Road to the automotive parts using cellulose nanofibers materials

Hiroyuki Yano, Naoki Obi, Arimitsu Usuki, Fumiaki Nakatsubo

PRESENTED BY:
Hiroyuki Yano
Professor
RISH, Kyoto University

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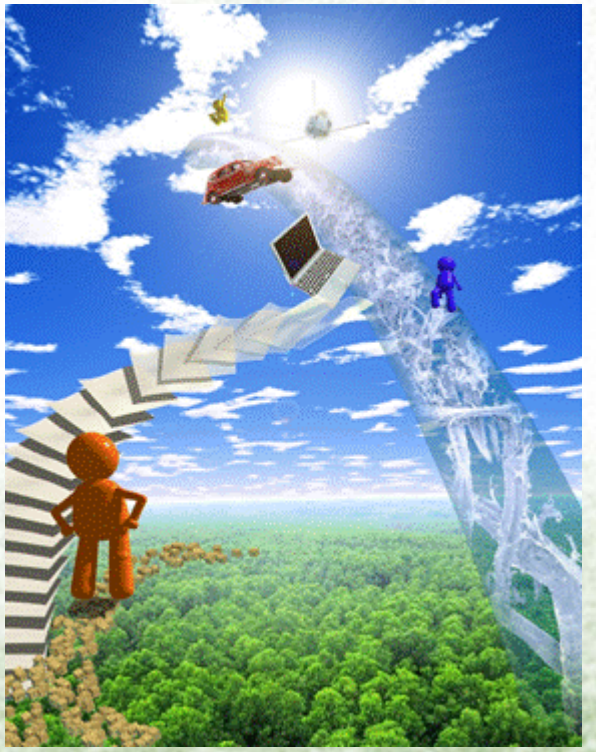
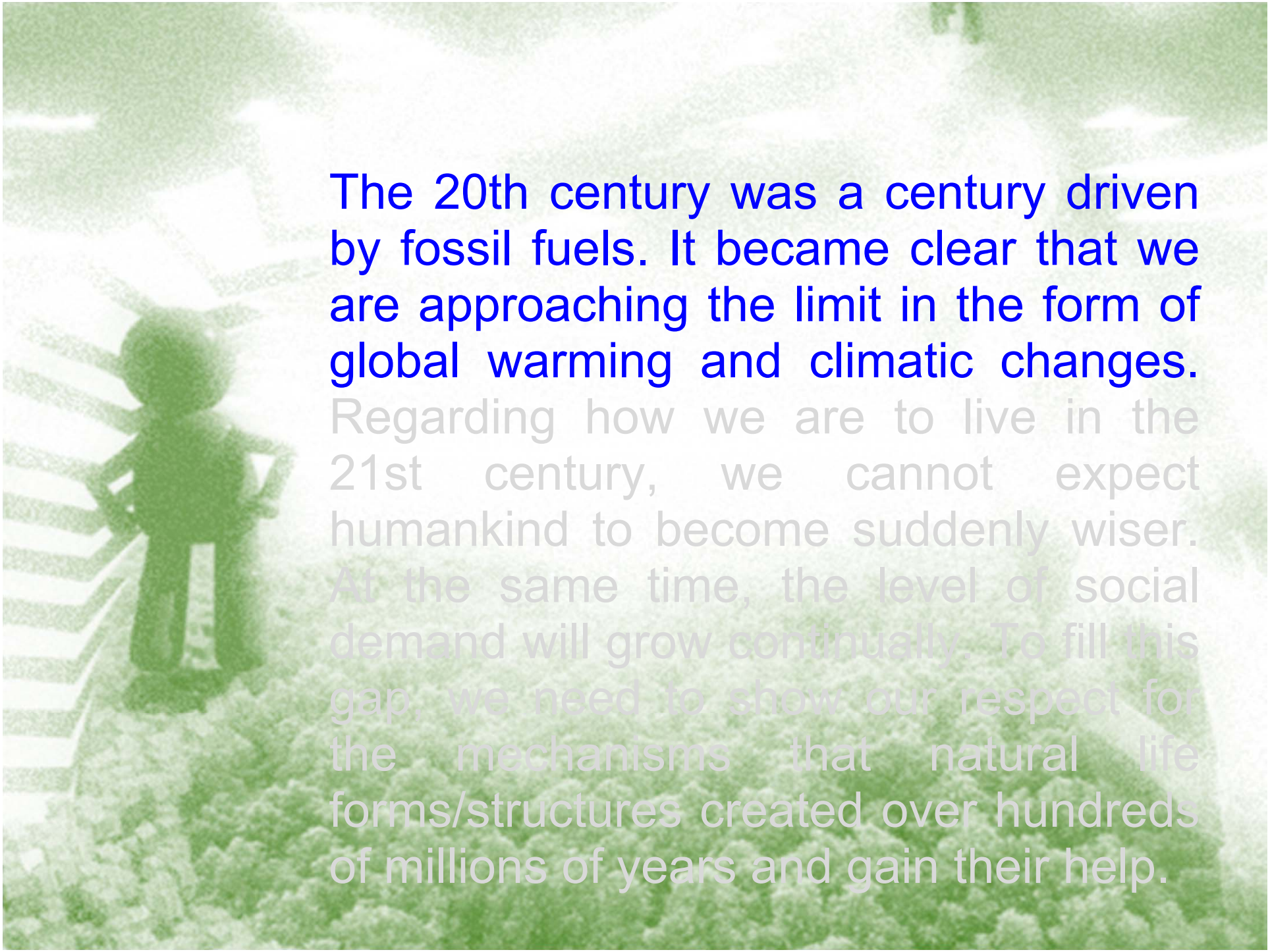
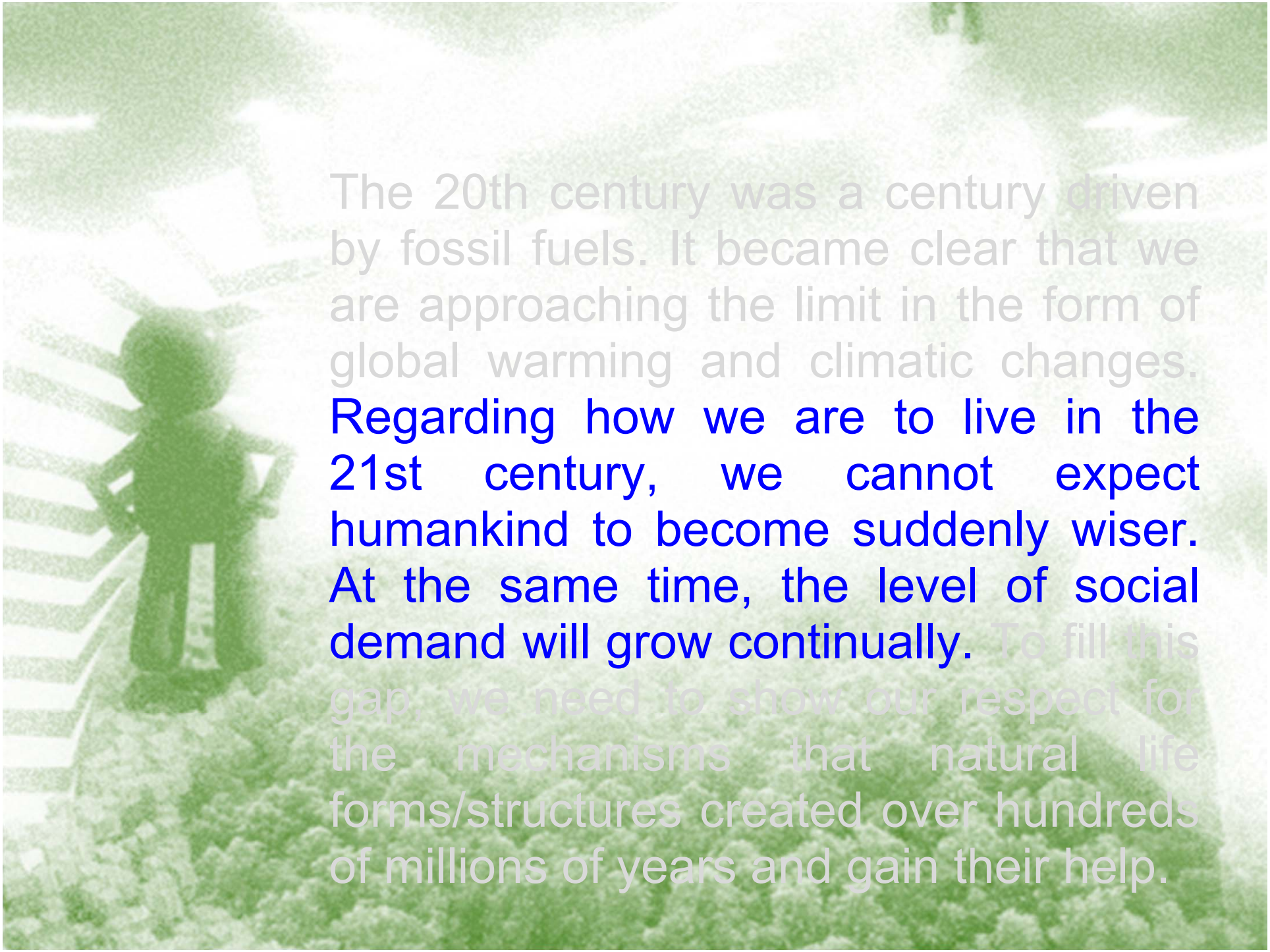


Hiroyuki Yano, Naoki Obi, Arimitsu Usuki, Fumiaki Nakatsubo
Research Institute for Sustainable Humanosphere
Kyoto University



The 20th century was a century driven by fossil fuels. It became clear that we are approaching the limit in the form of global warming and climatic changes. Regarding how we are to live in the 21st century, we cannot expect humankind to become suddenly wiser. At the same time, the level of social demand will grow continually. To fill this gap, we need to show our respect for the mechanisms that natural life forms/structures created over hundreds of millions of years and gain their help.



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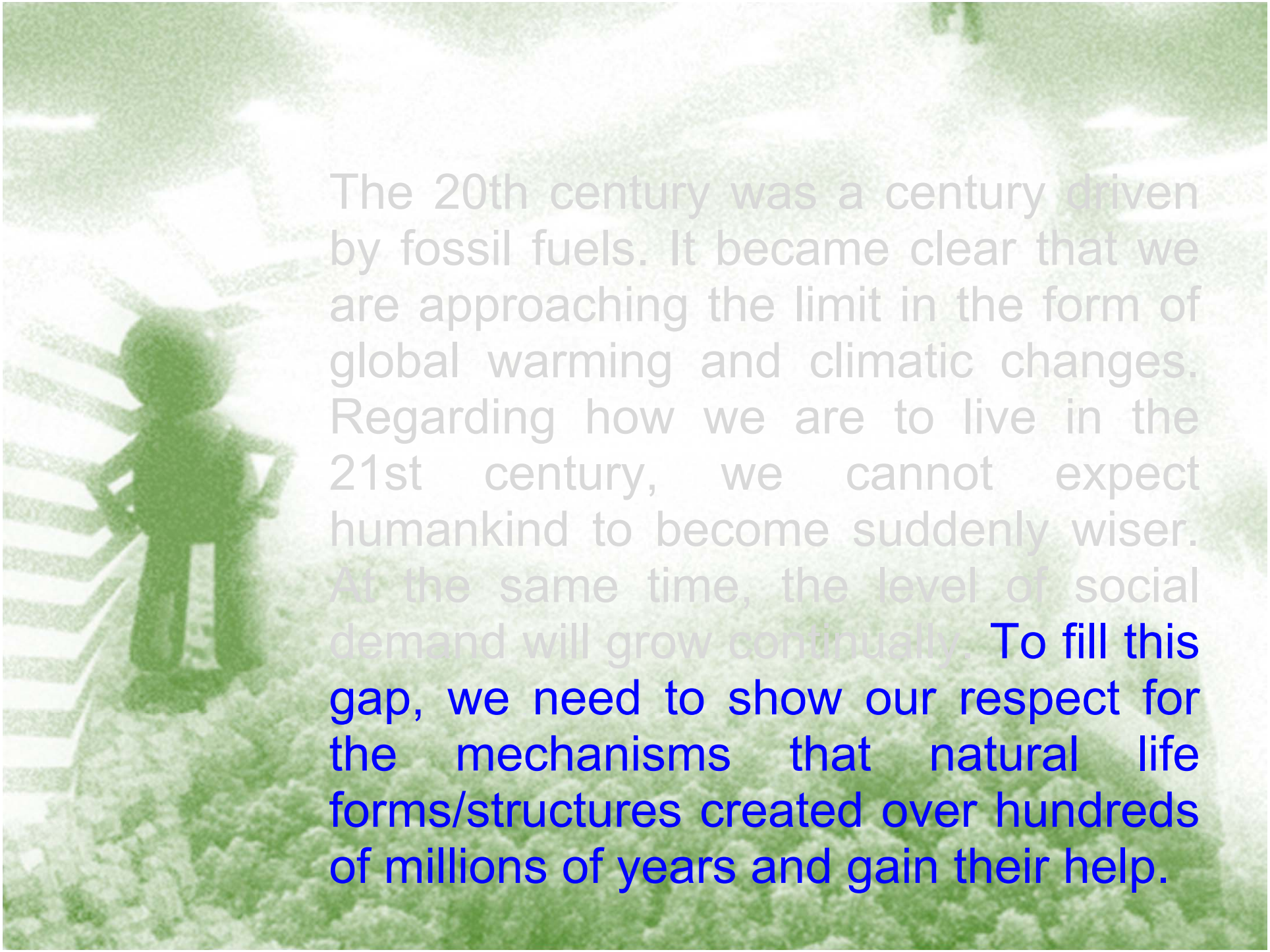

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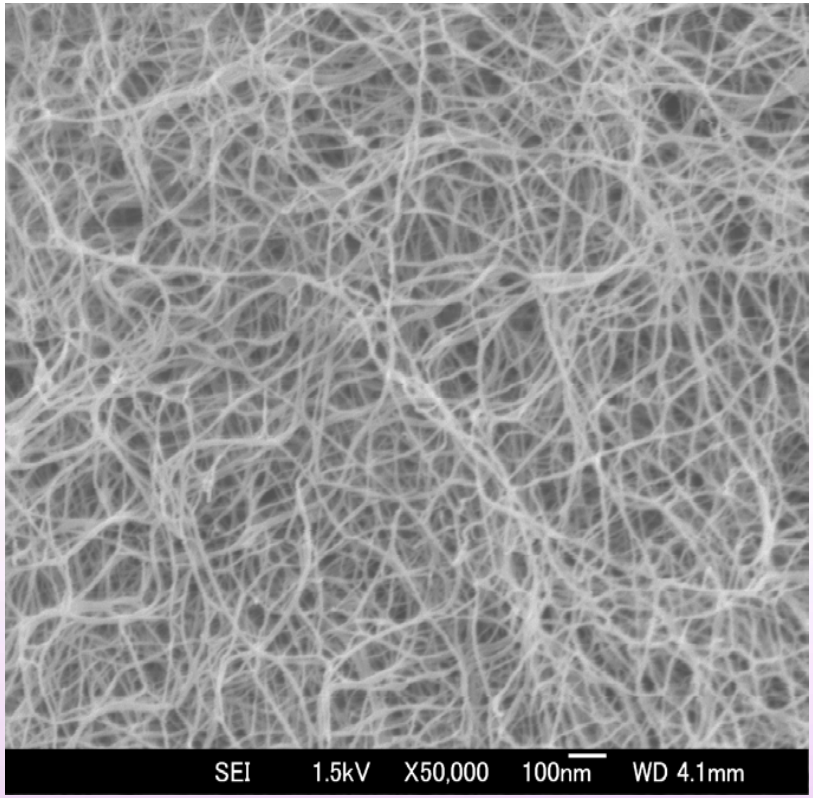
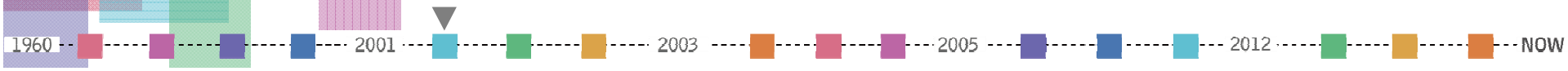
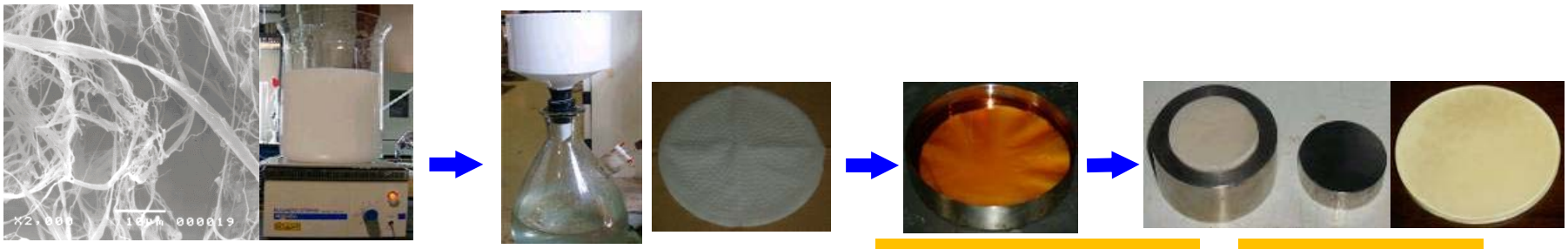
Cellulose Nanofibers
- Gift from Nature -



The most abundant bio-nanofibers on earth

High strength cellulose nanofibers composites 2001

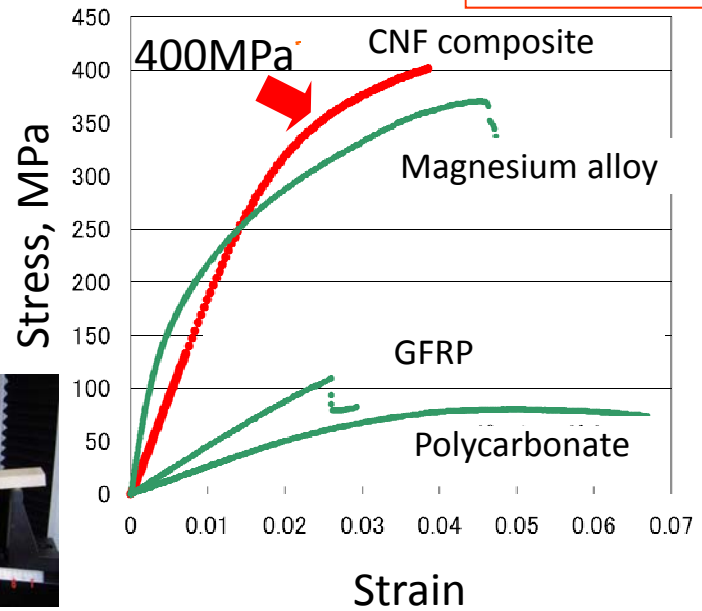




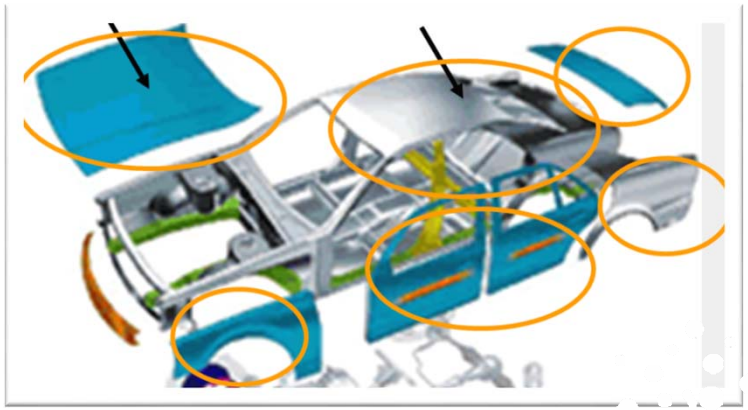
Water slurry of CNF → Filtration → PF resin impregnation → Molding

90%CNF!

Light weight and high strength



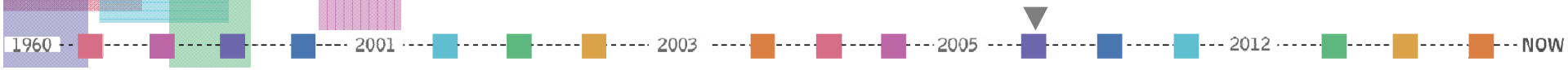
340-370MPa 270-340MPa



http://www.nsc.co.jp/tech/challenge/transport/car_01.htm

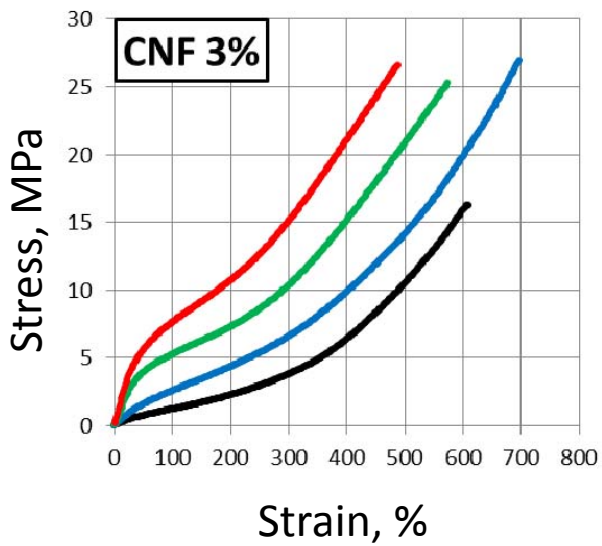
Cellulose nanofibers reinforced rubber

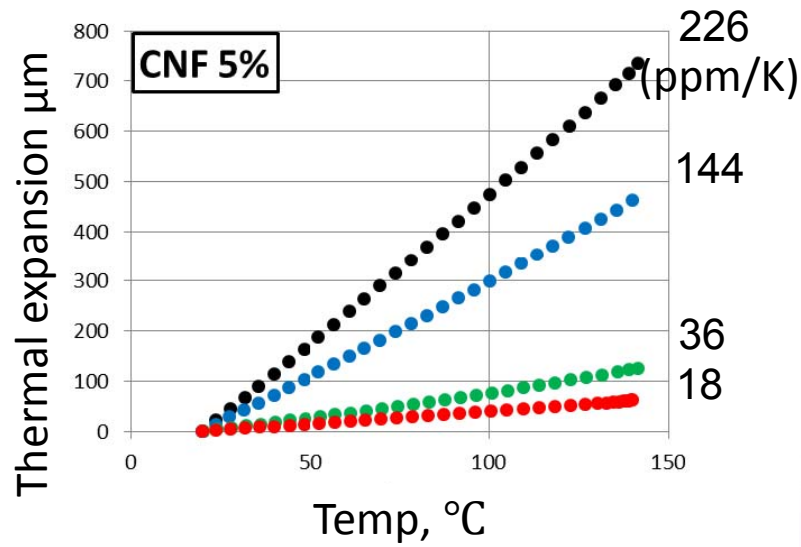
2006, 2011



3%CNF increased strength by 8 times

Significant decrease in thermal expansion



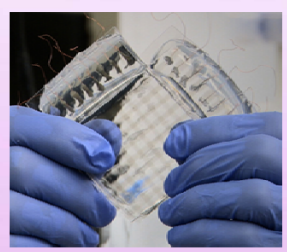


●Natural rubber ●unmodified ● Stearoylated ●Oleoylated

(Katoh, Nakatsubo, Yano:2011)

Light weight

Low thermal expansion

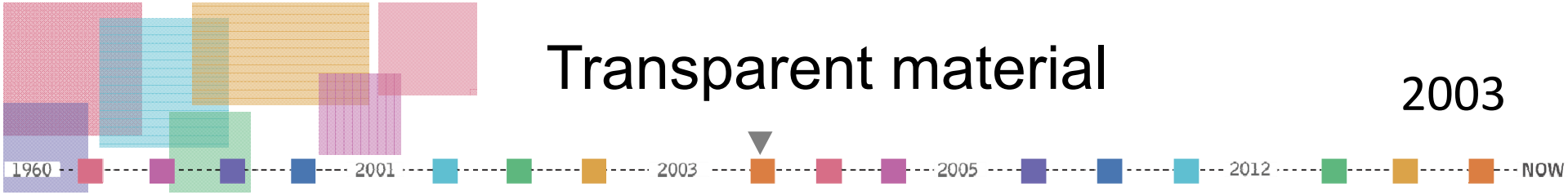


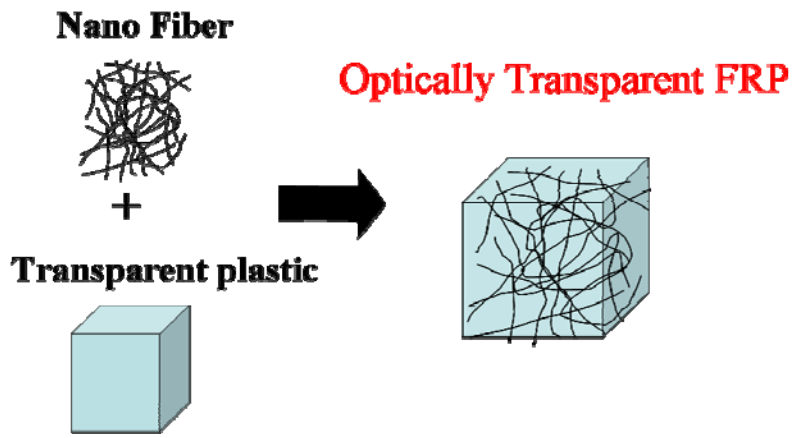
Someya,T. (2004-)

Devise and sensor

Transparent material

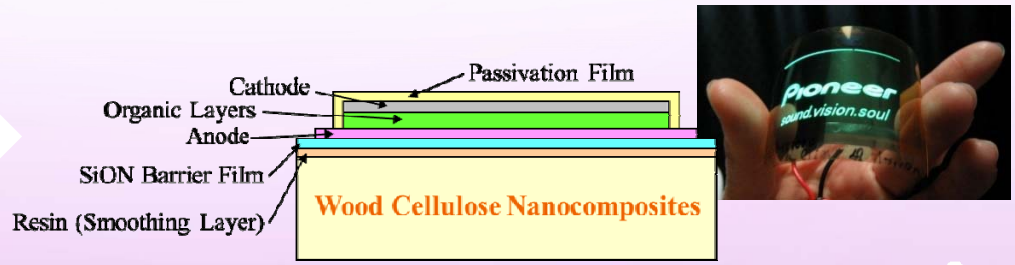
2003





A component less than optical wavelength can avoid light scattering making optically transparent composites

CNF reinforced low thermal expansion transparent composite



Organic EL device

As strong as steel, as thermally stable as glass, and as bendable as plastics

Kyoto University Alliance (2002-200

Strong demands for Structural Applications, especially plastics reinforcement

Global plastics market (production) in 2010 : 265 million ton

	North America	China	Europe	Japan	Korea	Taiwan
LDPE	9,312	9,857	7,900	1,948	2,078	103
HDPE	7,660		5,550	1,015	2,028	544
PP	7,826	9,167	8,800	2,709	3,806	1,215
PS	2,293	-	3,700	822	1,037	845
PVC	6,358	11,300	5,550	1,749	1,404	1,432
Others	13,184	13,283	14,900	3,999	2,675	2,192
Total (1000ton)	46,633	43,607	46,400	12,242	13,028	6,331

If we replace 5% of 300 million ton by $8/kg CNF, it generates $120 billion market.

Cellulose nanofiber project for structural application

METI: Ministry of Economy, Trade and Industry
NEDO: Affiliated organization of METI
MOE: Ministry of the Environment

The Cross-industrial Vertical Integration Project

2005-2006
METI Project
Production of CNFs and Their Applications
7 Companies, 2 Institutes

2007-2009
NEDO Project
CNF Reinforced Plastics and Rubber
5 Companies, 3 Institutes

2010-2012
NEDO Project
Chemical modification of CNF for Automotive Parts
4 Companies, 2 Institutes 7 Advisers

2013-2019
NEDO Project : Novel production process for LignoCNF/resin
3 Companies, 2 Institutes, 21 Advisers

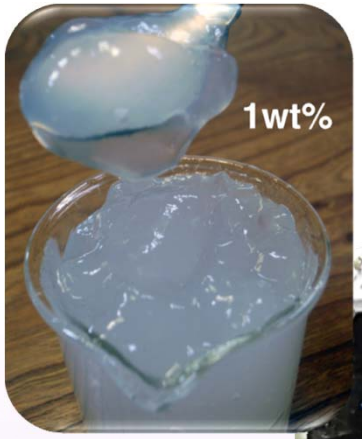
2016-2019
MOE Project
NCV

2005-2006

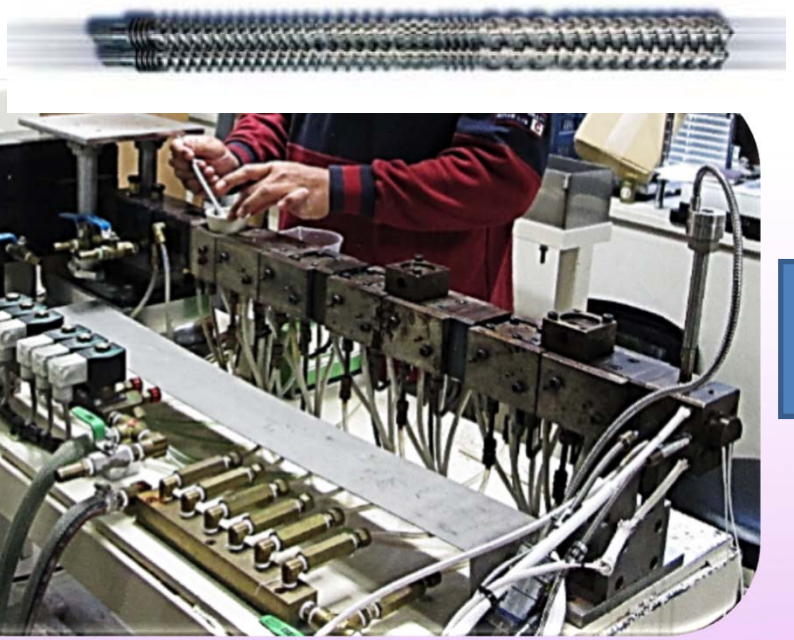
METI Project
Production of CNFs and Their Applications

7 Companies,
2 Institutes

It started from snowing

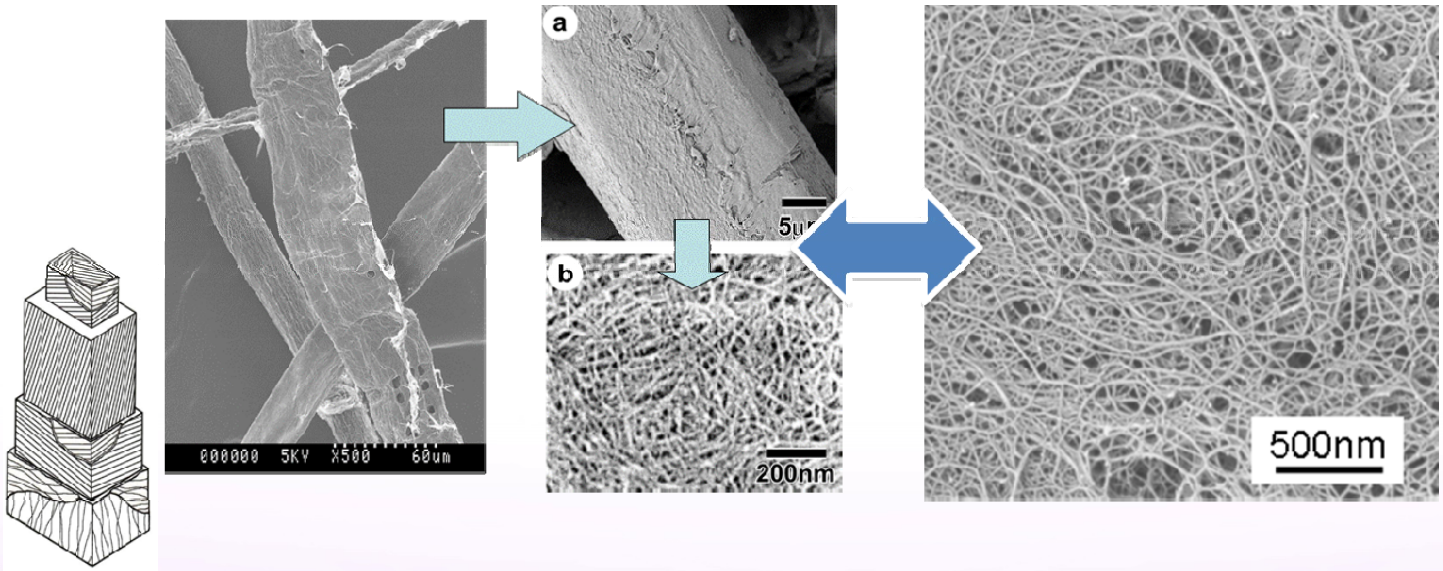


Twin Screw Extruder



Cost!

Pulp: nanostructured fiber



CNF is 5 to 12 Times higher costs than the starting pulp

To produce cellulose nanocomposites for commercial use, the processing of the materials must be developed from laboratory to industrially viable methods. (Oksman et al., Composites A, 2016)

Cellulose nanofiber project for structural application

METI: Ministry of Economy, Trade and Industry
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2005-2006

Nanofibrillation of wet pulp using Twin screw extruder

1st generation

2007-2009

Nanofibrillation of wet pulp and mix into melt polymers and rubber

Hydrophilic CNFs

2nd generation

2010-2012

Nanofibrillation of chemically modified dry pulp and mix into melt polymers

Hydrophobic CNFs

3rd generation

2013-2019

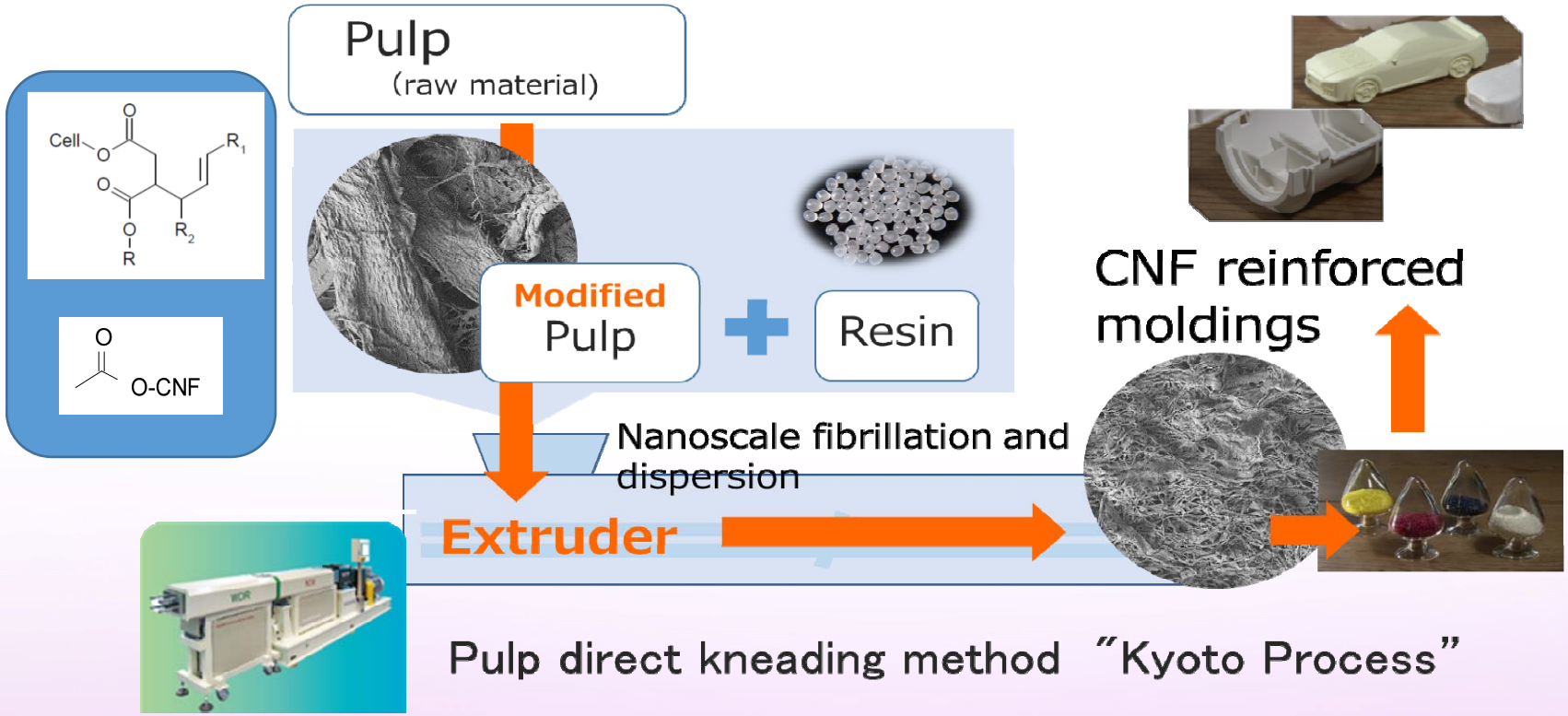
Novel production process for LignoCNF/resin

2016-2019

MOE Project

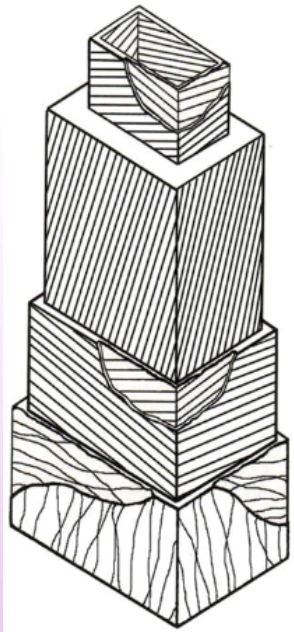
NCV

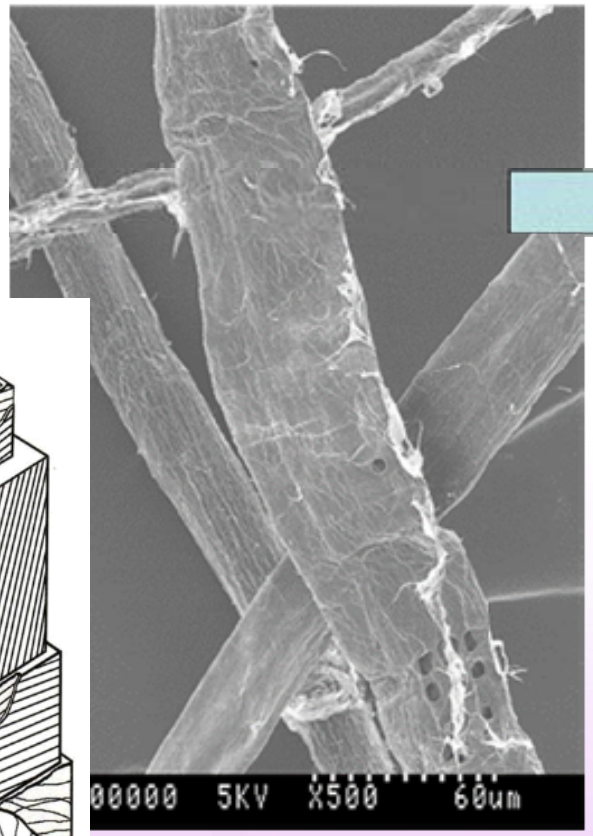
Kyoto Process®

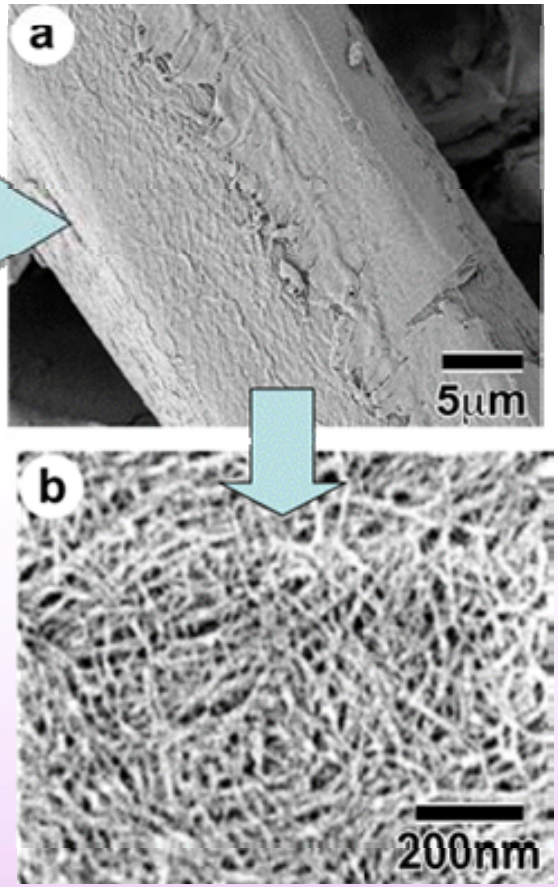


An integrated production process that simultaneously nanofibrillates the pulp and uniformly disperses the CNF in the resins

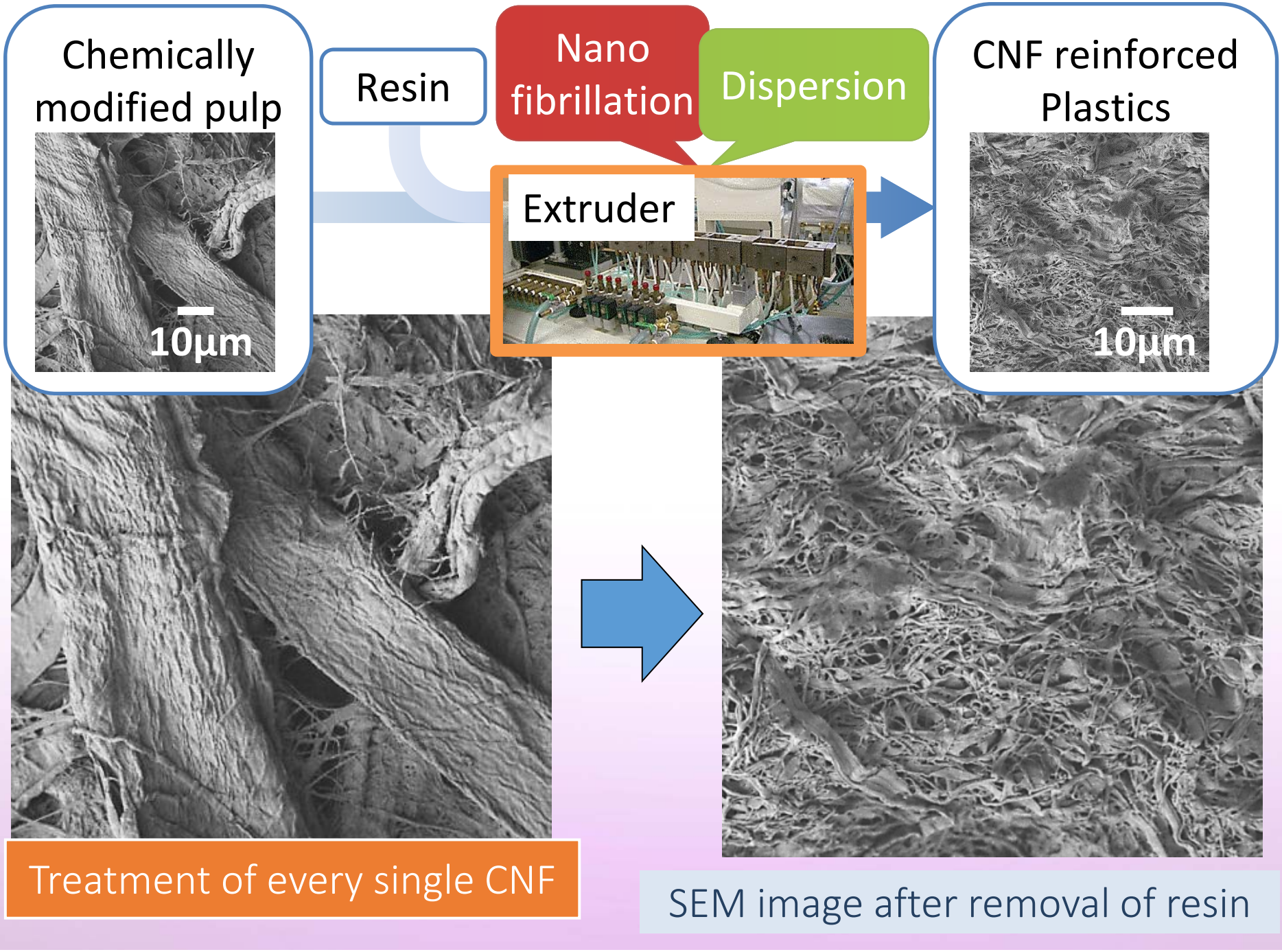
Micro to nanostructure of pulp



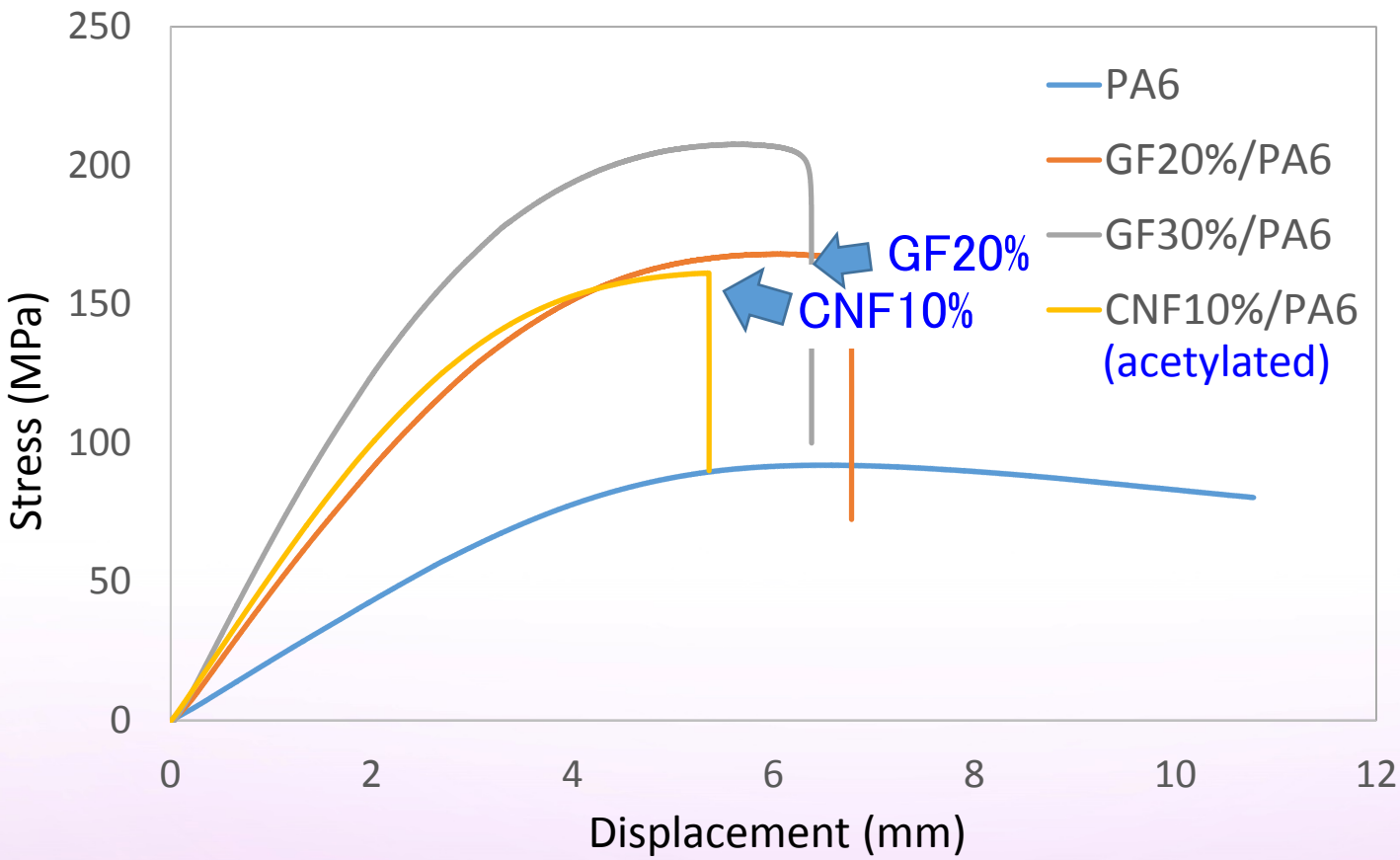




Surface modification of every single nanofiber!


Chemically modified pulp
10μm
Resin
Nano fibrillation
Dispersion
Extruder
CNF reinforced Plastics
10μm
Treatment of every single CNF
SEM image after removal of resin

PA6 composites, molded at 230℃



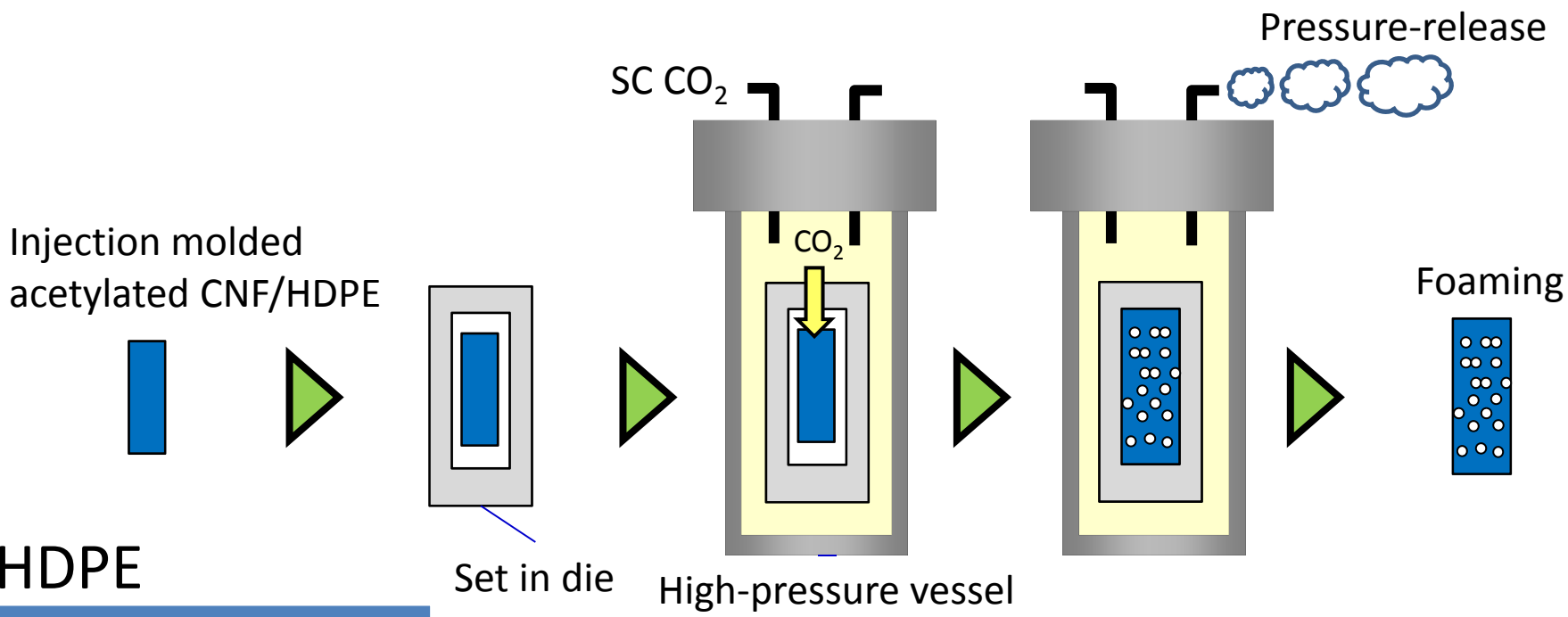
In bending	PA6	GF20%/ PA6	GF30%/ PA6	CNF10%/ PA6
E（GPa)	2.22	4.70	5.92	5.30
Strength (MPa)	91	175.7	210.8	160.0

Acetylated CNF reinforced composites

10wt% CNF

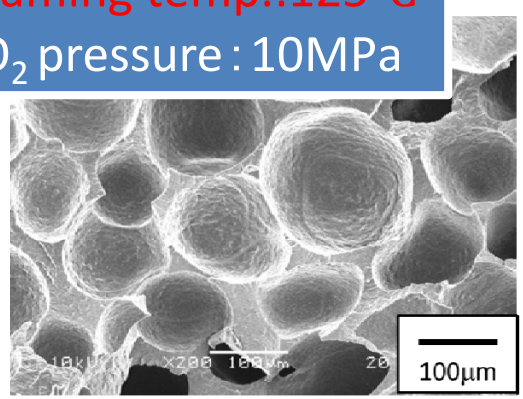
Resin, Melt. temp.	Neat Resin E, Gpa	CNF/Resin E, GPa	Neat Resin Bending strength, MPa	CNF/Resin Bending strength, MPa
PA6, 225°C	2.22	5.34	91	157
POM, 166°C	2.29	5.35	78	131
PLA, 170°C	3.41	6.40	108	119
ABS (200°C)	1.93	3.78	63	88
PA12, 175°C	1.24	3.15	52	89
PBT, 222°C	2.27	4.38	80	113
HDPE, 129°C	1.10	2.39	24	43
PP, 165°C	1.97	4.73	54	95

Foaming: SC CO_2 Foaming of CNF reinforced PA6/HDPE

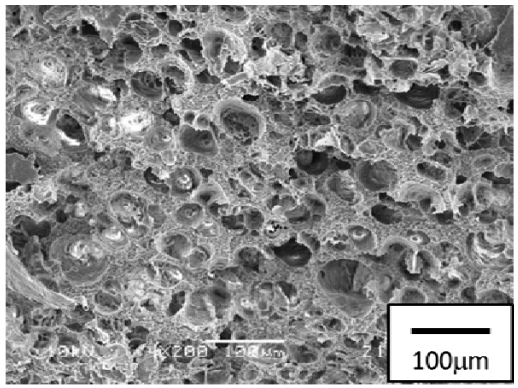


HDPE

Foaming temp.:125°C
CO_2 pressure : 10MPa



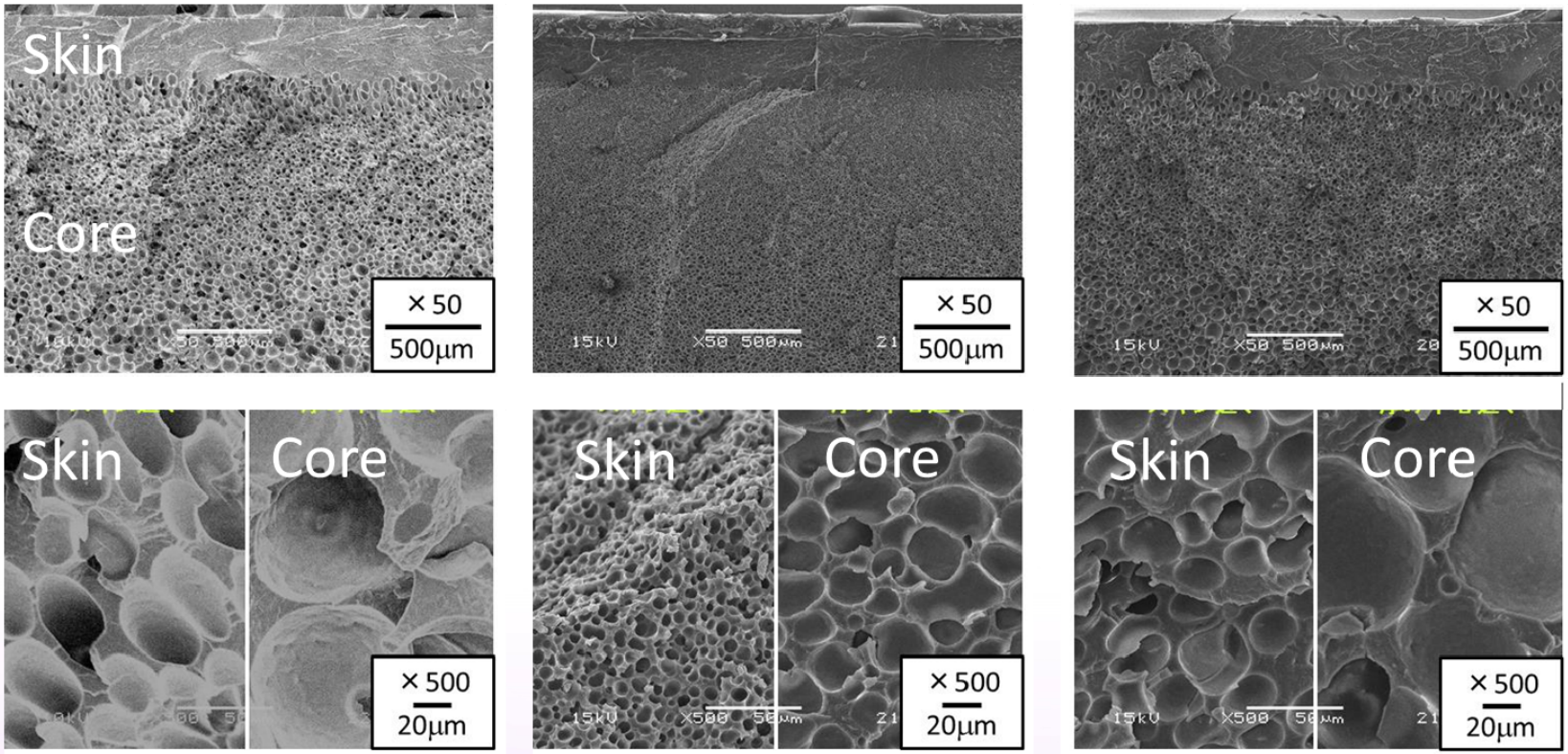
HDPE foam
(SG : 0.46)



Treated CNF/HDPE foam
(SG : 0.44、CNF : 10%)

Itoh, et al., 2012

PA6	CNF/PA6	Inorganic/PA6



PA6 2.5times | Ac-CNF5% 2.5times | Inorganic filler 5% 2.5times

Itoh, et al., 2016

9:16 Unprecedented Ultrahigh Expansion Injection-Molded Polypropylene Foams with Hydrophobic-Modified CNFs
–Masahiro Ohshima, Kyoto University

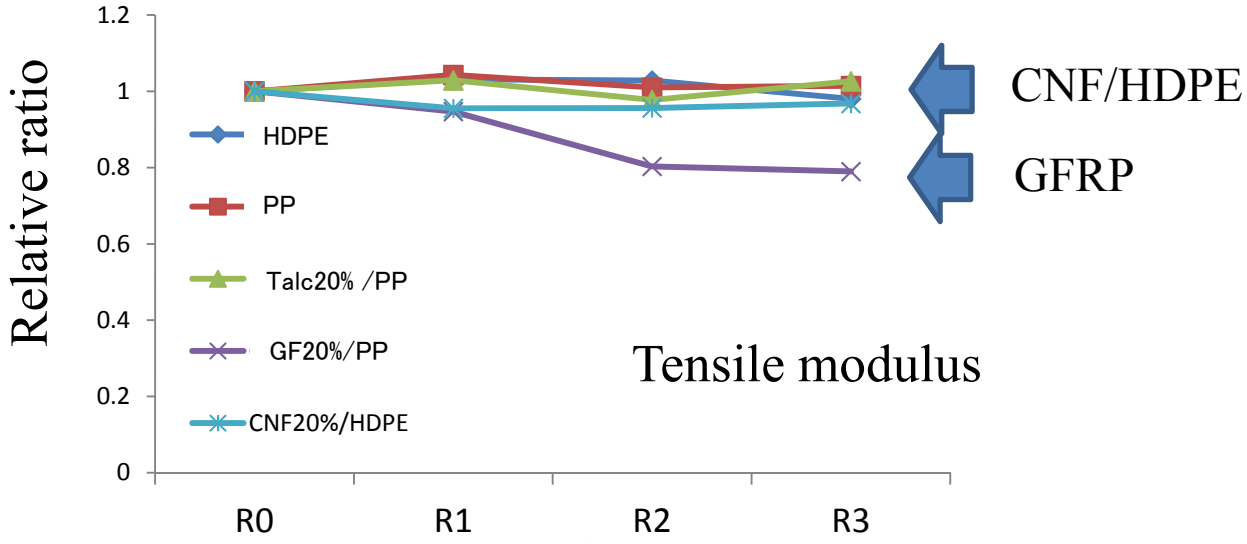
9:38 Development of Lightweight Foamed Plastics with High Mechanical Properties by Using Hydrophobic Modified CNF and Controlling Cell Morphologies
– Akihiro Ito, Kyoto Municipal Institute

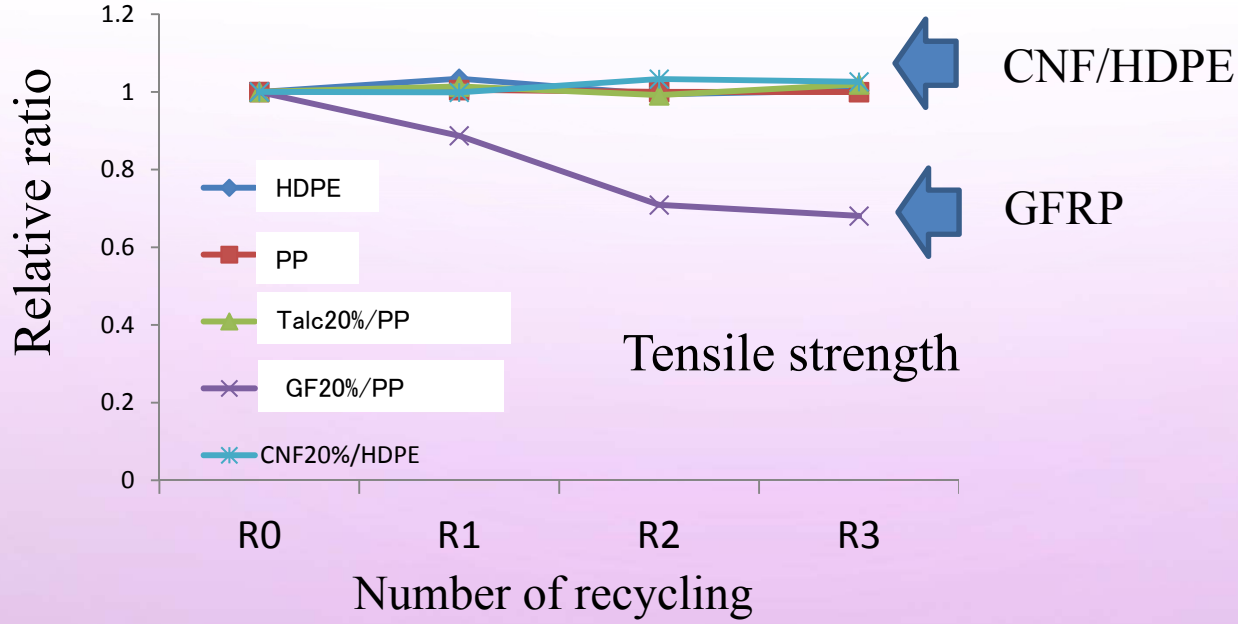
PA6 Engine cover, Injection molded at 280℃

CNF5%, foamed PA6		GF30% solid PA6
4.6 mm (foamed)	・・・ Thickness ・・・	2.75 mm
0.13 Pa m^4	・・ Rigidity (EI, 10mm width) ・・	0.13 Pa m^4
660 g	・・・ Product weight ・・・	960 g

Acetylated cellulose nanofiber reinforced foamed PA6 reduces the weight of engine cover by 30% compared to GF reinforced PA6.
It also improves surface smoothness of molded products.

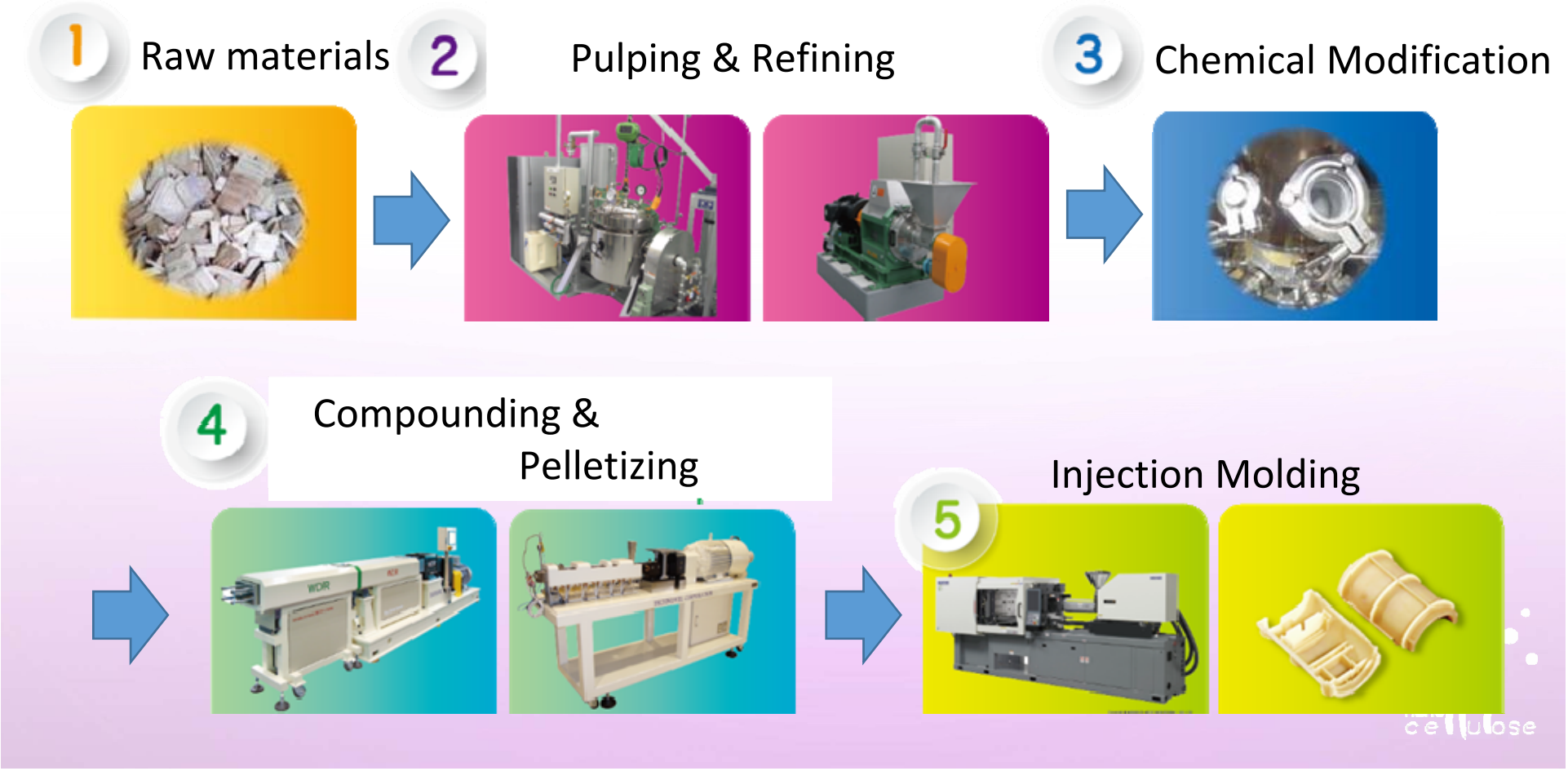
Recycle ability: molding→crushing→molding





Kyoto Process®

The continuous production process of lignocellulose nanofibers reinforced composites



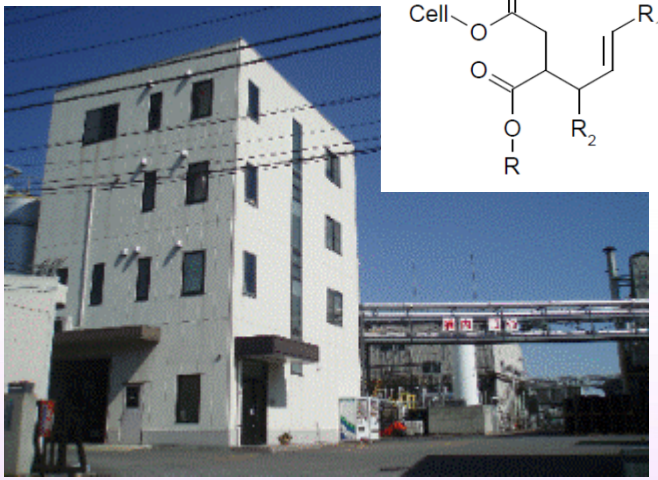
Kyoto Process®

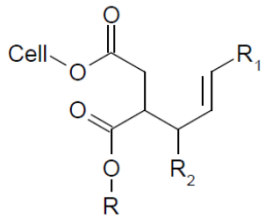
2016

Based on this continuous production process, a test plant with a production capacity of one ton/year of thermoplastic resins with 10wt% CNF starting from wood chips was constructed at RISH.

Commercial plant and test plant using Kyoto Process®

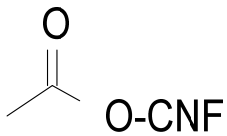
CNF/PP
200 tonnes/year (30% CNF, resin based)





Ryugasaki plant, Seiko
2014 (expanded in 2017)

CNF/PA6, etc.
10 tonnes/year (10% CNF, resin based)



Fuji plant, Nippon Paper Industries, 2017

asics Seiko PMC STARCEL® Kyoto Process®

World's first commercially-sold shoes with midsole made of cellulose nanofiber, a next-generation performance material

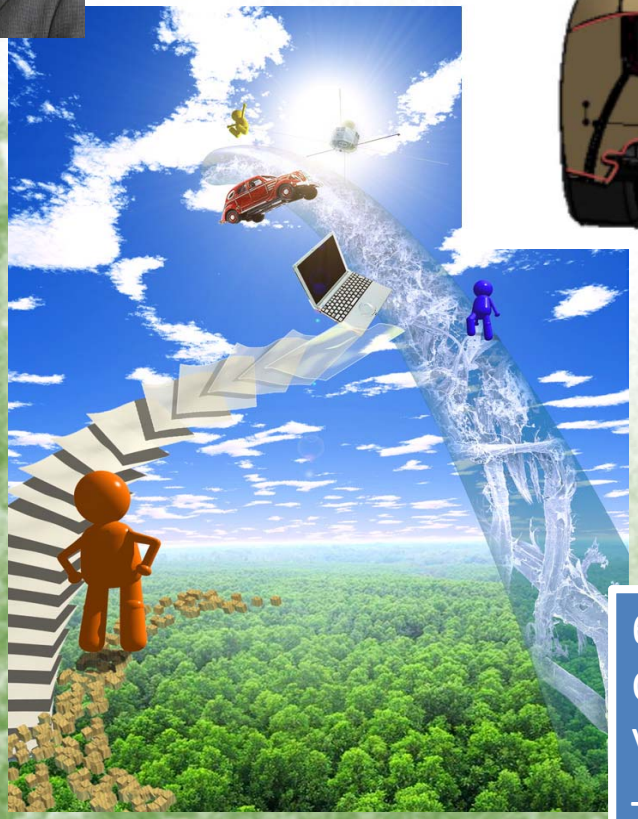
GEL-Kayano 25 High-Performance Running Shoe

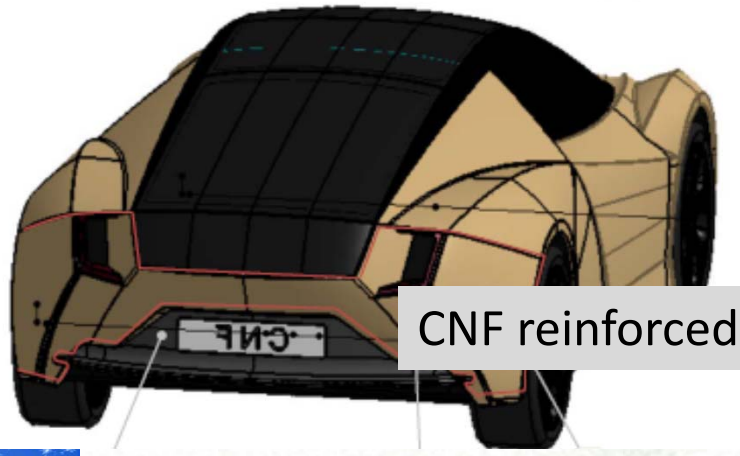
2mn pairs/year → 5mn pairs/year

2018, June 1 press release

NCV: Nanocellulose Vehicle

Dr. Usuki
RISH, Kyoto Uni.

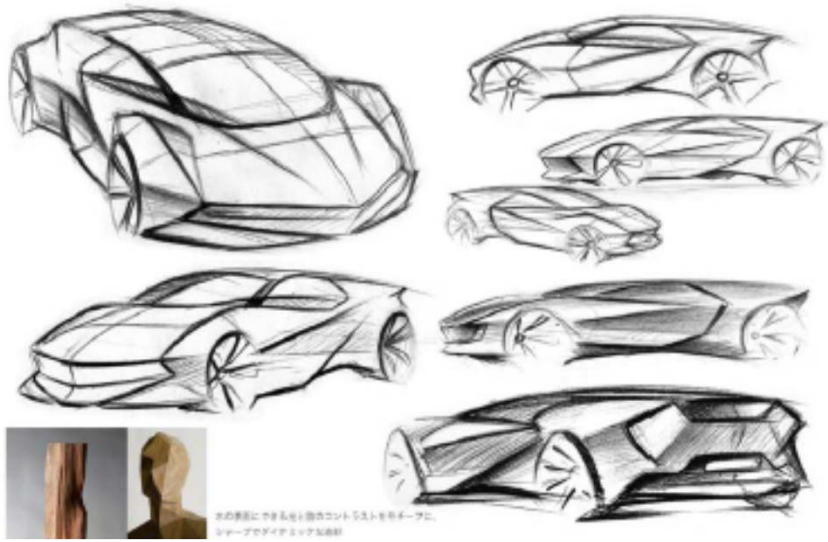


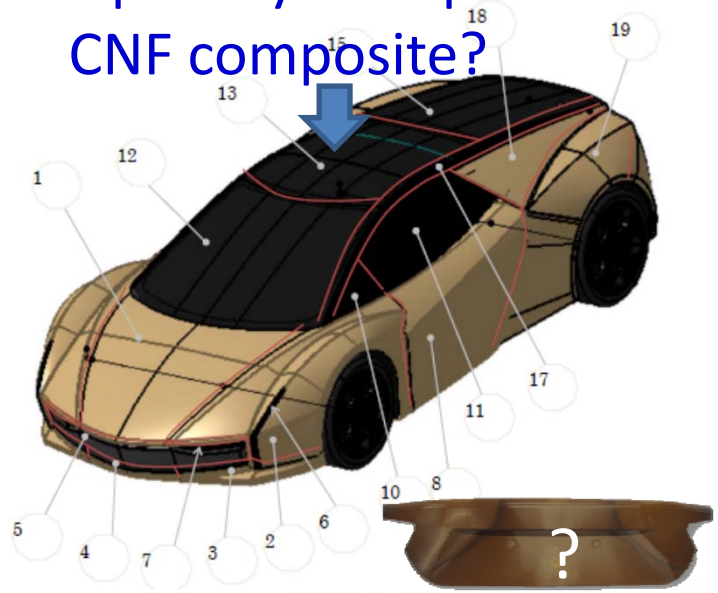


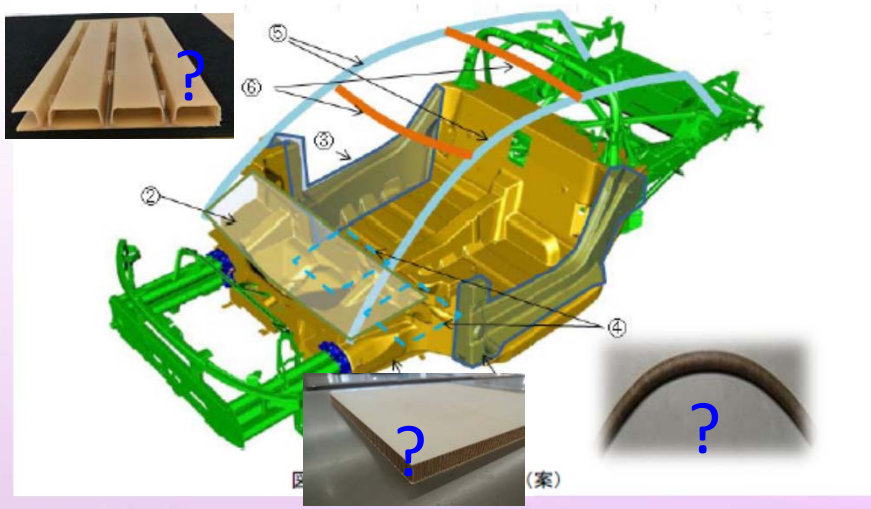
6 June, 8:32-
Overview and Progress of Nano Cellulose Vehicle (NCV) Project
– Naoki Obi, Kyoto University

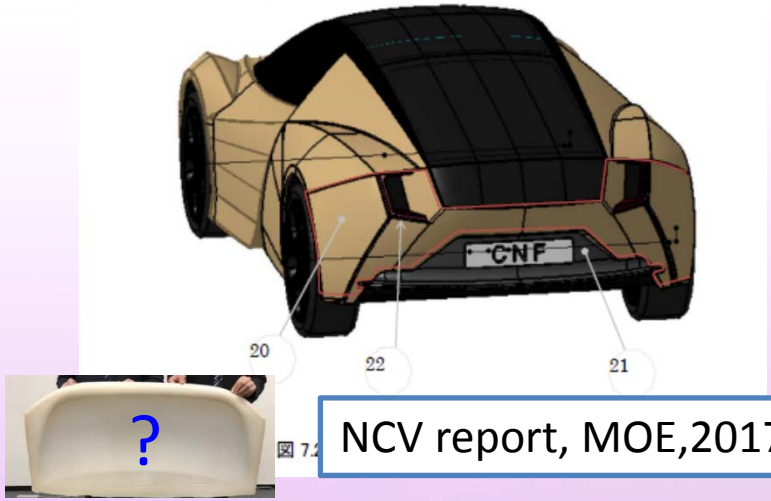
Tentative design of NCV (NanoCellulose Vehicle)

Optically transparent
CNF composite?





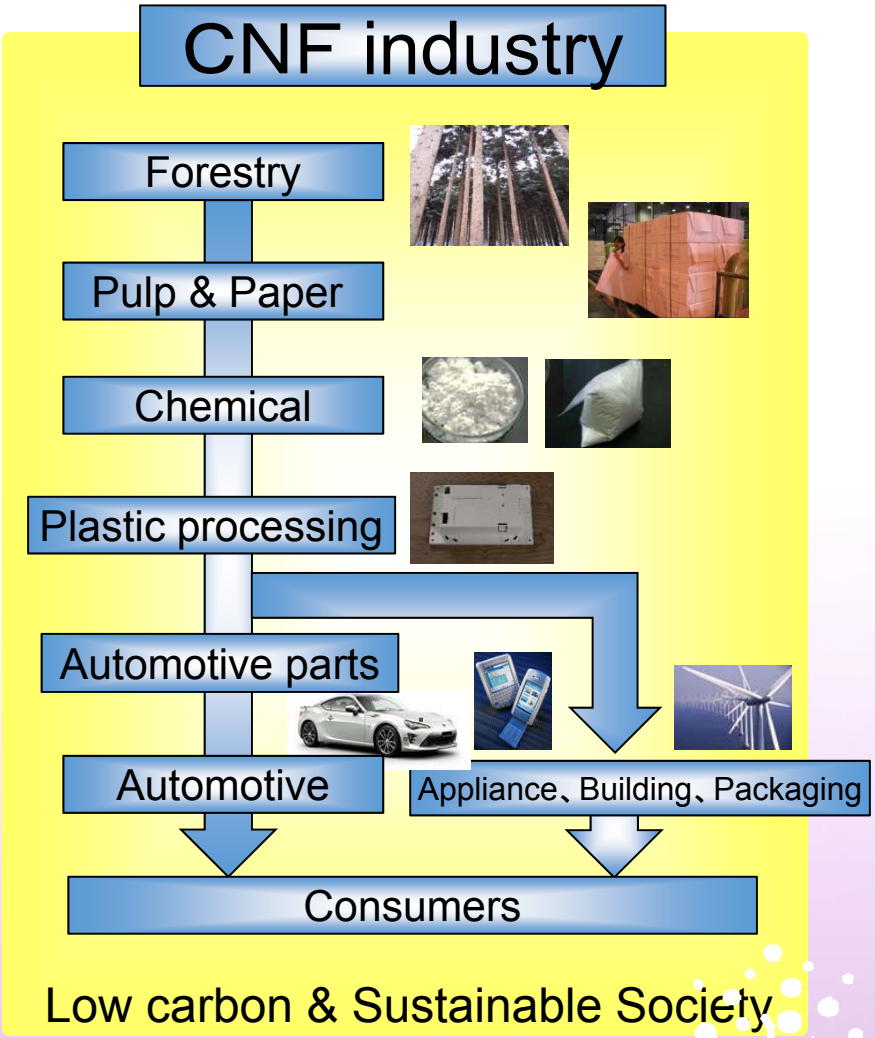




NCV report, MOE,2017

Tokyo Motor Show Oct. 24 – Nov. 4

Toward Japan's unique industrial form in 21st century



This research was conducted as part of METI's Consortium R&D Project for Regional Revitalization; the following NEDO projects: University-Launched Business Creation and Practical Application Research and Development Project, Development of Fundamental Technologies for Green-Sustainable Chemical Process Project, Technology Development of Manufacturing Processes for Non-Edible Plant-derived Chemicals Project; and MOE's Proving, Evaluation, and Verification for Introduction of CNF Materials for Social Implementation-Automotive Field Project.

Thank you for your attention

Thank you

PRESENTED BY:

Hiroyuki Yano

Professor

RISH, Kyoto University