DEVELOPMENT OF LIGHTWEIGHT FOAMED PLASTICS WITH HIGH MECHANICAL PROPERTIES BY USING HYDROPHOBIC MODIFIED CELLULOSE NANOFIBER AND CONTROLLING CELL MORPHOLOGIES

AUTHORS:

Akihiro Ito, Takeshi Semba, Kazuo Kitagawa, Masahiro Ohshima, and Hiroyuki Yano

PRESENTED BY:

Akihiro Ito

Senior researcher

Kyoto Municipal Institute of Industrial Technology and Culture

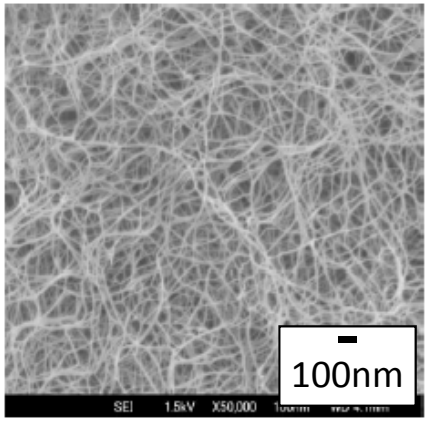
TAPPI

Outlines

1. Melt Flow properties of CNF/PA6 composite in KYOTO PROCESS®
2. Foaming properties of CNF/PA6 composite
3. Foaming properties of CNF/PA6 composite + PA6 type thermoplastic elastomer

Cellulose Nanofiber (CNF)

Cellulose nanofiber (CNF)
produced by mechanically disintegrating cellulose fiber bundles, typically from wood, into nanoscale fibrils with diameters ranging from 10-100 nm and lengths varying by several micrometers.

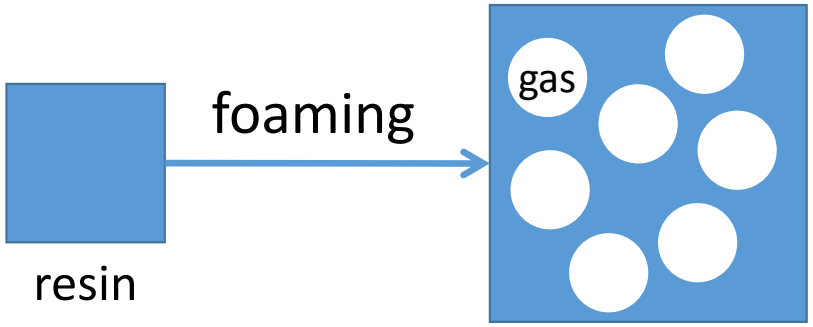


Provided by Dr. Awano (Kyoto-univ.)

Excellent properties
- five times stronger but has 1/5 the density, compared with steel
- 1/50 the linear thermal expansion, compared with glass
- a large specific surface area
- readily available

Various applications
For example, as a reinforcement fiber in plastics

Foaming



【Merit】

- Lightweighting
- Heat and electric insulation
- Sound and shock absorption
- Dimension stabilization

【Demerit】

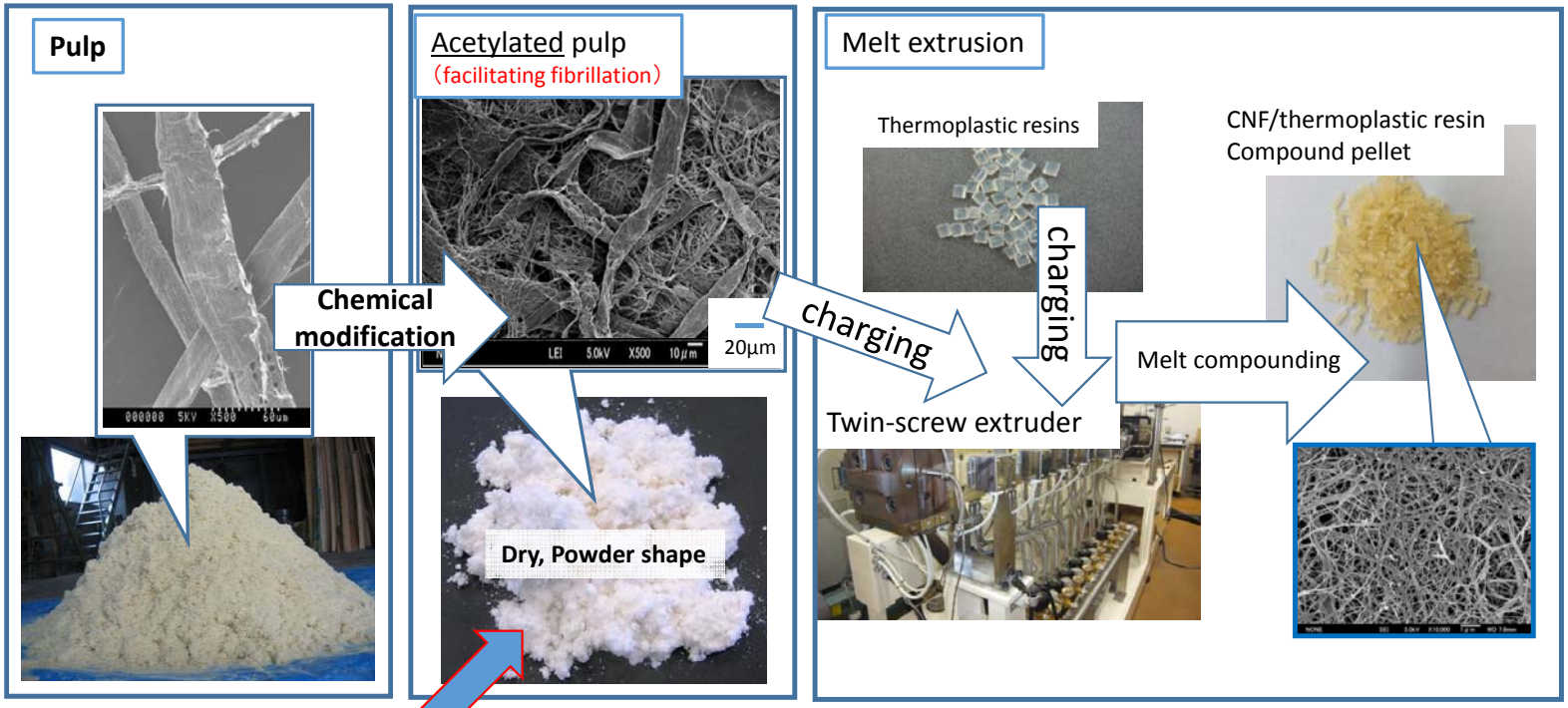
- Decrease of mechanical and thermal properties

【Resolution method】

- Decreasing bubble radius
- reinforcing foaming material

CNF

Preparation of materials

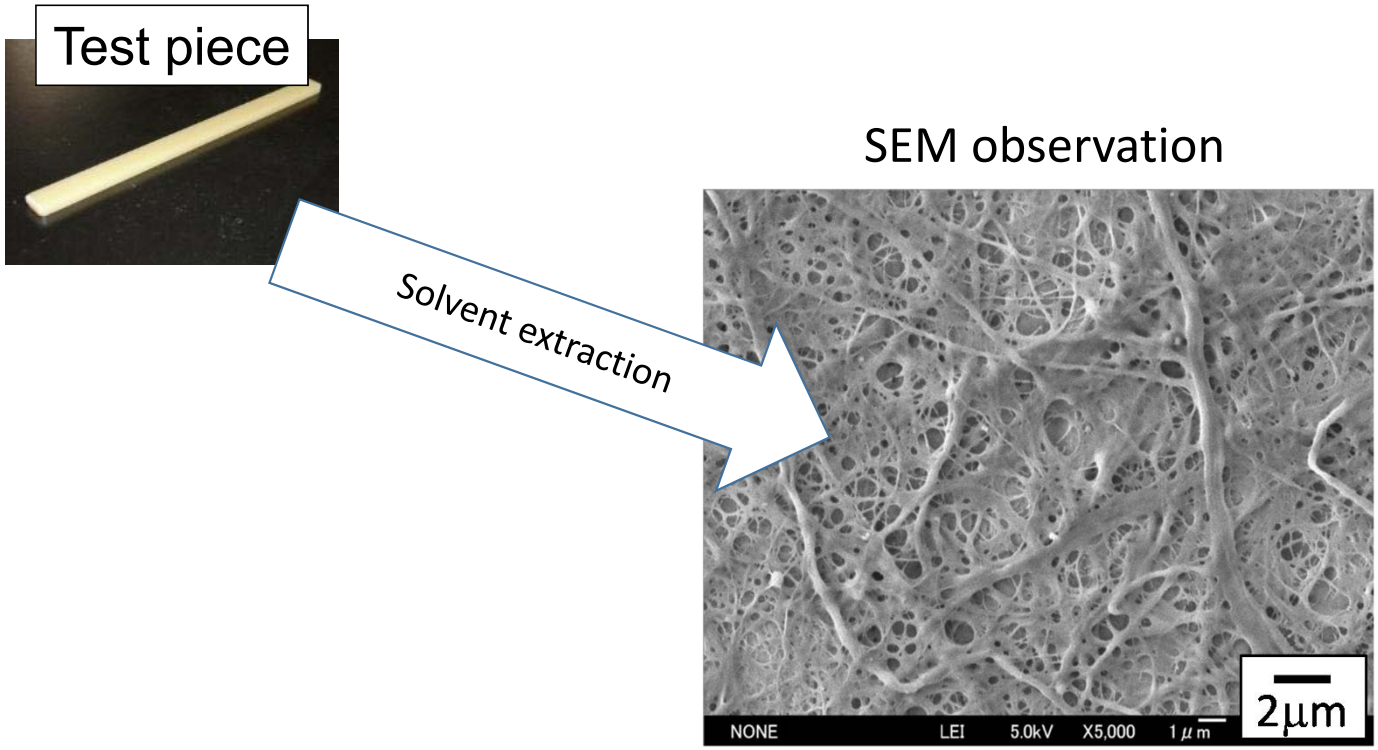


High wet content, tackness

KEY POINTS

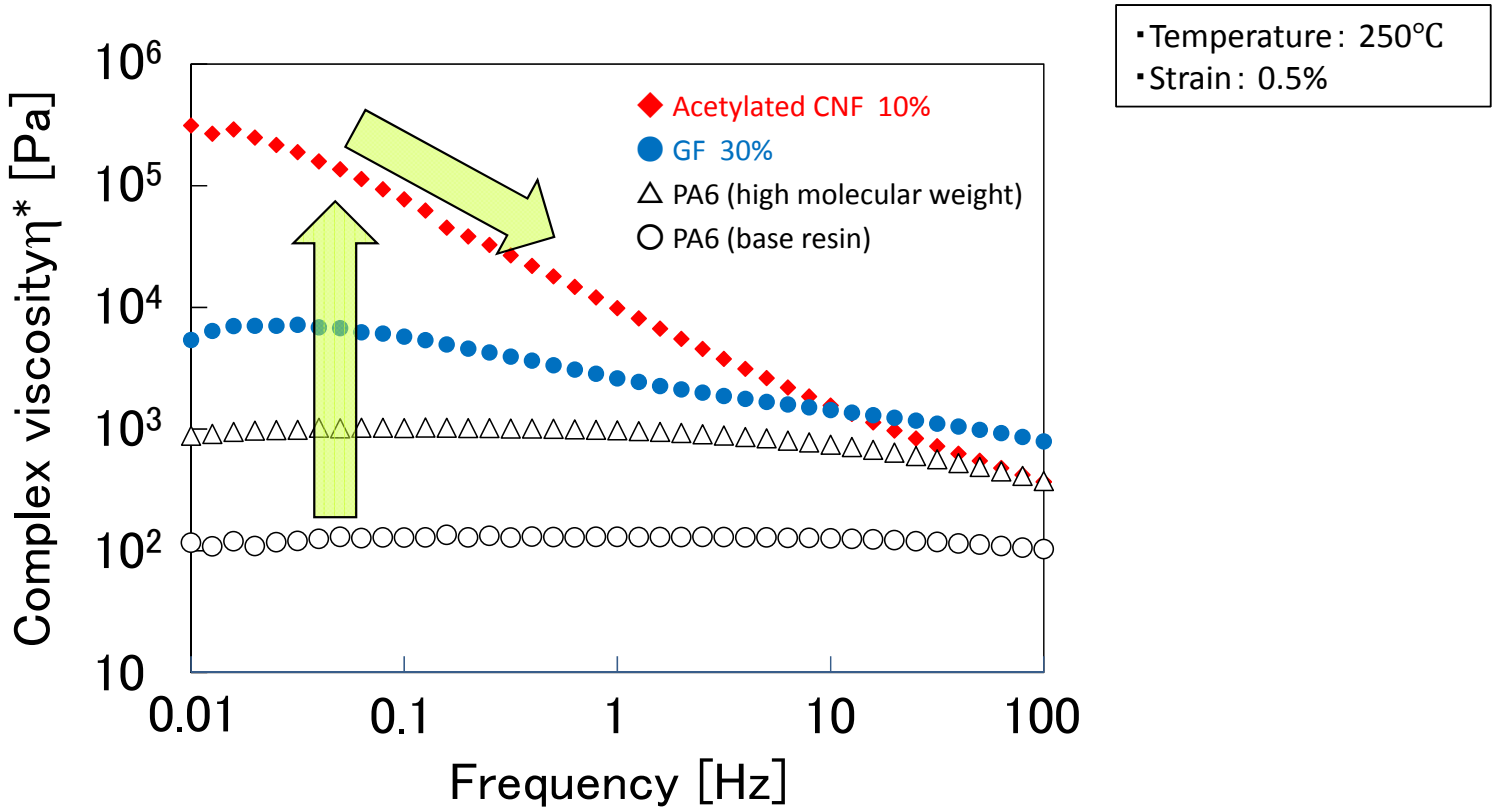
- Simplifying a manufacturing process
- Reducing a manufacturing cost

CNF morphologies



Pulp was fibrillated and became CNF during kneading process

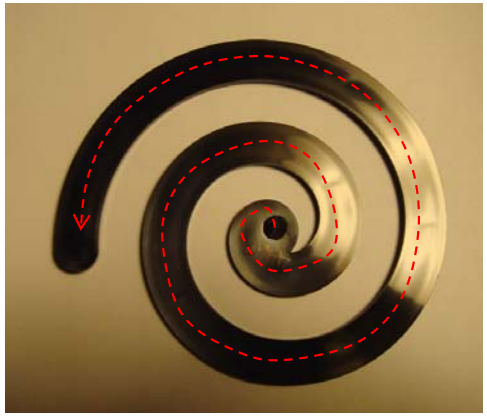
Viscoelastic measurement



・PA6(high molecular weight) ・・・ High η* at the frequency from 0.01 to 100 Hz

・Acetylated CNF ・・・ The same value as PA6(base resin) at high frequency (→ equivalent injection moldability)
High η* at low frequency (→ reduction of bubble size)

Spiral Flow test



Measuring the flow length

Cylinder tmp.: 250°C
Mold temp.: 80°C
thickness: 2mm
Injection time: 3sec
Screw speed: 100rpm

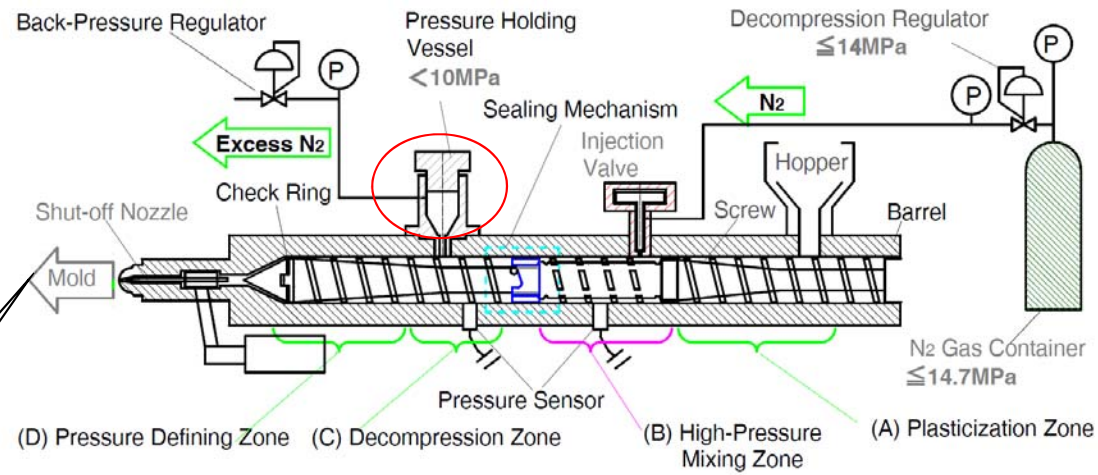
Material	Injection condition		Plasticization	Flow length
	Pressure [MPa]	speed [mm/s]	Torque [%]	L [mm]
PA6 (base resin)	10	10	9	188
		50	10	188
		100	10	188
PA6 (high molecular weight)	10	10	23	24
		50	20	27
		100	21	27
Acetylated CNF10%/PA6	10	10	13	86
		50	12	98
		100	12	105

Acetylated CNF10%/PA6…

- High injection speed → Long flow length
- Low plasticization torque and long flow length, compared to PA6 (high molecular weight)

Foam molding

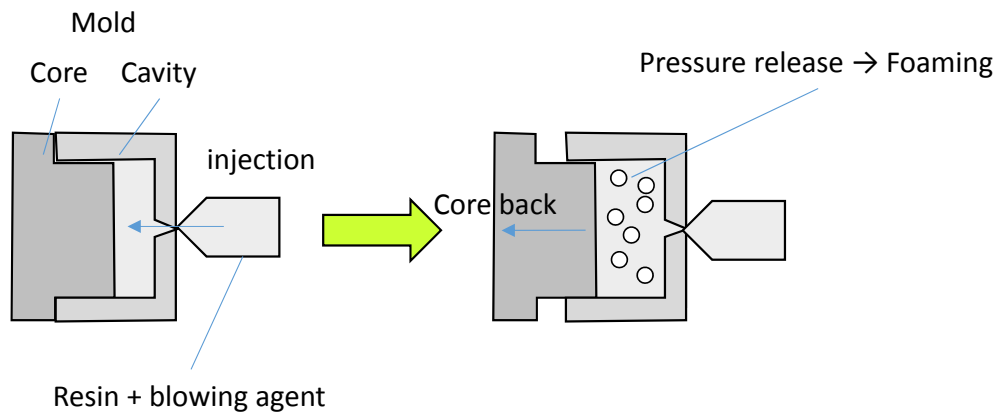
Physical foaming injection molding machine



A. Yusa, S. Yamamoto, H. Goto, and M. Ohshima: FOAMS2015 Book of Abstracts, O-24 (2015).

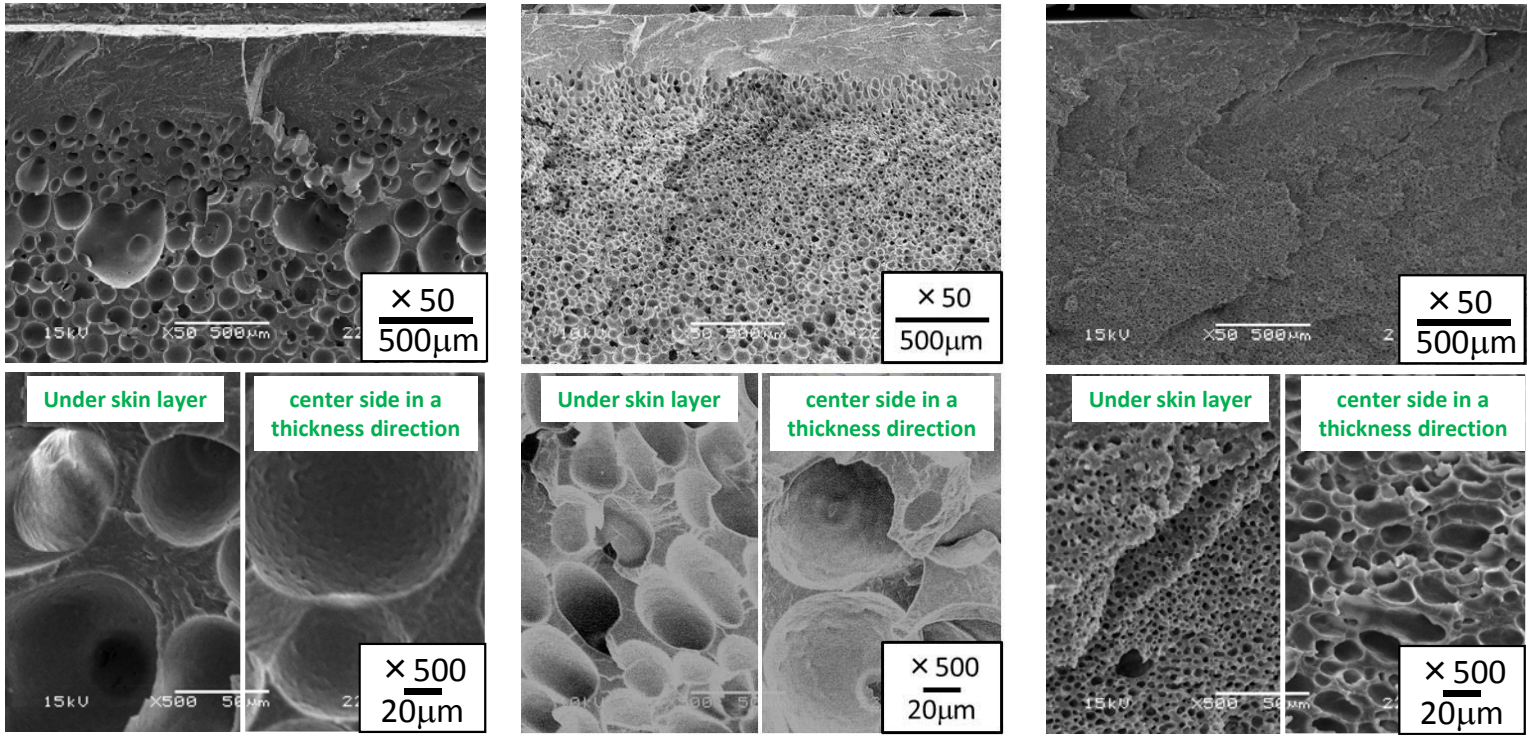
Mold opening operation

Core back operation



Cell morphology

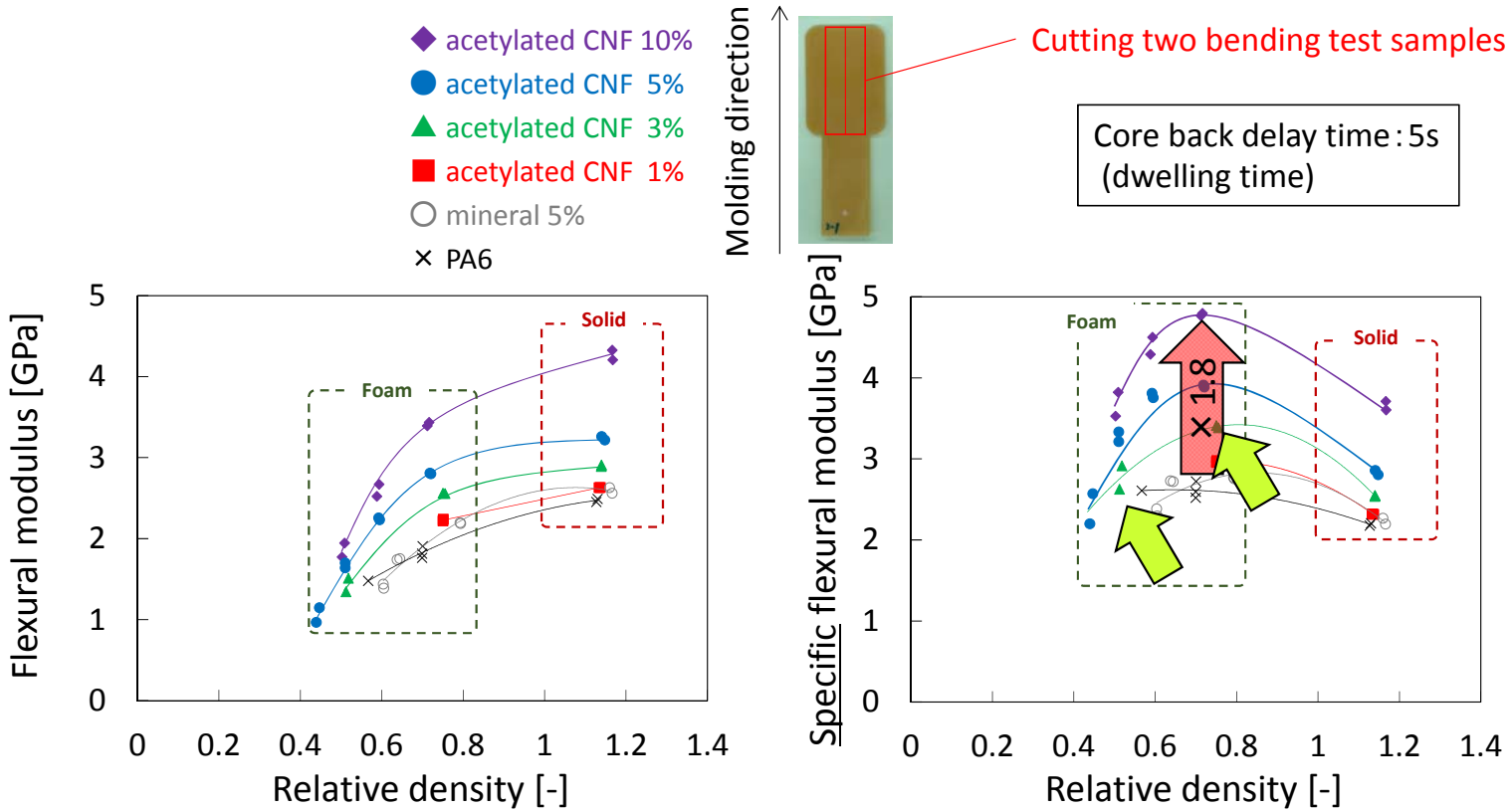
expansion ratio : 2



PA6 (base resin) | PA6 (high molecular weight) | Acetylated CNF5%

Cell size
PA6 (base resin) ≒ PA6 (high molecular weight) ＞ Acetylated CNF5%

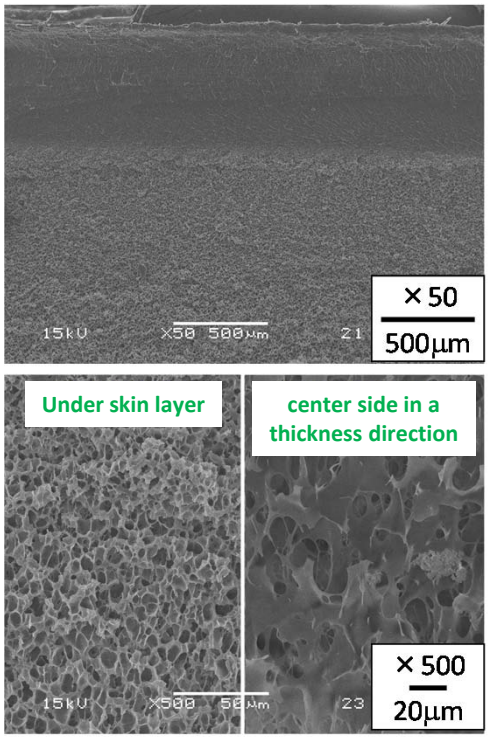
Three-point bending test -flexural modulus-



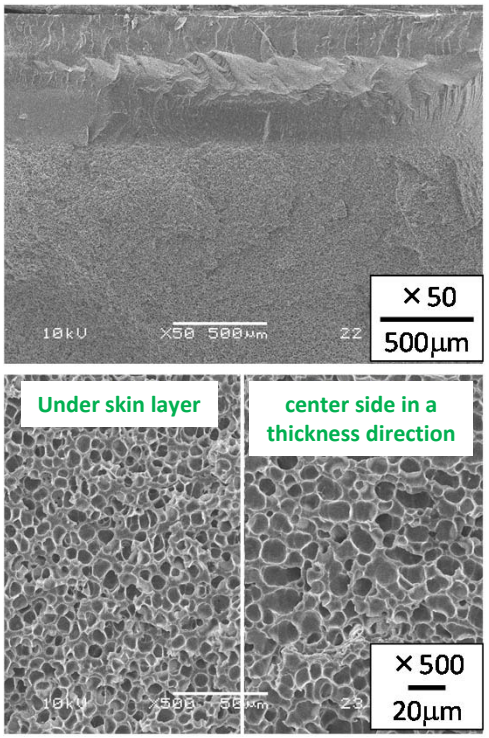
・Although the flexural modulus decreased by foaming, the foams of acetylated CNF / PA6 which had higher modulus and lower density than the unfoamed PA6 were produced.
・Specific modulus showed a maximum at a relative density of 0.7
・Acetylated CNF10% showed 1.8 times the specific modulus of PA6 in a relative density of 0.7.

The effect of relative density in cell morphology

Content of CNF: 3%



Relative density: 0.46



Relative density: 0.76

On low density (high expansion ratio) conditions, Open cells were obtained at center side in a thickness direction.

→ decrease in specific flexural modulus and specific flexural stress

Scale up trial

Car engine cover

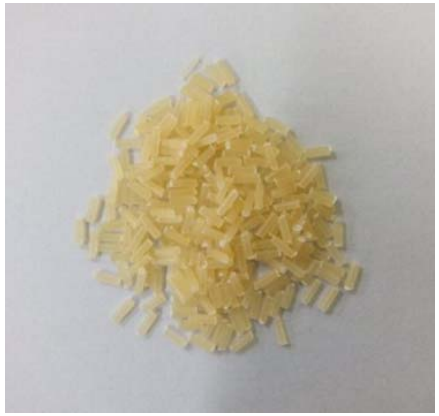
Acetylated CNF5%PA6

- High rigidity
- smooth surface

Molding: Daikyo Nishikawa

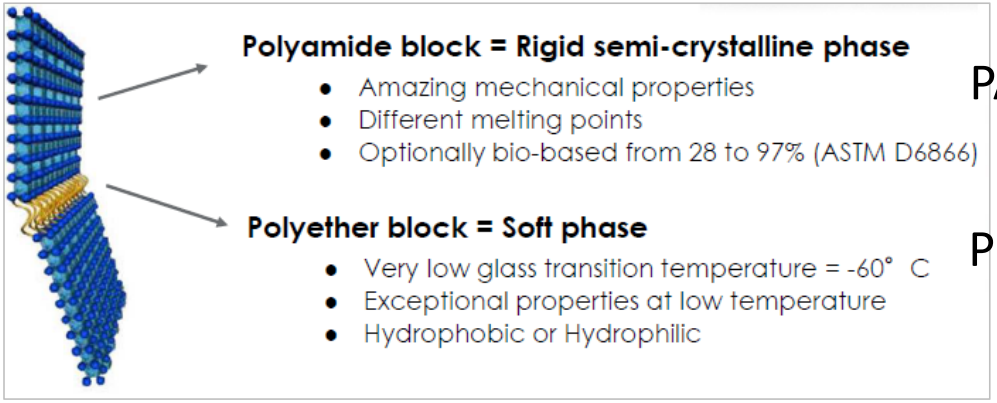
Expansion to thermoplastic elastomer

Acetylated CNF10%/PA6
Compound pellet



High miscibility

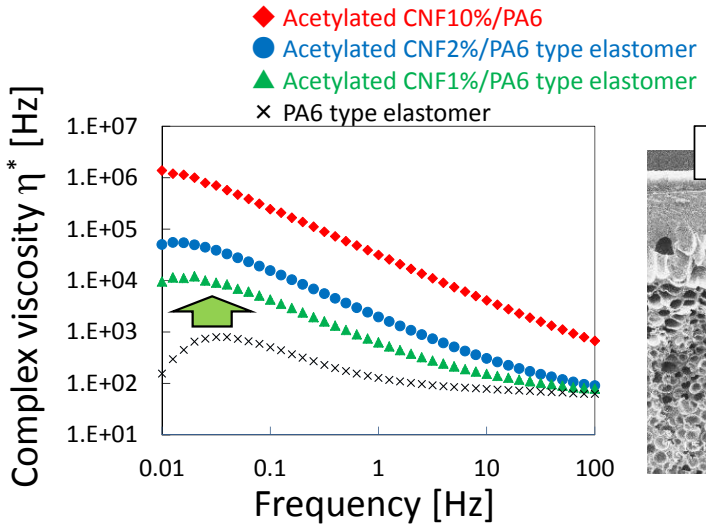
PA6 type thermoplastic elastomer



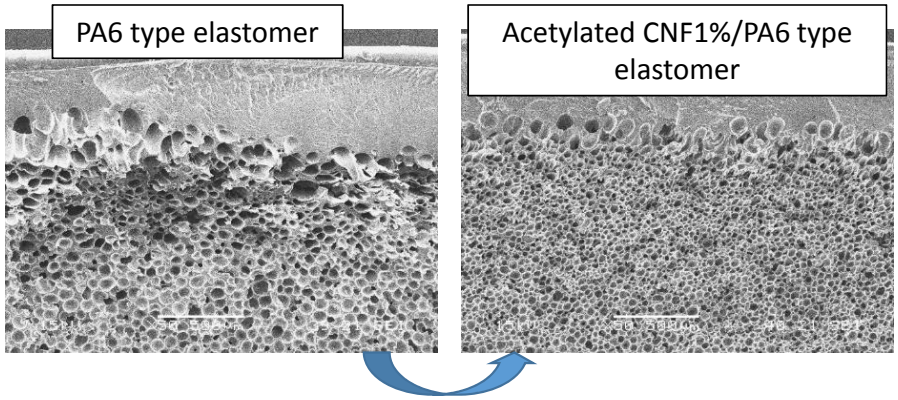
Injection molding

Arkema PEBAX®

Foaming properties of CNF/PA6 composite + PA6 type thermoplastic elastomer

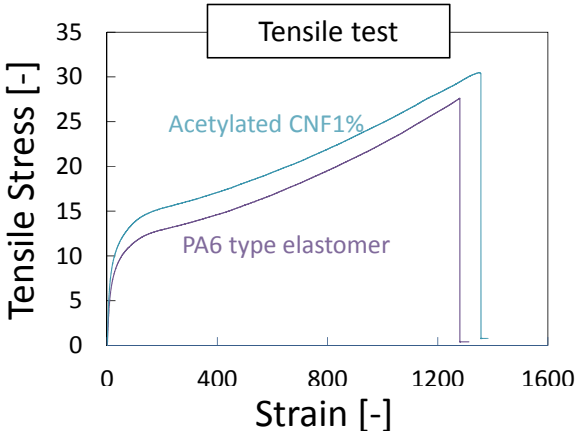


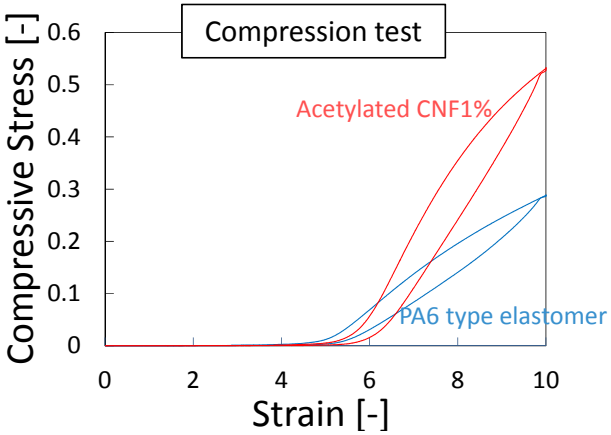
Foam injection molded pieces
- Core-back
- expansion ratio: 2



Only 1wt% addition of CNF increases η* → Good dispersion

Cell: Smaller, more homogeneous





Increasing compressive stress while maintaining flexibility

CONCLUSIONS

1) The addition of CNF decreased the bubble size of PA6 foams while keeping moldability.

2) The Acetylated CNF10%/PA6 foams exhibited 1.8 times the specific modulus of PA6 in a relative density of 0.7.

3) The addition of CNF to PA6 type thermoplastic elastomer was found to be effective in reducing cell size and increasing compressive stress while maintaining flexibility.

ACKNOWLEDGEMENT

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Thank you

PRESENTED BY

Akihiro Ito

Senior researcher

Kyoto Municipal Institute of Industrial Technology and Culture

itbba608@tc-kyoto.or.jp