2014 Photovoltaic Module Reliability Workshop
NREL, Golden, CO
February 25–26, 2014

Panasonic

Stability of encapsulants using Cu electrode

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Motivation

Replacing Ag on a photovoltaic cell with a Cu electrode has attracted increased attention as a way to meet the market need for lowering cost.
However, Cu acts as a catalyst for the thermal-oxidative degradation of polymer.

$$ROOH + Me^{n+} \rightarrow RO\cdot + Me^{(n+1)+} + OH^{-}$$
$$ROOH + Me^{(n+1)+} \rightarrow ROO\cdot + Me^{n+} + H^{+}$$

Me : Metal (Cu, Co, …)

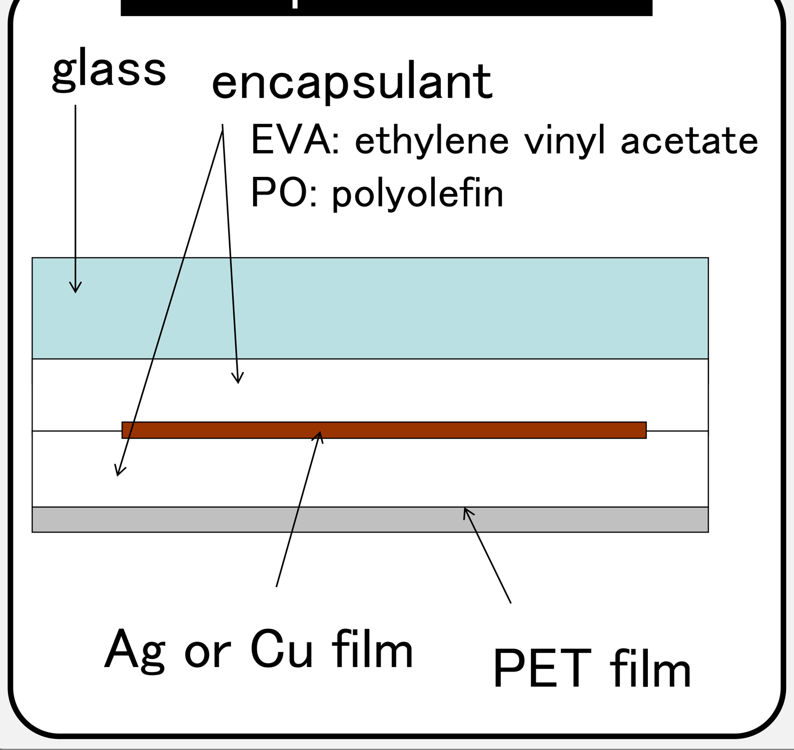
Therefore, we have compared the various impacts of Cu-catalyzed degradation by testing the discoloration and tensile strength of encapsulants.

Conclusions

1. **Cu acts as a catalyst for the thermal-oxidative degradation of encapsulants.**
2. **There is a great difference between the lifetimes of Cu-contacting encapsulants.**
3. **Correlation between discoloration and lifetime is confirmed.**

Discoloration testing of Cu-contacting encapsulants

Sample structure



(1) High temperature testing

Condition
- ■ 120 ºC
- ■ 1000 hours
- ■ Ambient air

(2) Evaluation method

- ■Reflectivity measurement
- ■Appearance inspection

Sample	A	B	C	D	E	F
Polymer	EVA	EVA	EVA	PO	PO	PO
Discoloration with Ag※3	◎	◎	◎	◎	◎	◎
Discoloration with Cu※3	○	△	△	◎	○	○

※3 ◎ :no discoloration ○ : yellow discoloration △ : brown discoloration

■All **Ag**-contacting encapsulants do **not discolor.**
■Most **Cu**-contacting encapsulants **discolor.**

◆ Cu acts as a catalyst for the thermal-oxidative degradation of encapsulants.

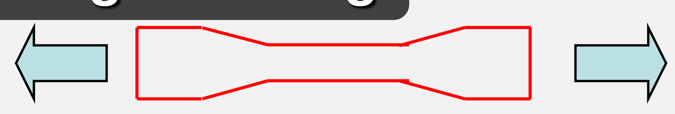
Tensile strength of Cu-contacting encapsulants and analysis of lifetime by using Arrhenius model

(1) High temperature testing

Condition
- ■ 120 ~ 140 ºC
- ■ 1000 hours
- ■ Ambient air

(2) Tensile strength testing

Condition



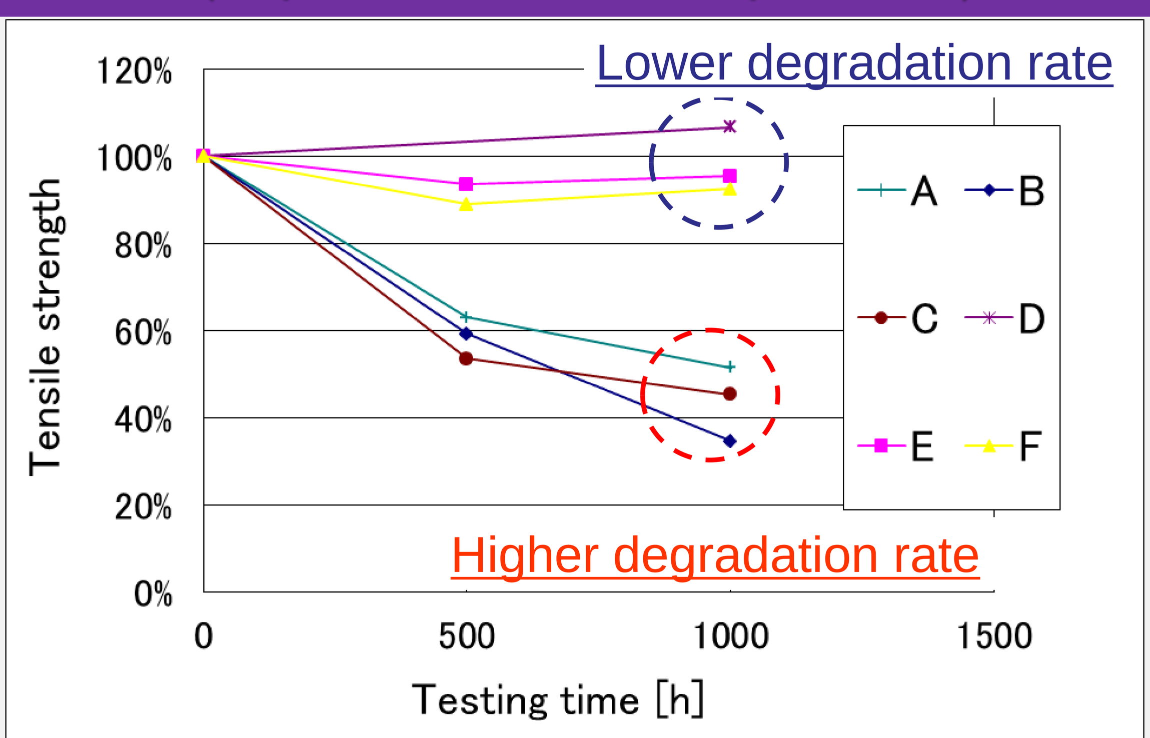
- ■Dumbbell shape(JIS K7113-2)
- ■Room temperature (25 ºC)
- ■1.4 mm/sec

(3) Arrhenius analysis

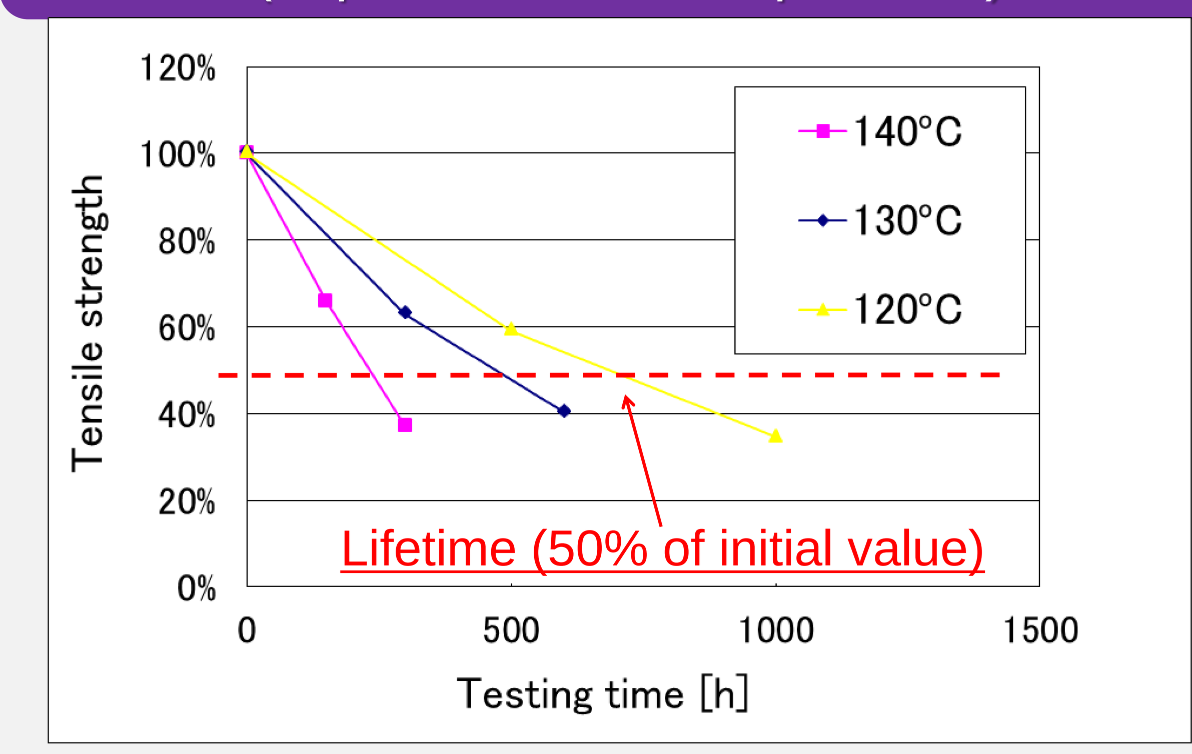
$$L = A \cdot \exp\left(\frac{Ea}{kT}\right)$$

L: Lifetime(the time when the tensile strength decreases to 50% of initial value)
A: Pre-exponential factor
Ea: Activation energy
K: Boltzmann constant
T: Temperature

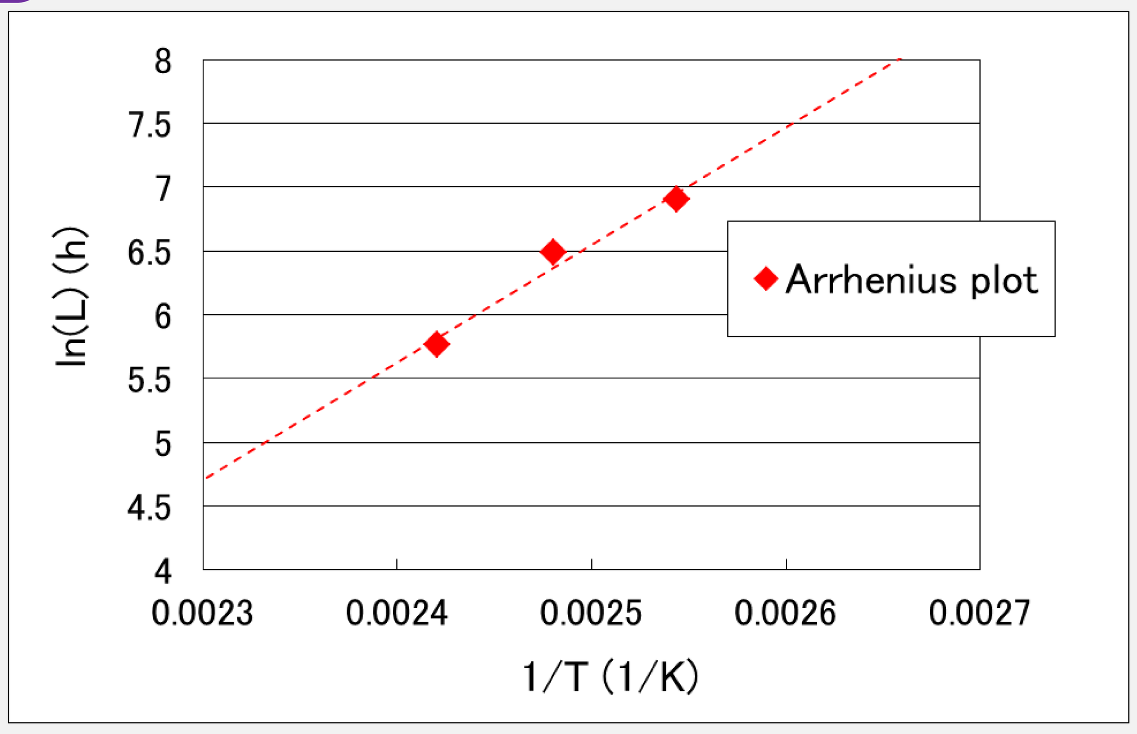
Results of tensile strength testing at 120 ºC (dependence on encapsulants)



Results of tensile strength testing for sample B (dependence on temperature)



Results of Arrhenius plot for sample B



■The tensile strength decreases as testing time increases.
■The decrease in tensile strength is different between encapsulants.
■The degradation rate increases as temperature increases.
■Linear correlation is shown between ln(L) and 1/T.

Sample	A	B	C	D	E	F
Polymer	EVA	EVA	EVA	PO	PO	PO
Discoloration	○	△	△	◎	○	○
Lifetime※4	○	○	△	◎	◎	◎

※4 ◎:Stable ○:over 50 years △:under 50 years

◆ There is a great difference between lifetimes of the encapsulants.
◆ Correlation between discoloration and lifetime is confirmed.

Why does this difference occur?
1. **Different polymer structures (EVA, PO, etc.)**
2. **Different additives : concentrations, types (antioxidant agent, HALS, crosslinking agent, etc.)**

Future plans

1. **Compare high temperature testing and outdoor testing (some papers show a non-linear Arrhenius plot for PO degradation).**
2. **Develop novel method to quantify Cu-catalyzed degradation (yellow Index, transmittance, etc.).**
3. **Develop high durability encapsulants.**