16th International Conference on
Device Packaging

Design Rule Study of Compression Molding Process on Polymer Cavity Packages

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NIPPON KAYAKU

KAYAKU ADVANCED MATERIALS (formerly MICRO CHEM)

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Outline

1. Background
2. Compression Molding Advantages
3. Molding Compound Filing Test
4. Molding Resistance Test on the Polymer Cavities
5. Theoretical Review
6. Conclusion

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1. **Background**
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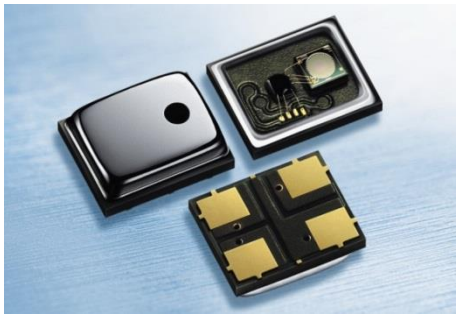
Cavity Package Demand

Source: Apple website

MEMS Microphones



Source: Infineon website

RF Filters

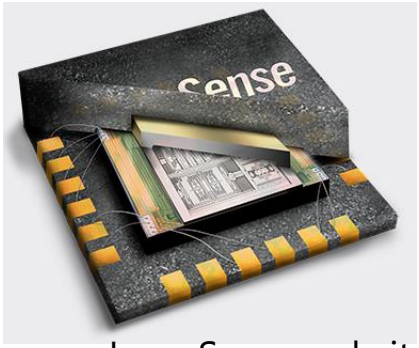
Source: Murata website

SAW

Source: Broadcom website

BAW

MEMS Gyroscopes

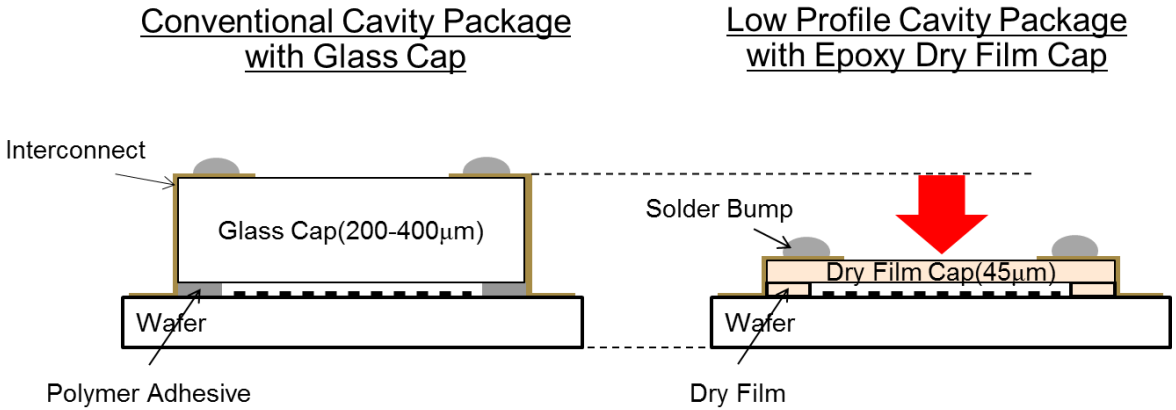


Source: InvenSense website

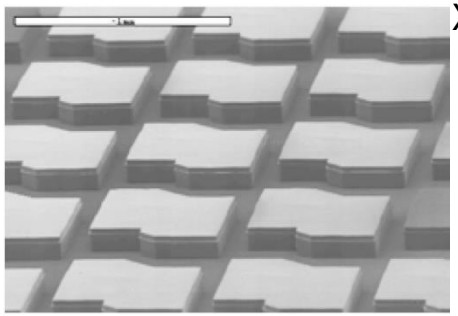
Polymer Cavity PKG Advantages

- Low Cost
- Low Profile

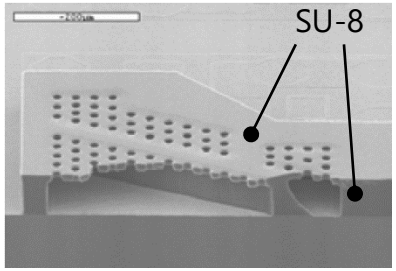
LAW PROFILE CAVITY STRUCTURE



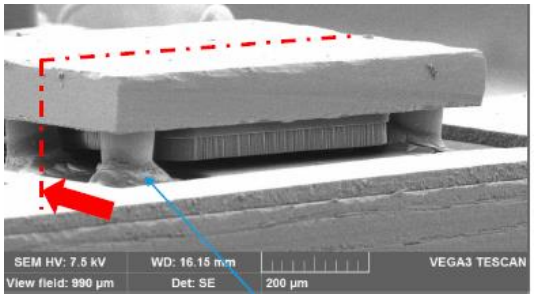
RF Filter Photo-epoxy Based WLP



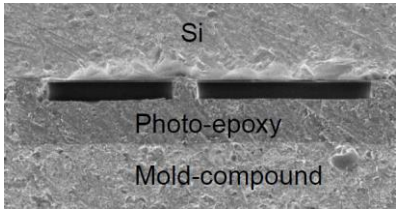
X-section before capping



M. Franosch *et al.*, Mikrotechnik Tagung Buchs 2007



X-section after molding

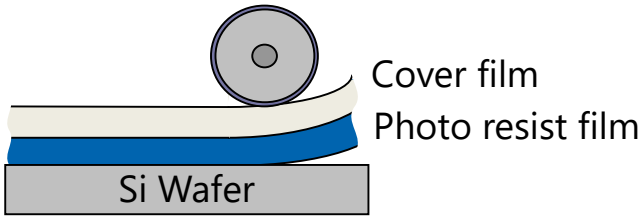


R. Aigner, MEMS Summit 2016

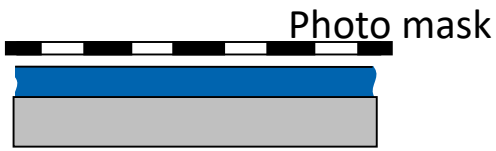
- Polymer cavity PKG is a key technology for new generation RF filters.

Fabrication Process of Polymer Cavity Structure

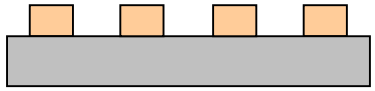
1. Dry film(SU-8 3000CF DFR) lamination as the wall layer



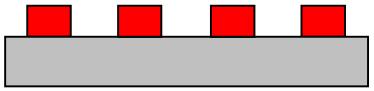
2. Expose the wall layer



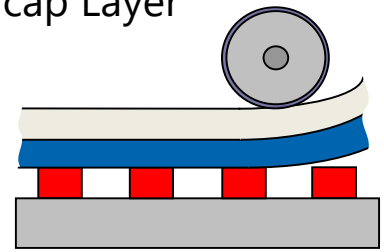
3. PEB and develop the wall layer



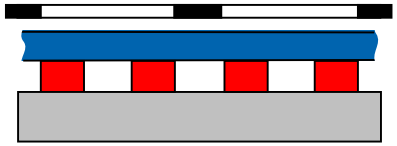
4. Hard bake the wall layer



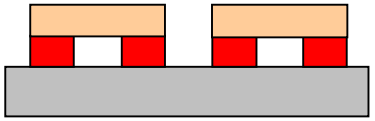
5. Dry Film(SU-8 3000CF DFR) Lamination as the cap Layer



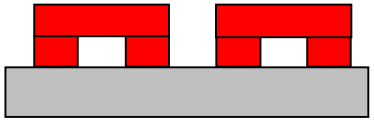
6. Expose the cap layer



7. PEB and develop the wall and cap layer



8. Hard bake the cap and wall layer



Outline

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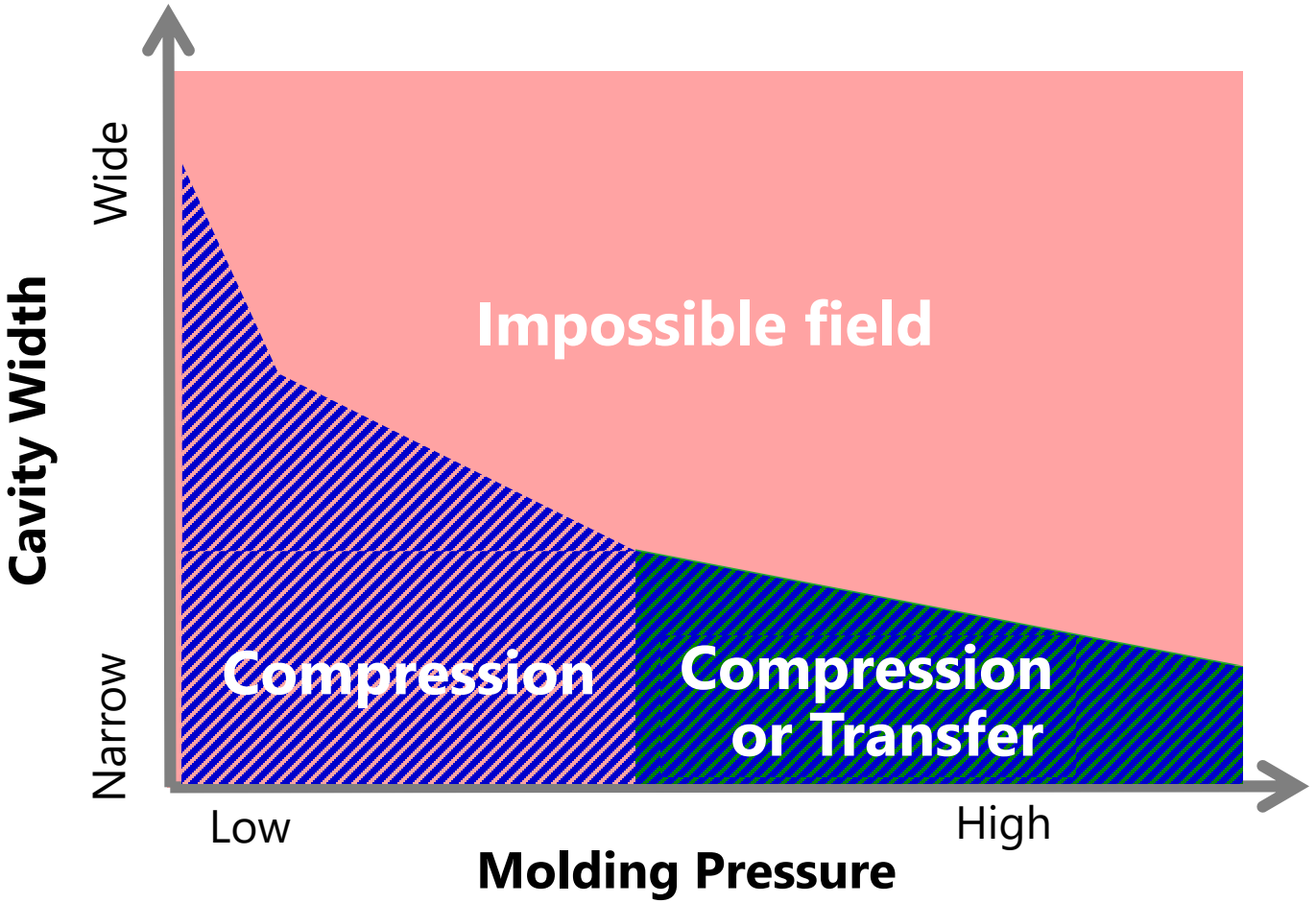
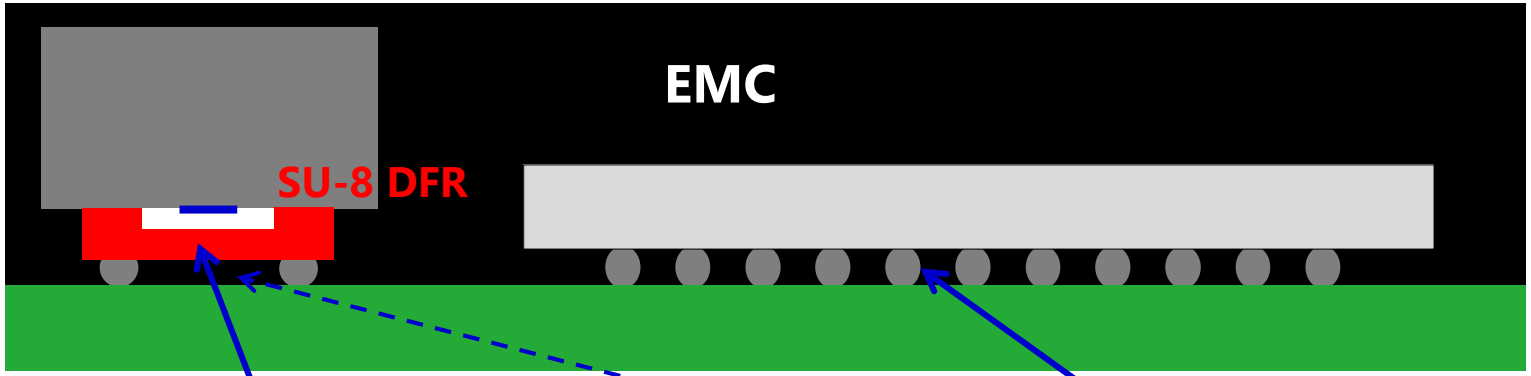
Transfer Molding Limitation



- Low pressure molding are required to fabricate wider and thinner cavity PKG.
- And compression molding is very promising for such low pressure molding.

Two Major Feasibility Studies by Compression Molding



Molding resistance of the SU-8 polymer cavity

Molding Resistance Test on the Polymer Cavities

EMC filling performance

Molding Compound Filing Test

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Filling Test Procedure and Condition

< Filling Test DOE : FCCSP >

- Die size 5 x 5 mm
- Bump height 50 um
  Pitch 200 um
  dia. 90 um

*Die thickness : 100 um EMC thickness : 500 um

F/C bonding on substrate at 2 corners and 4 centers

Compression Molding

Dicing and grinding

Observe filling performance

EMC	Mold pressure (MPa)	Mold temperature (℃)
Version A (Standard)	1	150, 175
	2	150, 175
	3	150, 175
Version B (High Flowable)	1	150, 175
	2	150, 175
	3	150, 175

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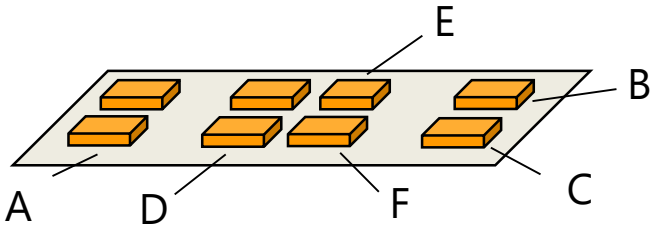
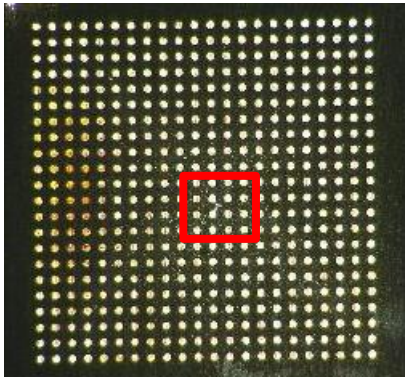
Filling Test Result

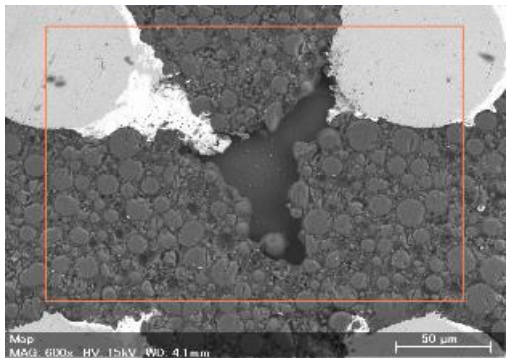


A,B,C・・・corner position
D,E,F・・・center position

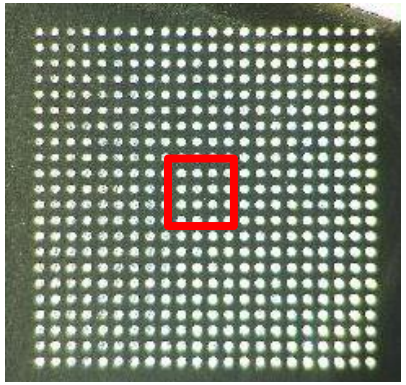
Die	Version A (Standard)			Version B (High Flowable)		
	1MPa	2MPa	3MPa	1MPa	2MPa	3MPa
A	Good	Good	Good	Good	Good	Good
B	Good	Void	Good	Good	Good	Good
C	Void	Void	Good	Good	Good	Good
D	Void	Void	Good	Good	Good	Good
E	Void	Good	Good	Good	Good	Good
F	Good	Void	Good	Good	Good	Good

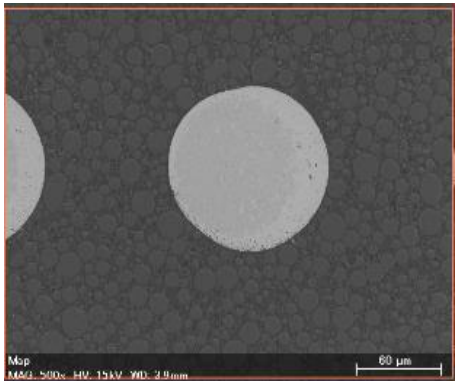
Bad Filing Example





Good Filing Example





Version B showed better filling ability than Version A.

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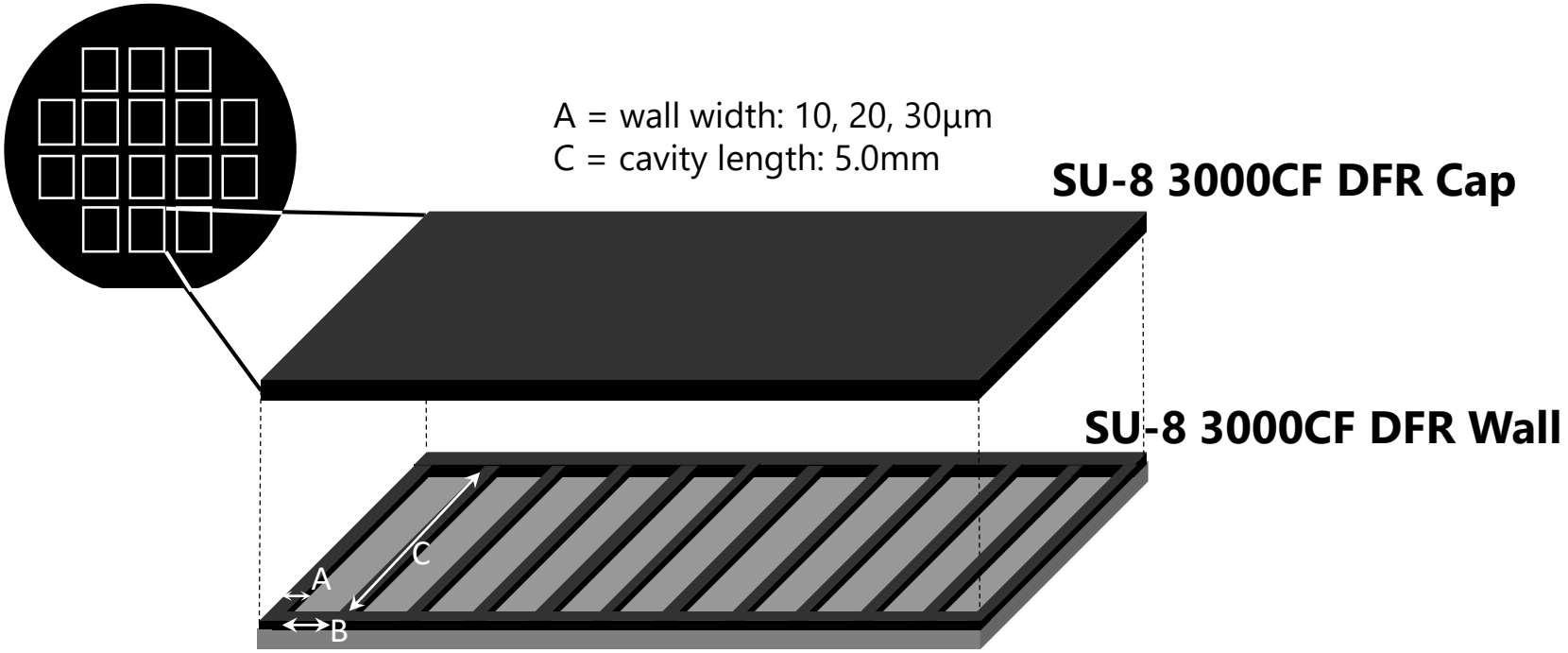
Molding Test Chips

SU-8 3000CF DFR Wall and Cap Geometries on a wafer



B = 280µm 260µm 240µm 220µm 200µm 180µm
270µm 250µm 230µm 210µm 190µm 170µm

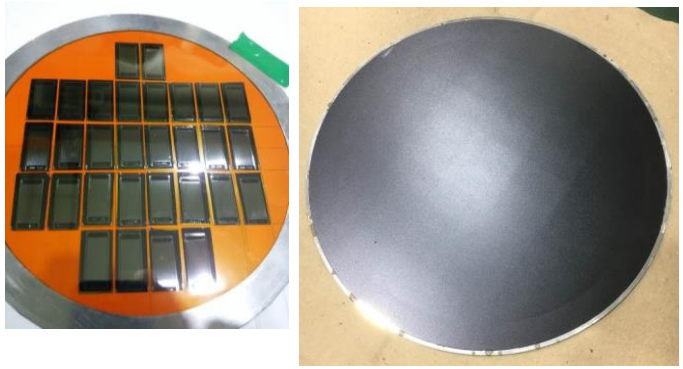
B = cavity width: Every 10µm between 10µm and 500µm

Molding Resistance Test Evaluation Criterion

Factors and Levels:

EMC	Compression Molding Pressure	SU-8 3000CF DFR Cap thickness
Version B	1 MPa	20, 30, 45 µm
	2 MPa	20, 30, 45 µm
	3 MPa	20, 30, 45 µm

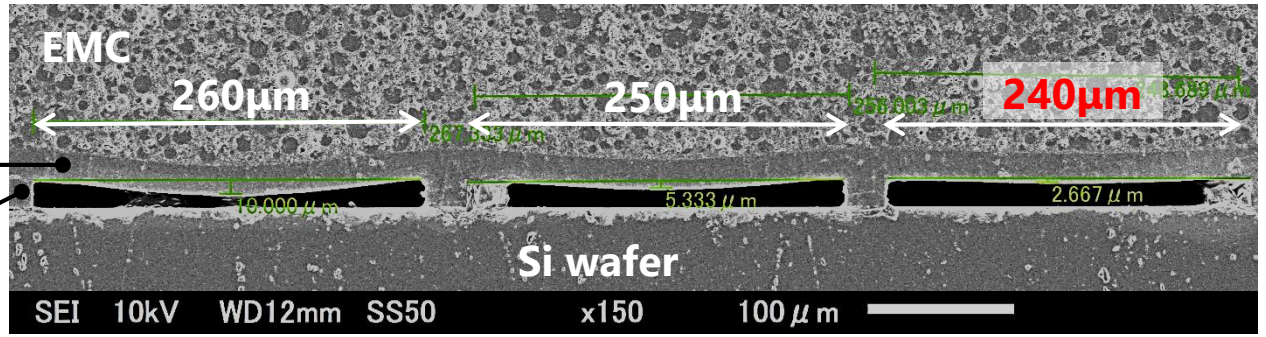
<Before and after Molding>



Evaluation:

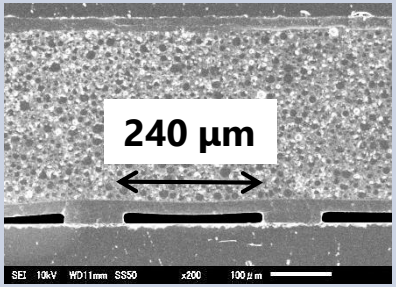
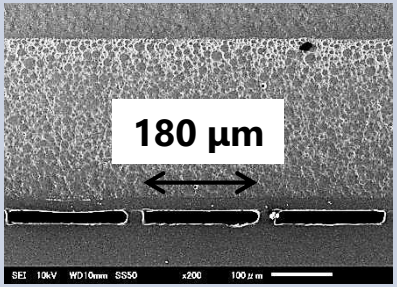
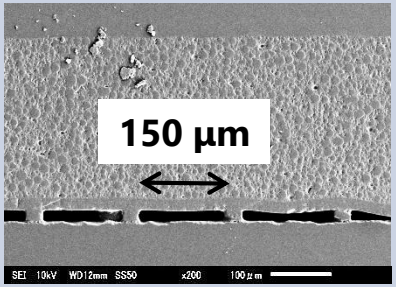
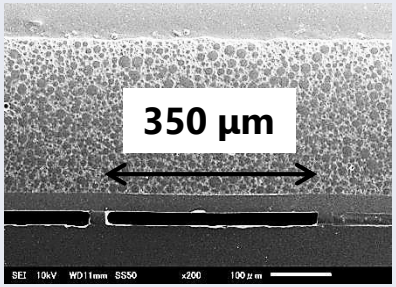
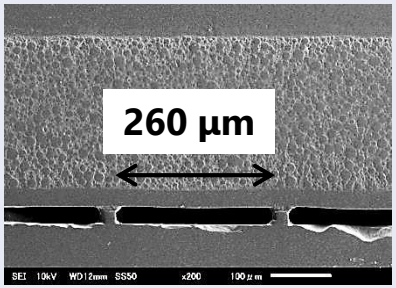
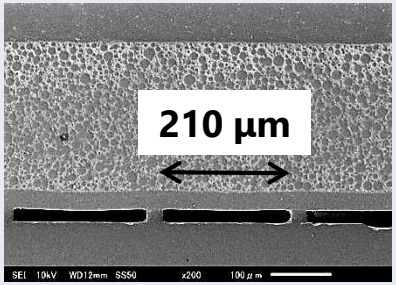
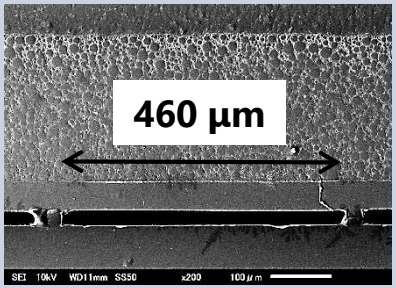
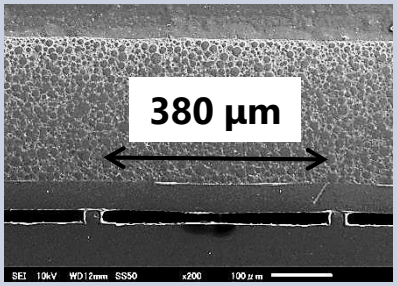
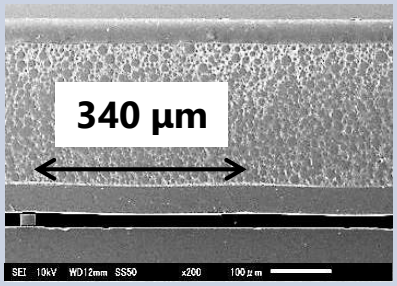
1. Measure max cap displacement (δ_{max}) after molding
2. Find max cavity width which gives <5µm δ_{max}

Ex) 1MPa, 20µm thick cap



δ_{max} 10.0 µm 5.3 µm 2.7 µm

Molding Resistance Test Result

Cap thickness	1 MPa	2 MPa	3 MPa
20um			
30um			
45um			

Proportional to the cap thickness

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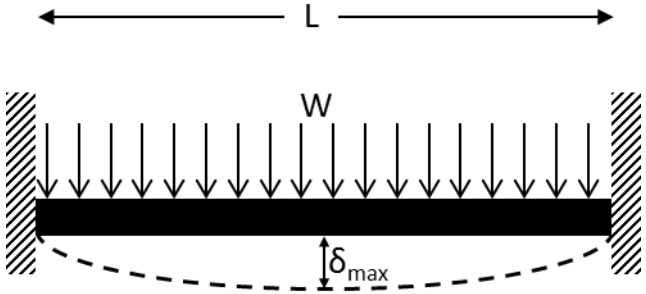
Theoretical Review

Theory of both ends fixed uniformly distributed load

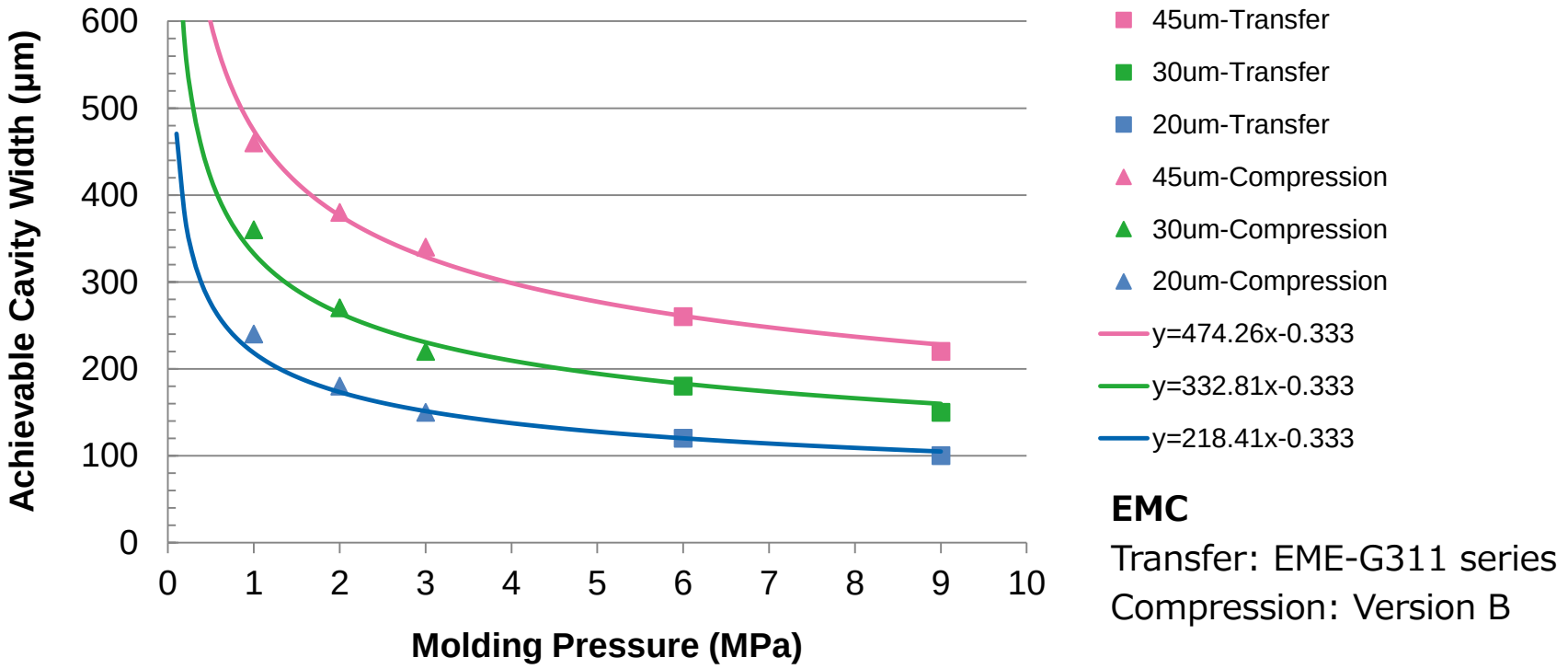


δ_{max} Displacement at the center(mm)
W Total load(N)
L Length of the material(mm)
E Young modulus of the material(N/mm^2)
I Moment of inertia(mm^4).

$$L^3 = 384EI/\delta_{max} W$$

Source: Mechanics of Materials, Volume 1, Chapter 6

Transfer/Compression Comparison

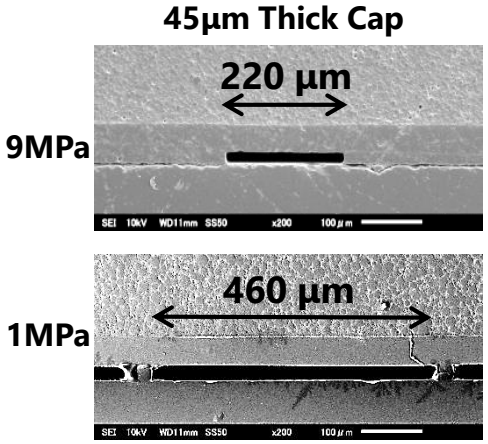


EMC
Transfer: EME-G311 series
Compression: Version B

- Molding resistance test was done at 1 to 3 MPa that can not be realized by Transfer molding process.
- Actual results close to the theoretical curve based on 6 MPa were obtained.

Executive Summery

- Molding Compound filling test and Molding Resistance test were conducted by compression molding.
- Version B which is a high flowable EMC showed better filling ability than Version A, standard type.
- Low pressure compression molding demonstrated that molding resistance and molding filling ability are compatible.
- The relationship between cap thickness, molding pressure and cavity width are clarified to determine the polymer cavity package design rule.



- Compression molding at 1-3MPa with Version B is very promising to fabricate wider SU-8 polymer cavity packages.

Acknowledgements

- The authors would like to thank Teikoku Taping System that helped DFR lamination.

- The authors would like to thank Sumitomo Bakelite Co., Ltd. and Towa Corporation that greatly helped compression molding experiments.