山形大学 YAMAGATA UNIVERSITY

CEATEC 2021 (October 2021)

Barrier Technologies

Gas barrier technologies are important key technologies in flexible organic electronics devices (OLEDs, OPV, etc.).

We have several technologies for evaluating barrier properties.

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

This material reviews fundamentals of gas barrier and our gas barrier technologies.

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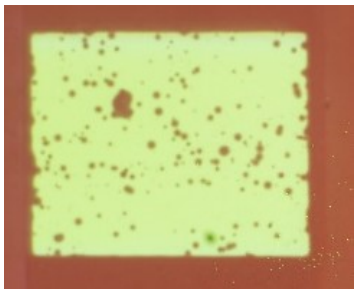
Gas barrier in flexible organic electronics devices

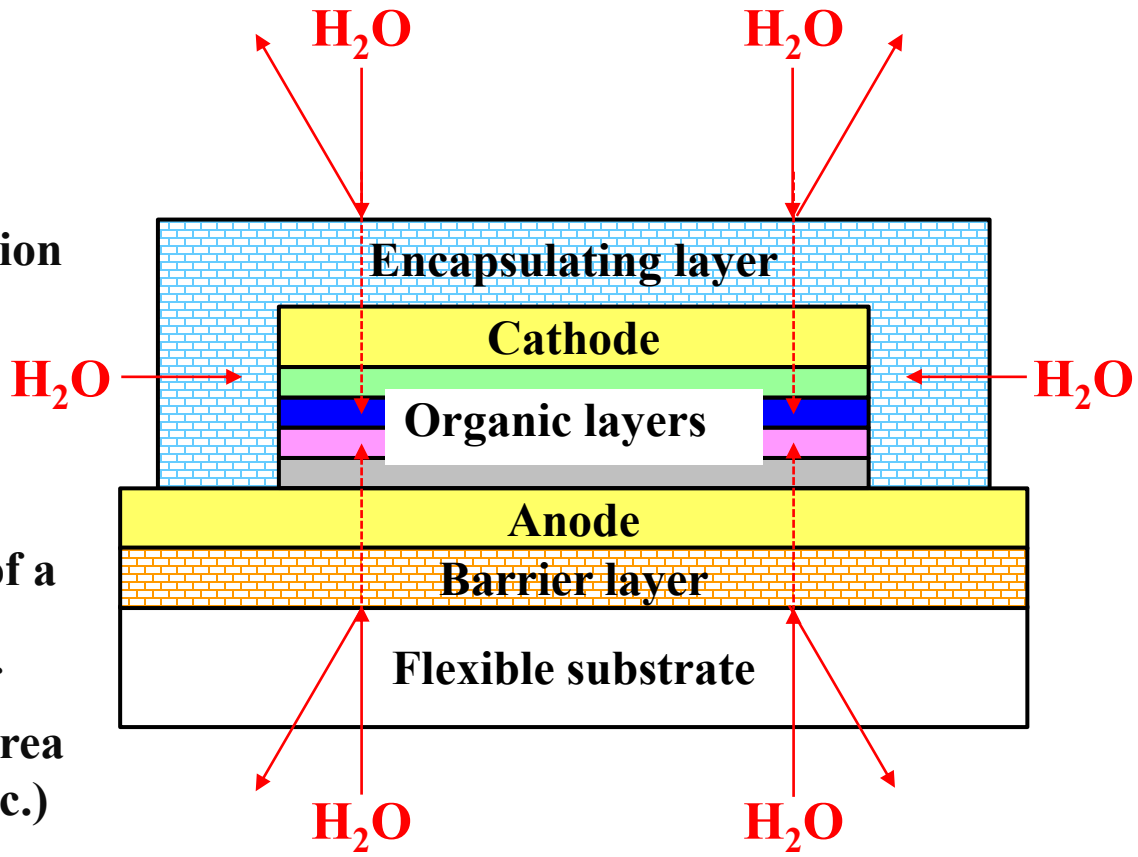
- ✓ Flexible organic electronics devices degrade by penetrations of gasses such as H_2O.
- ✓ Therefore, barrier technologies protecting gas penetration are noncausality required.

Initial:
Uniform emission



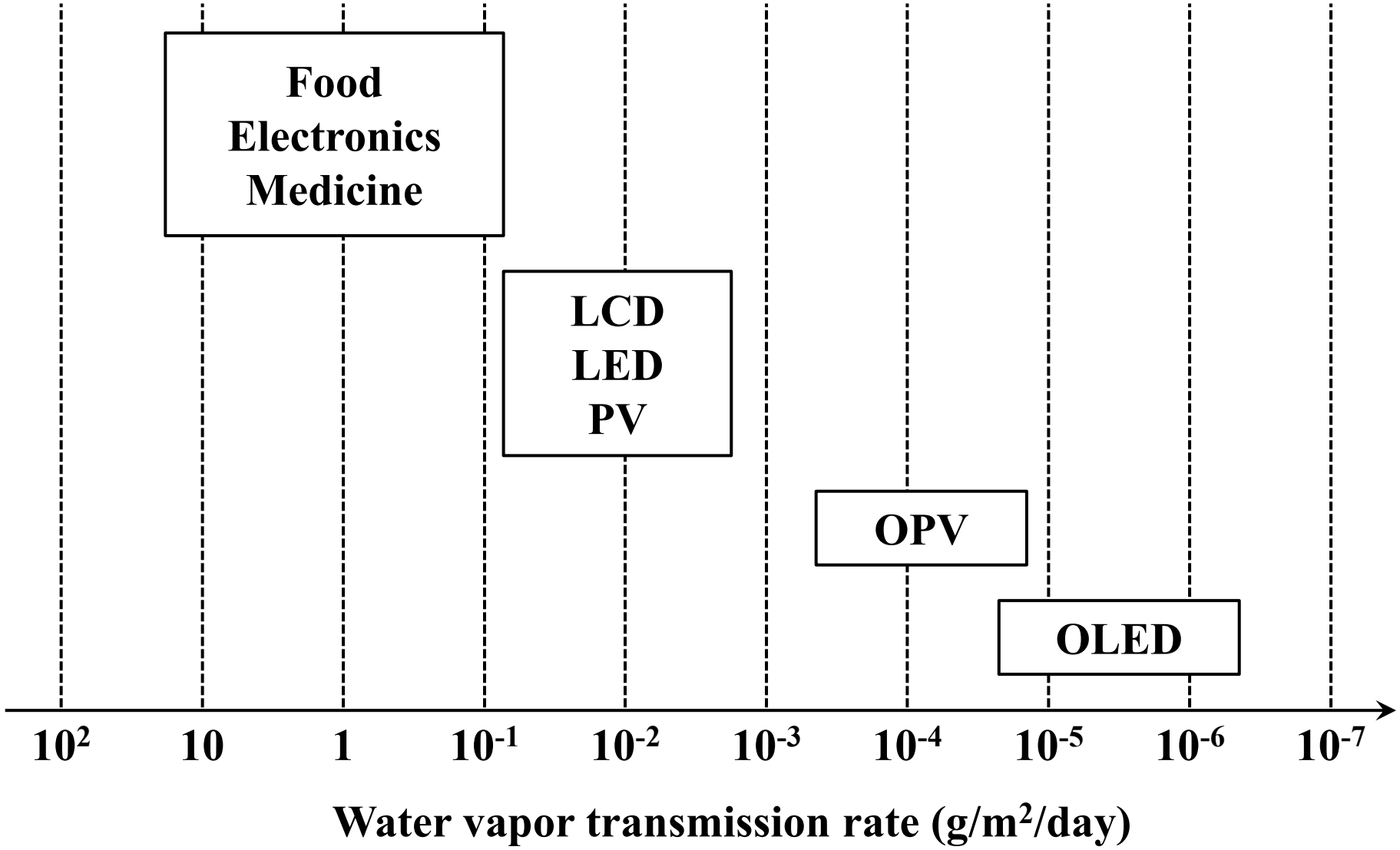
After storage of a certain time:
Appearance of non-emitting area
(Dark spots, etc.)

Example of OLED degradation by moisture penetration

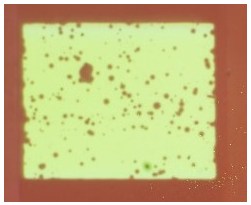
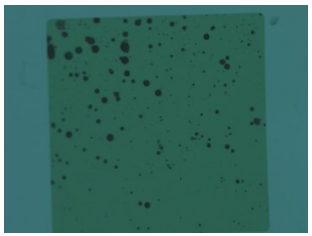


Example of gas penetration and protecting technologies

Required WVTR of flexible substrates



Three types of evaluation technologies for barrier properties

	OLED device	Ca corrosion method	Differential pressure
Points	Evaluation of degradation of OLED devices under storage.	Evaluation of degradation of Ca which is deposited on a sample.	Use of equipment for evaluating the amount of gas passing a sample.
Advantages	・Evaluation of actual OLED device.	・Possible to calculate WVTR ・Visualization of degradation for discussing reasons of degradation. ・Parallel evaluation of plural samples.	・Possible to calculate WVTR ・Non-need of device fabrication ・Possible to evaluate non-transparent samples
Disadvantages	・Calculation of WVTR is difficult. ・Need to care of other disturbing factors such as out-gas from inside of OLED device. 	・Need of device fabrication ・Evaluation of only transparent samples ・Evaluation of only H_2O 	・Need to care of other disturbing factors such as defects and pinholes of samples ・Only one sample evaluation ・No visual image 

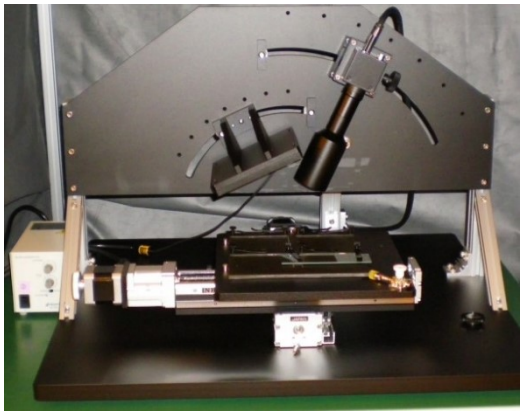
Ca corrosion method

✓Evaluation of degradation of Ca deposited on a sample [1]

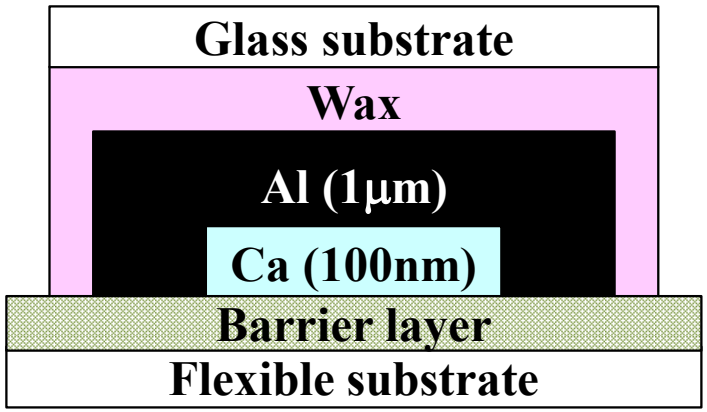
- $Ca+2H_2O \rightarrow Ca(OH)_2+H_2$

✓WVTR is able to be calculated from the results of Ca corrosion.

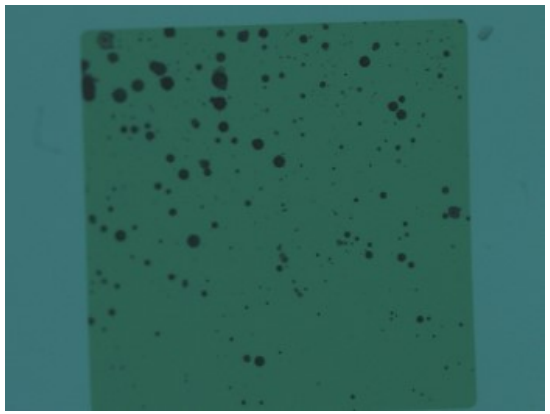
- WVTR : Water Vapor Transmission Rate ($g/m^2/day$)



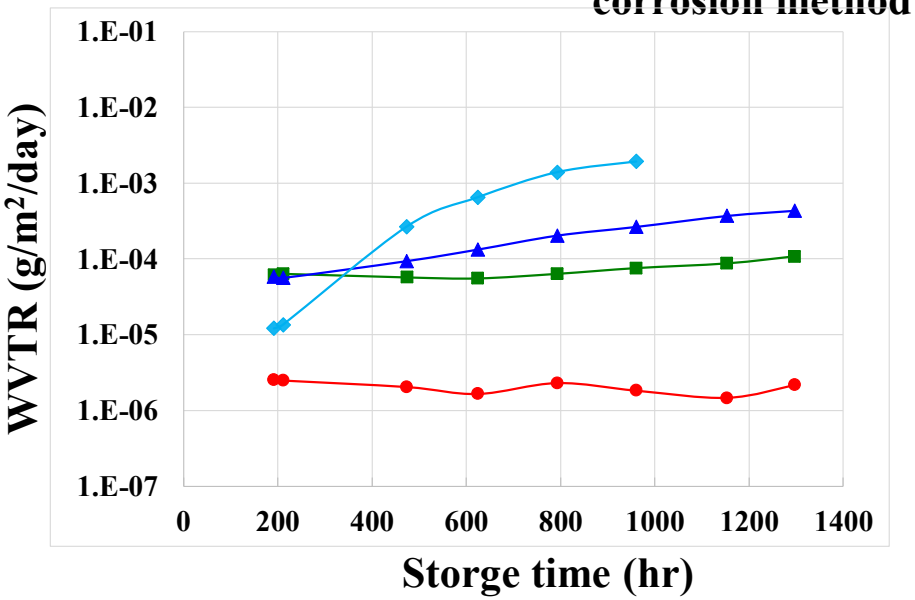
Equipment for Ca corrosion method



Ca corrosion device

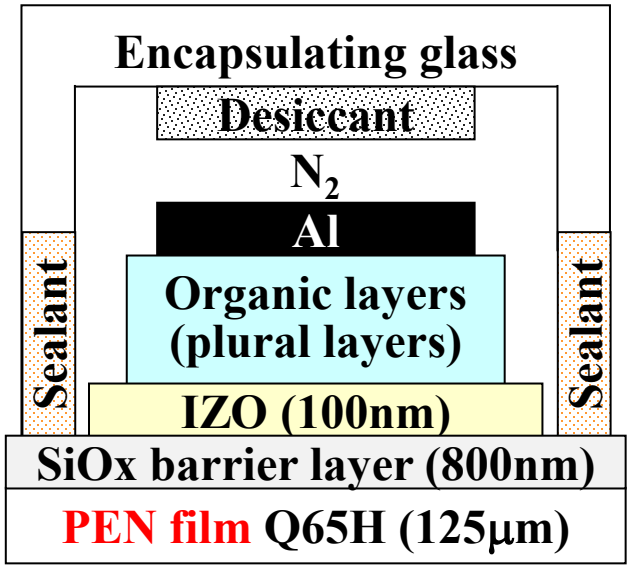


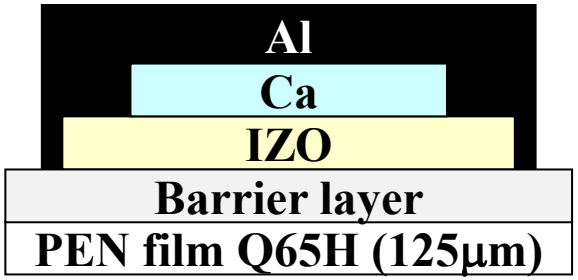
Degradation of Ca corrosion device

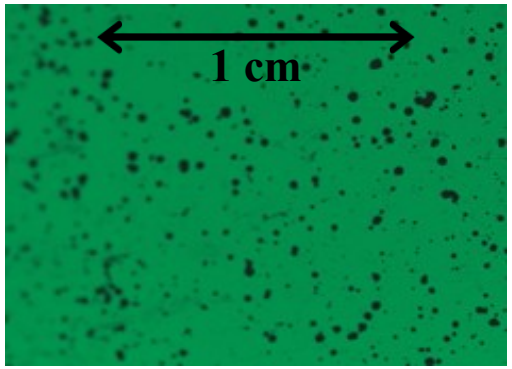


[1] G. Nisato, M. Kuilder, P, Bouten, L. Moro, O. Philips, N. Rutherford, SID 03 DIGEST, P-88 (2003).

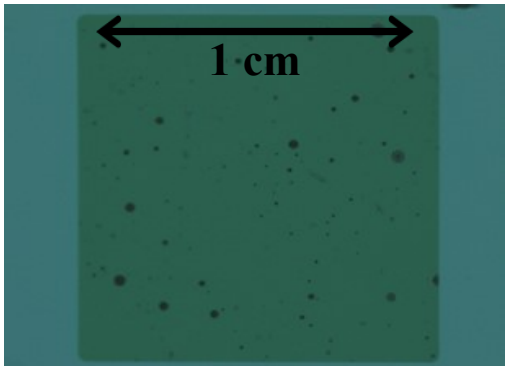
OLED device and Ca corrosion test







Dark spots of OLED
(after 560hours)



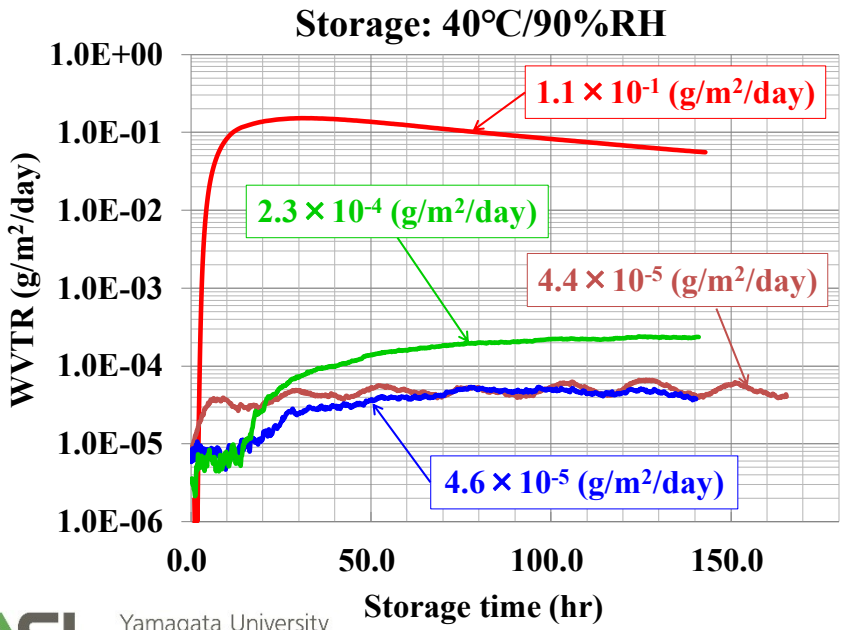
Ca test
(after 595 hours)

<Storage tests under 40 ℃ and 90 %RH>

〔K. Taira, T. Furukawa, N. Kawamura, M. Koden, T. Takahashi, *IDW'17*, FLXp1-8L (2017).〕

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

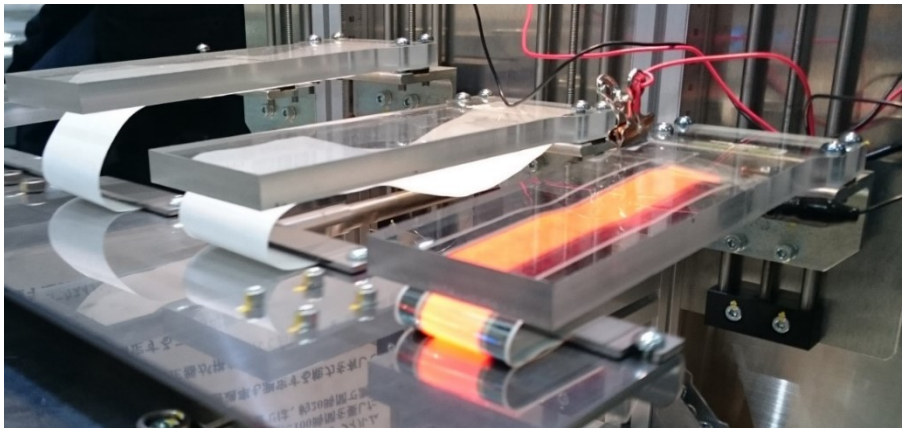
- We provide WVTR (Water Vapor Transmission Rate) evaluation, using the WVTR measurement equipment "Super Detect" of MORESCO.
- The "Super Detect" utilizes the MA method (Modified differential pressure method with an Attached support) developed by the collaboration of MORESCO and AIST (National Institute 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.



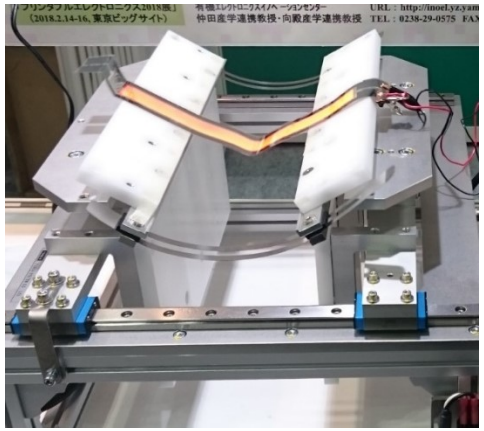
WVTR equipment (MA method)

Bending equipment

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



U-shape sliding



Folding

Both-side bending

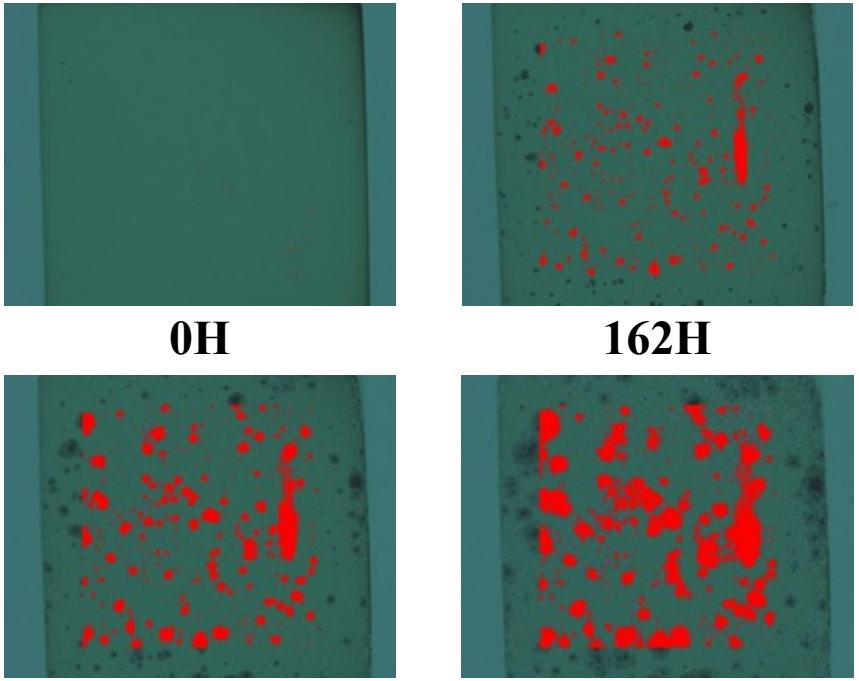
Example of barrier technologies

EXPEEK® barrier films by the collaboration with KURABO

✓ The Si_3N_4 layers (100nm) by sputtering show poor barrier ability with the WVTR of the order of $10^{-3}g/m^2/day$.

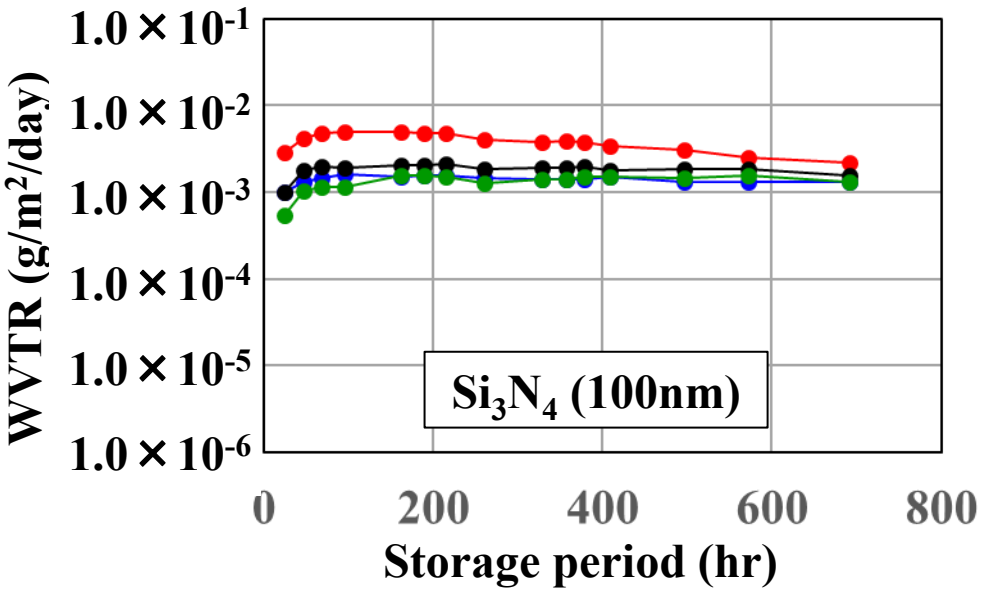
Collaboration KURABO

Si_3N_4 (100nm) by Sputtering
EXPEEK Film



Typical results of Ca corrosion tests

Storage test: 40°C/90%RH



WVTR values calculated by Ca corrosion tests of four samples

T. Yuki, T. Nishikawa, M. Sugimoto, H. Nakada, M. Koden, IDW'20, FLX2-3 (2020).

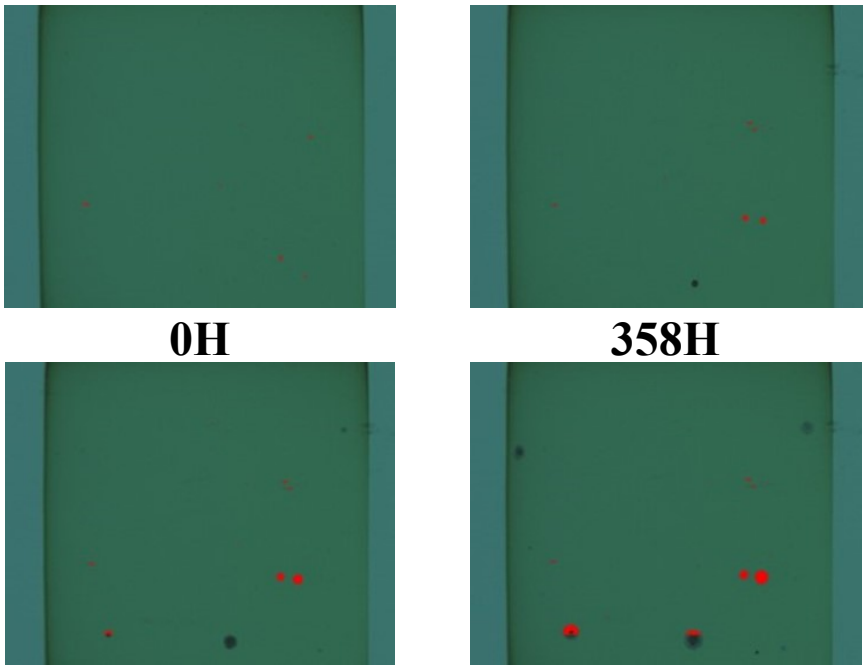
Example of barrier technologies

EXPEEK® barrier films by the collaboration with KURABO

✓ The three layers staking with Si_3N_4 (100nm) by sputtering and Al_2O_3 (90nm) by ALD (Atomic Layer Deposition) achieve good barrier ability with the WVTR of the order of $10^{-5}g/m^2/day$.

Collaboration KURABO

Si_3N_4 (100nm) by Sputtering
Al_2O_3 (90nm) by ALD
Si_3N_4 (100nm) by Sputtering
EXPEEK Film



Typical results of Ca corrosion tests

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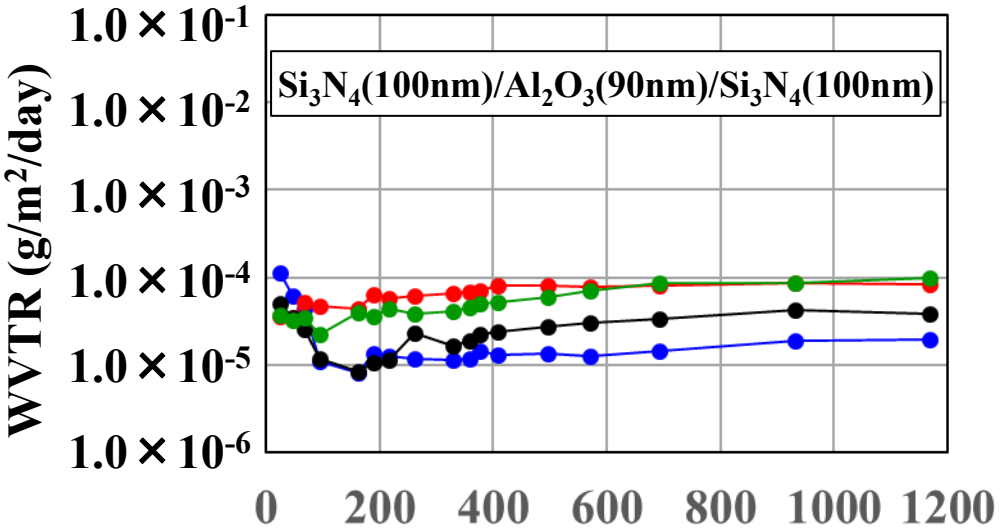
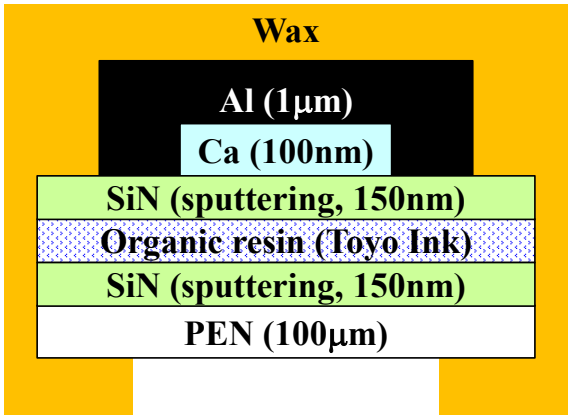


WVTR values calculated by Ca corrosion tests of four samples

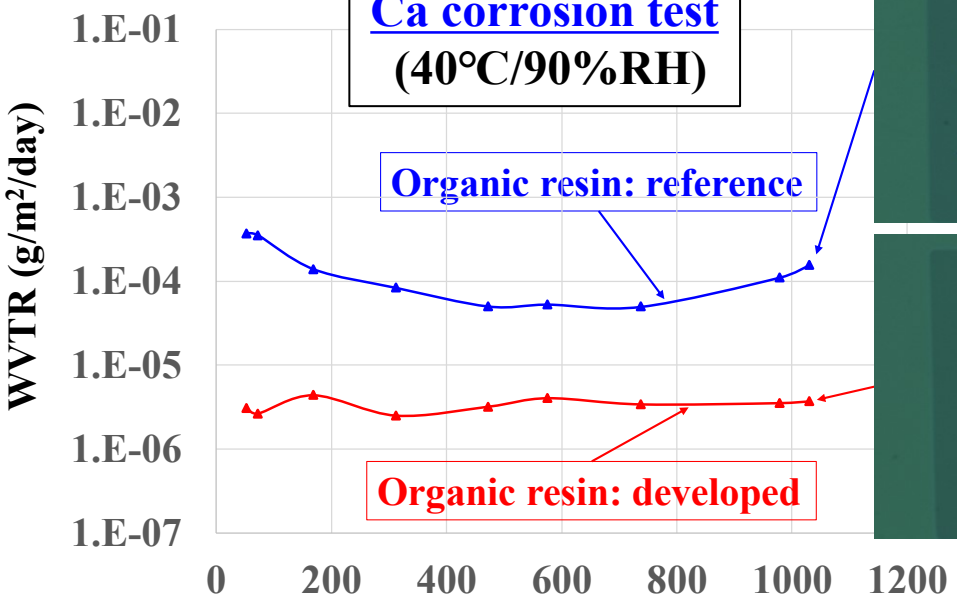
T. Yuki, T. Nishikawa, M. Sugimoto, H. Nakada, M. Koden, IDW'20, FLX2-3 (2020).

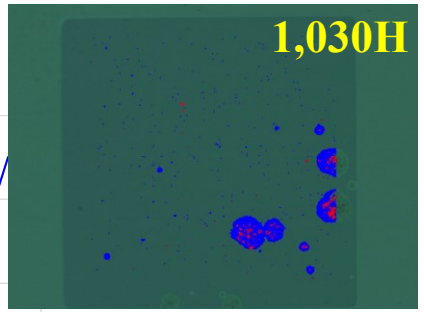
Example of barrier technologies

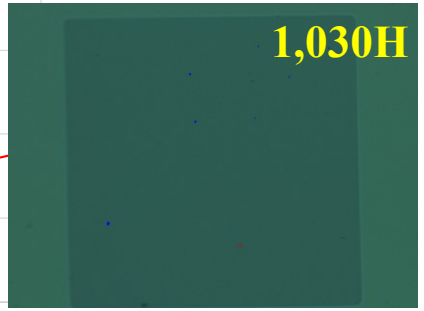
TFE (Thin Film Encapsulation) using UV-IJ resin of TOYO INK

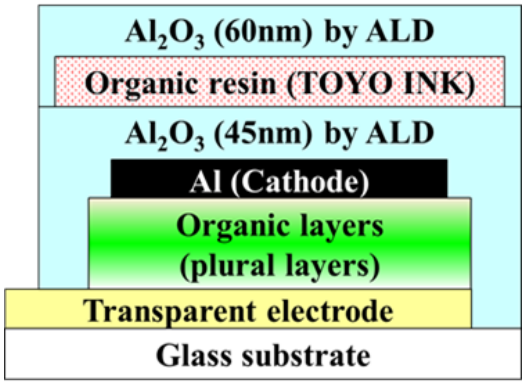


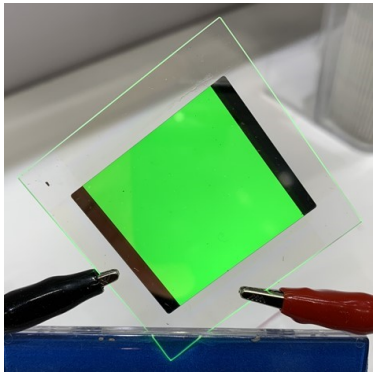
Device structure of Ca corrosion test











"JFlex2020" (Oct. 2020 / Tokyo)

Collaboration

TOYO INK SC HOLDINGS CO., LTD.

Summary

Our barrier technologies 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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