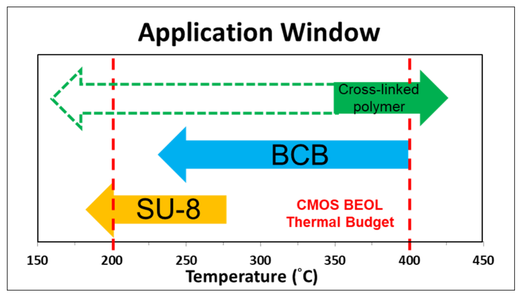
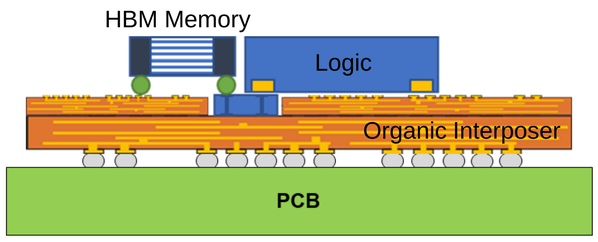
Investigation of Bonding Reliability in Low-Temperature Curable Photo-Sensitive Polyimide Film

Jui-Han Liu, Bruce Peng, Demin Liu, and Kuan-Neng Chen | National Yang-Ming Chiao Tung University

Introduction and Motivation

- Photo-sensitive Polyimide (PSPI) is widely used in advanced packaging because of its convenient processing, cost-effectiveness, and electrical performance.
- To mitigate warpage concerns and enhance integration yield, we aim for a lower thermal budget, achieving curing and bonding temperatures below 200 ℃.
- As curing temperature lowered, cross-linked polymer film quality decreased, the trade-off between process requirements and polymer chemistry was investigated.





Organic Interposer for rapid data access

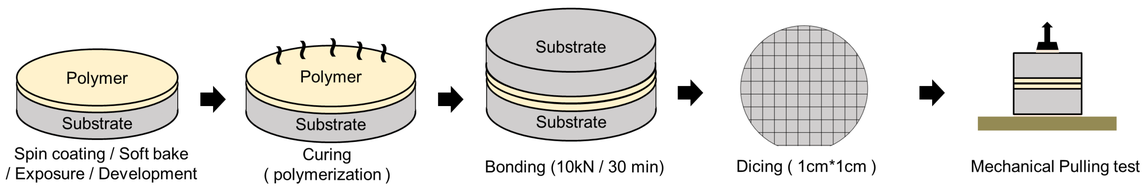
Material Properties

- PI_A serves as the benchmark material. PI_A⁺ includes an additional curing catalyst, PI_B incorporates a crosslinker for a 150ºC-curing, and PI_C is a preimidized film.

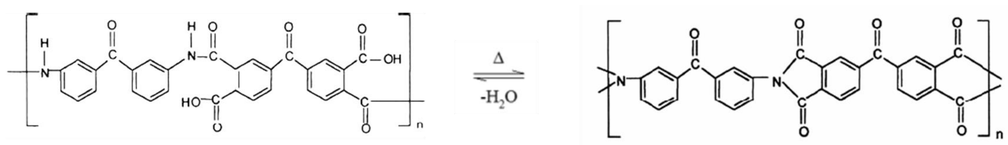
Material Candidate	Polyimide_A	Polyimide_A⁺	Polyimide_B	Polyimide_C
Type	Precursor	Precursor	Precursor	Pre-imidized
Curing Condition (ºC.Hr)	230.3H	200.3H	150.3H	170.2H
Tensile Strength (MPa)	181	178	124	123
Young's Modulus (GPa)	2.49	2.62	2.8	2.8
Tg (ºC)	208	210	182	242
CTE (ppm/ºC)	57	50	71.3	62
Elongation (%)	83	74	68	65

Experimental Procedure

- PI is spin-coated onto 4-inch substrate, cured in a nitrogen oven, followed by wafer-level bonding under 4*10^{-6} torr working pressure, 10k N of force for 30 minutes.
- After bonding, samples are diced into 1*1 cm^2 dies, SEM image and pulling test are used for bonding quality verification.



Polyimide Imidization



Reliability Test Condition

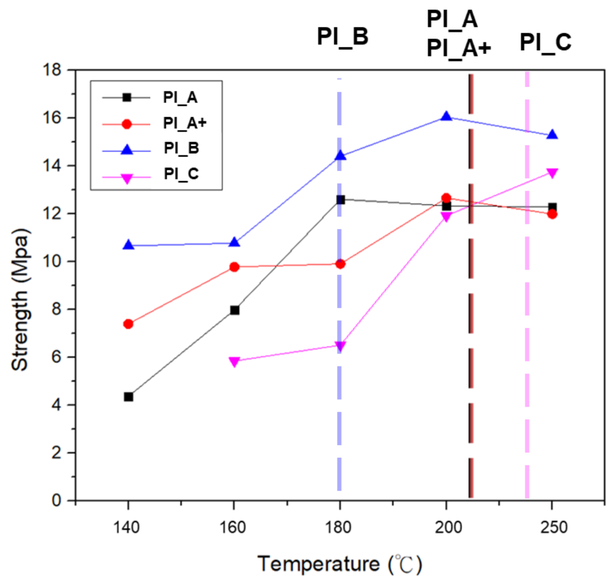
- **Temperature cycling test**
  - -55 ℃ ~125 ℃ (500/1000 cycle)
- **Pressure Cooker Test**
  - 121℃ / 100% R.H (96 hrs)
- **High Temperature Storage**
  - 150℃ (24/48 hrs)

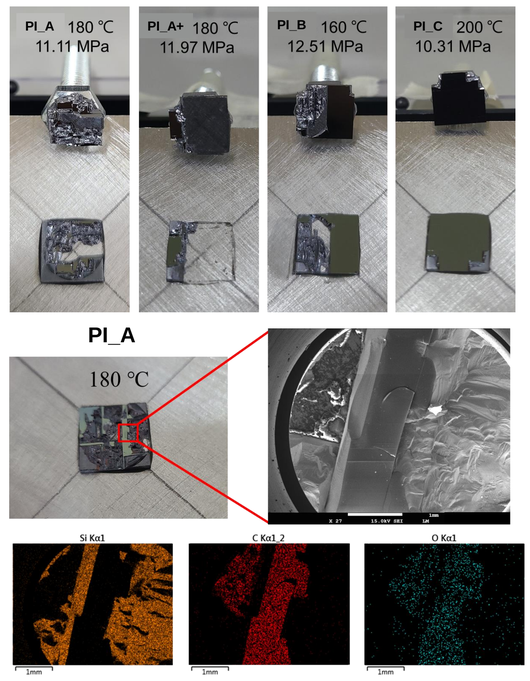
Description

- TCT testing, as a fatigue test, impacts the mechanical properties of the films.
- PCT testing, under rigorous humidity conditions, intrusion of moisture leads to gradual hydrogen failure between films.
- High-temp. environmental test by storing under 150 ºC for 24 / 48 hours

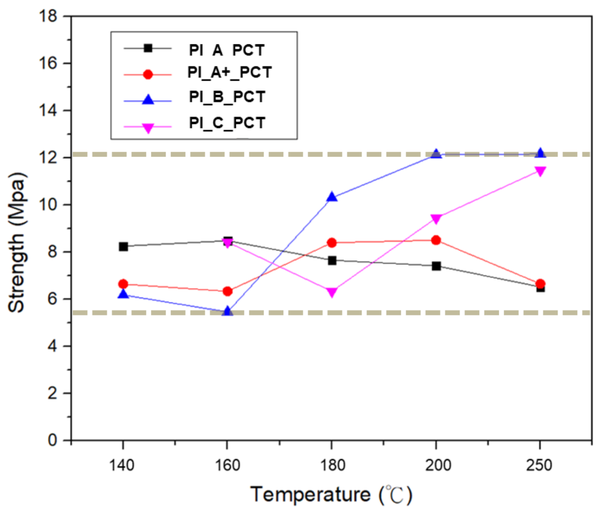
Results and Discussion

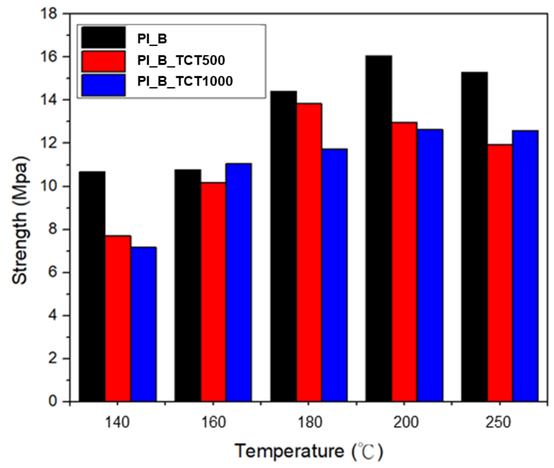
- The difference between Tg and bonding temperature affect the pull strength of PI films.
- Reliable bonding strength is achieved below 200 ℃.





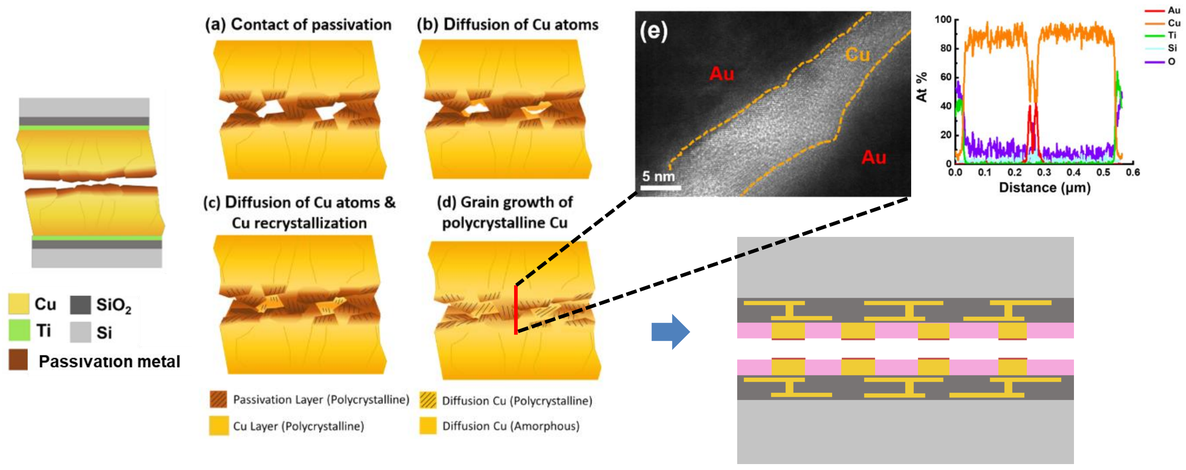
- PI_B stands out due to its lowest Tg before the reliability tests.
- After PCT test, failure of Hydrogen bond makes the bonding strength comparable.
- Bonding strength of each film declines after reliability tests but retains sufficient strength.





Summary and Future Work

- Tested PI films exhibit good bonding strength after each reliability test, confirming the robustness of low-temperature-cured PI bonding below 200 ℃.
- 3DIC lab at NYCU is currently working on the low-temperature Cu/Polyimide hybrid bonding platform, combining Cu-to-Cu bonding with passivation metal.



Cu-to-Cu bonding with passivation metal

Cu / Polyimide hybrid bonding

Acknowledgement

- I would like to thank NYCU 3DIC lab and Semiconductor Research Corporation (SRC) for supporting this research.

2023 UCLA CHIPS Workshop
Poster Session

UCLA CHIPS CENTER FOR HETEROGENEOUS INTEGRATION AND PERFORMANCE SCALING