International Display Manufacturing Conference (IDMC'15), S4-4 (2015).

OLEDs with metal-mesh electrode

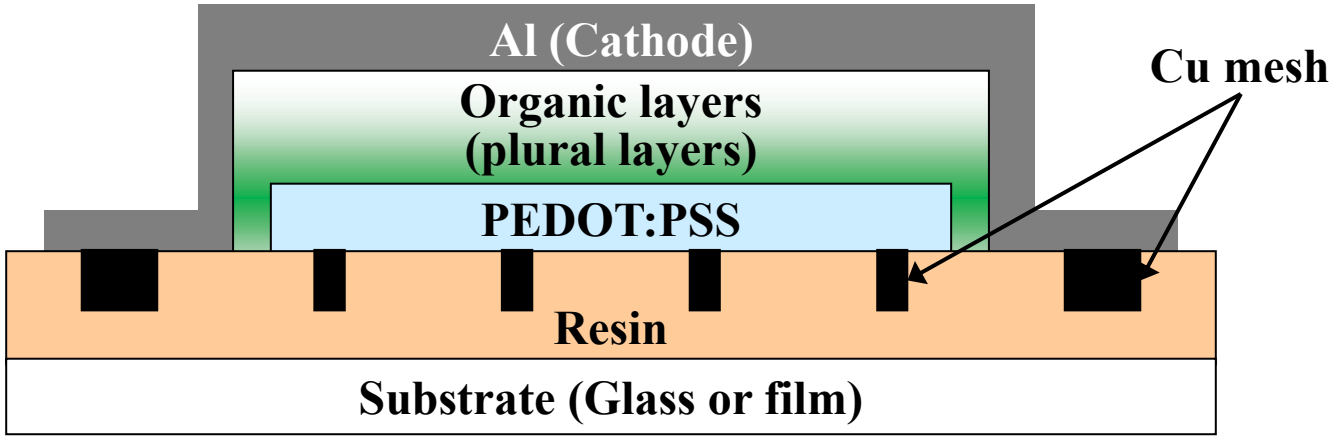


Substrate: Glass



Substrate: PEN

substrate：60mm × 100mm



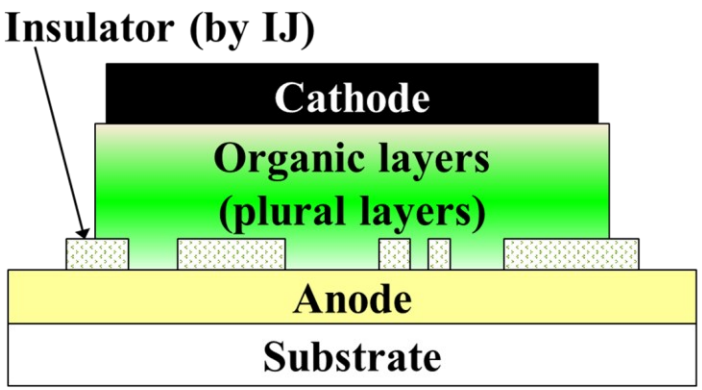
Collaboration

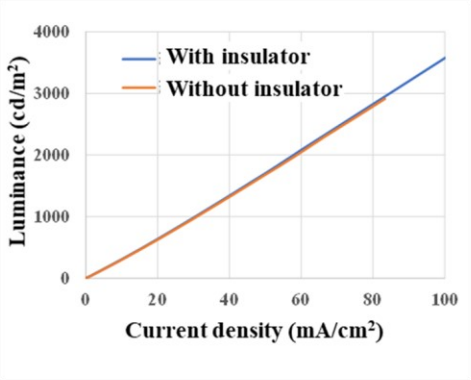
Toyo Aluminium K.K., Prof. Takeshi Sano (INOEL, Yamagata University)

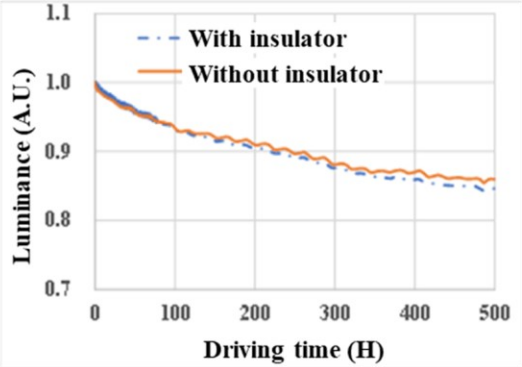
Publication

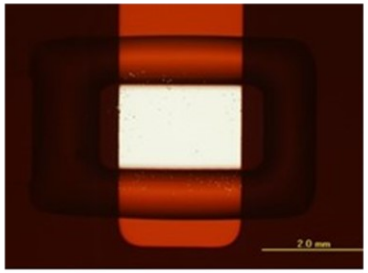
- M. Koden, N. Kawamura, T. Yuki, H. Nakada, R. Waguri, K. Den, R. Nakao, H. Minamiyama, The 31th Meeting of Japan OLED Forum, S7-2 (2020).
- R. Waguri, K. Den, R. Nakao, H. Minamiyama, MES2020, 1B1-2 (2020).
- Yamagata University；“JFlex2020” (Jan. 2020 / Tokyo), “TCTJAPAN” (Jan. 2020 / Tokyo, “JFlex2019” (Jan. 2019 / Tokyo).

OLEDs with on-demand patterns

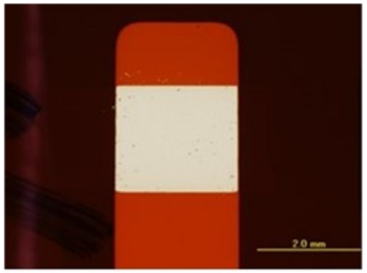






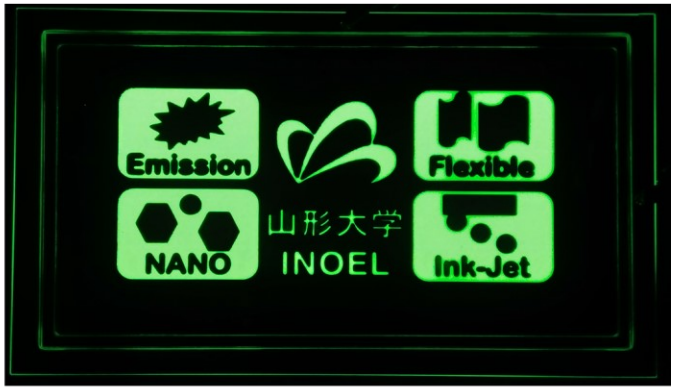


With insulator



Without insulator

Substrate size：50mm × 50mm



Substrate size：60mm × 100mm

Collaboration TOYO INK SC HOLDINGS CO., LTD.

Publication

- M. Sugimoto, Y. Fukuchi, H. Tsuruta, M.Koden, H. Nakada, T. Yuki, A-COE 2021, PA-17 (2021).

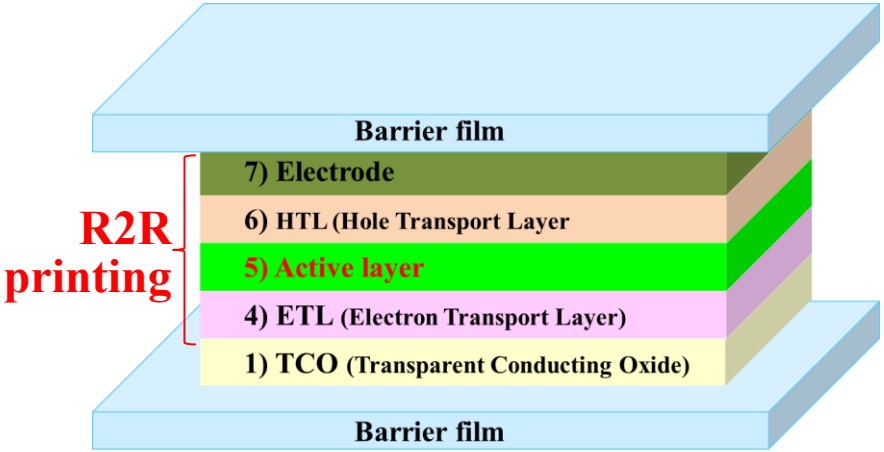
Printed flexible OPV fabricated roll-to-roll (R2R) processes

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.

Developed technologies

- ■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

Collaboration MORESCO Corporation / ideal star inc.

Publication

- ●Yamagata University；“JFlex2020” (Jan. 2020 / Tokyo).
- ●Yamagata University; “PVEXPO 2021”」(Mar. 2021 / Tokyo).
- ●Yamagata University；Press Release 2019.11.6.
- ●MORESCO；Press Release 2019.11.6.

Summary

Our technologies on flexible organic electronics devices (OLED, OPV, etc.) contribute practical R&D in industrial companies by collaborations using our rich knowledge and skills.

Please do not hesitate to contact with us.

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