
INTELLIGENT MATERIAL

**ABLE TO ADJUST ITSELF ACCORDINGLY
TO ENSURE THE HIGHEST LEVEL OF COMFORT
& AFFINITY WITH HUMAN BODY**

SMP Technologies Inc.



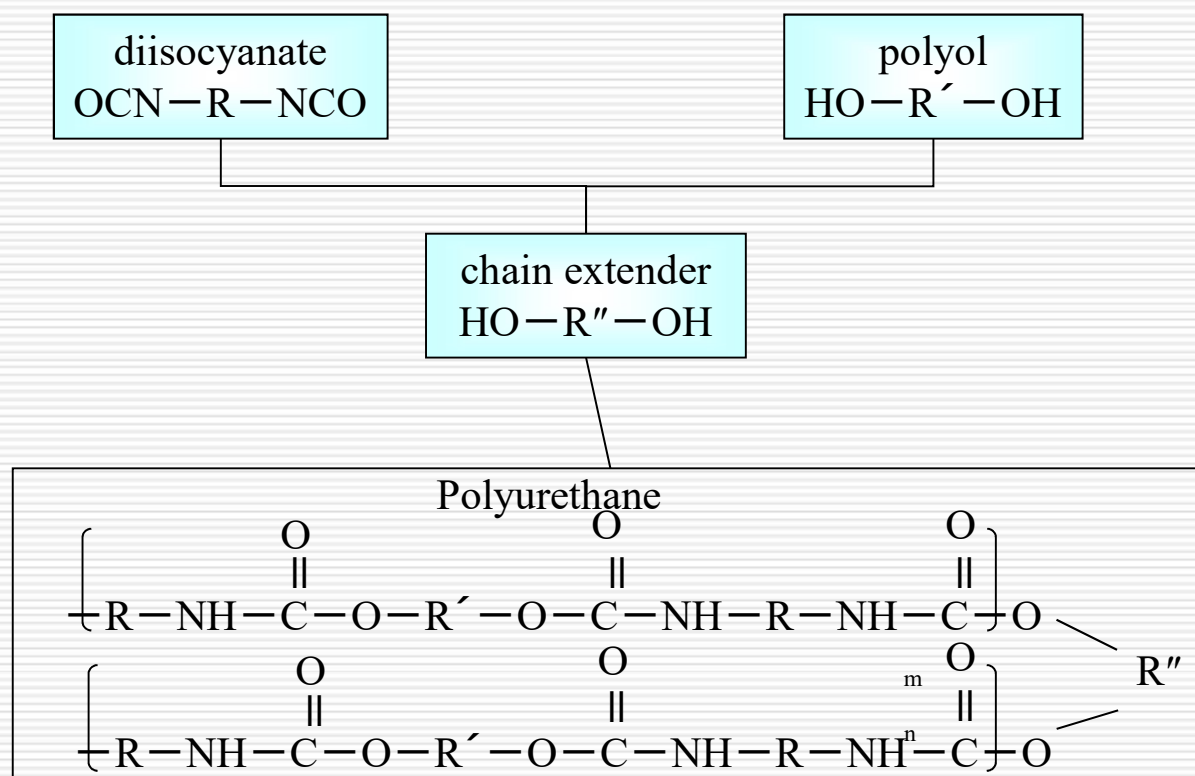
Introduction

Shape Memory Polymer(SMP)

“DiAPLEX” is the newly developed intelligent material which changes its features according to temperature. (Mitsubishi Heavy Industries Patented.)

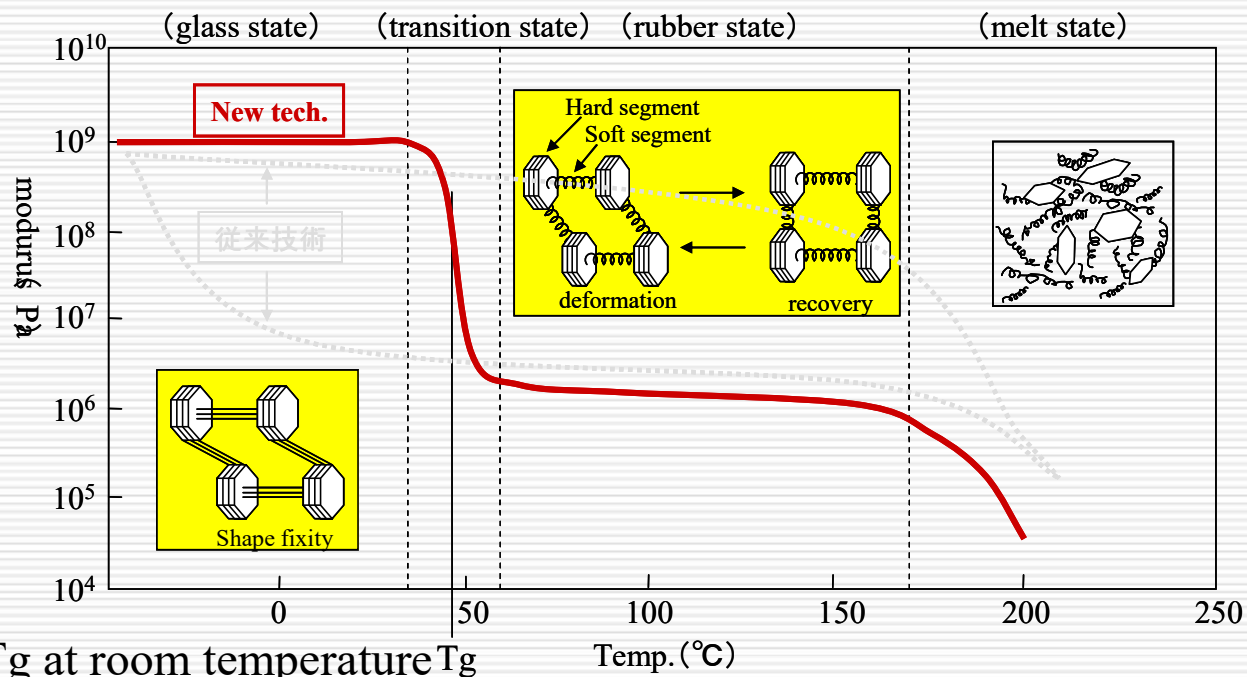
1. A large reversible change in elastic modulus across the **glass transition temperature (T_g)** is unique to **SMP**.
2. A wide range of new applications for the **SMP** materials are expanding in such fields as a space exploration, medical, clothing, food packaging , health care, toys, and more.

SMP based on Polyurethane



SMP designed by
chemical components,
molecular weight,
mixing ratio.

What's SMP

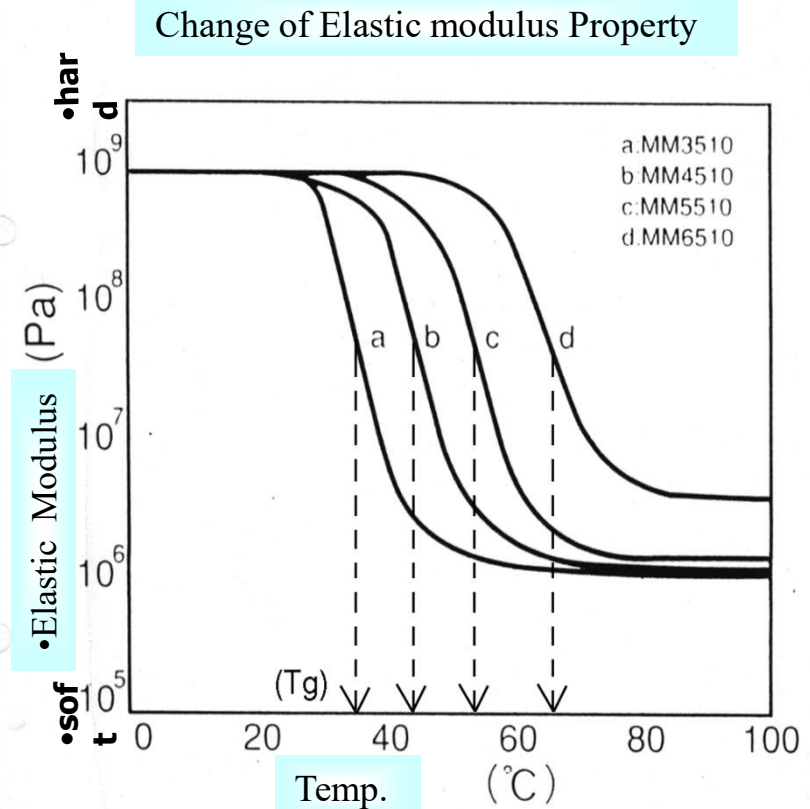


- Tg at room temperature Tg
- Narrow transition state
- Drastic change of properties at transition state

Property of DiAPLEX(1)

□ Elastic Modulus Property

- The elastic modulus changes largely at the temperature below(hard state) and above (soft state) the glass transition temperature (T_g)
- T_g setting of the material can be designed at the desired temperature between $-40\text{ C} \sim 90\text{ C.} (-40\text{F} \sim 194\text{F})$



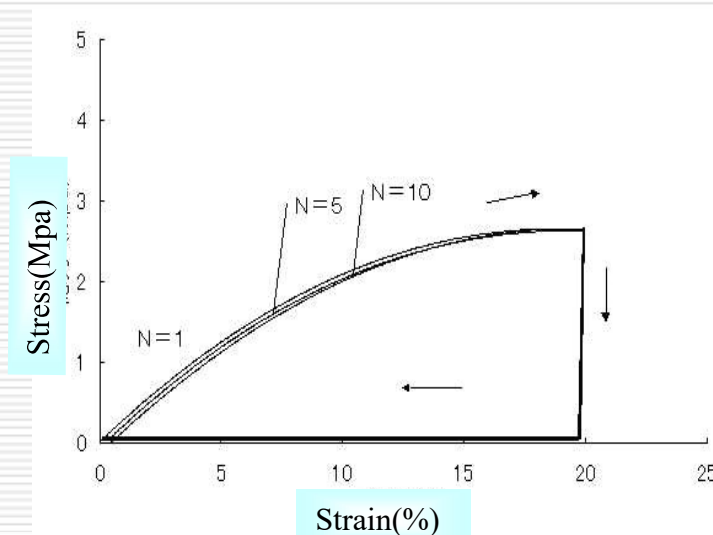
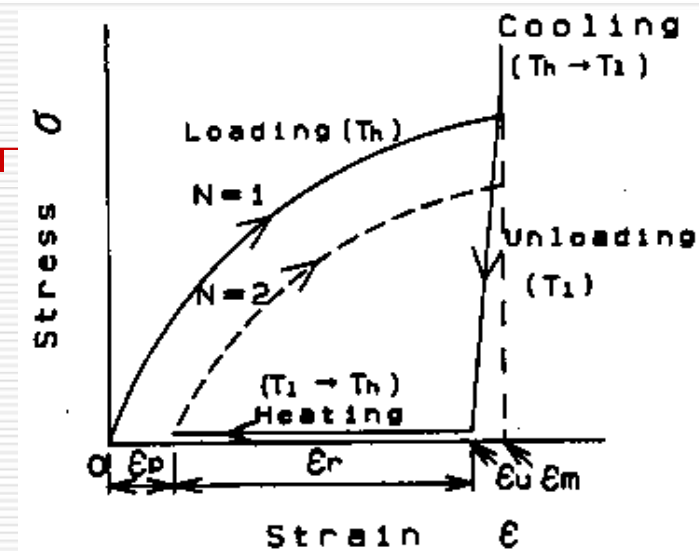
Property of DiAPLEX(2)

□ Shape recovery and rigidation

- At a temperature higher than the T_g , Shape **memory polymer (SMP)** can easily change form by applying low stress.

To remove the external force at the low temperature ($<T_g$) the formed shape is retained.

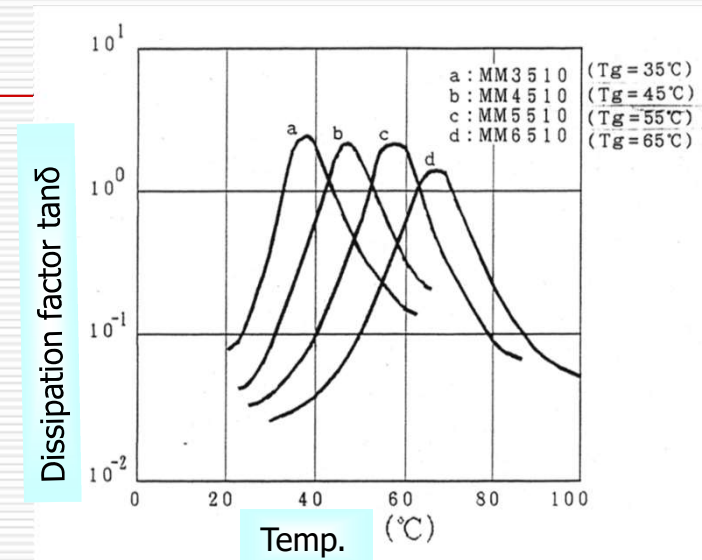
- To heat **SMP** with no external force from a low temperature to a temperature higher than T_g . It eliminates the strain, resulting in recovery of its original shape.
- **SMP** allows the maximum strain can be applied up to **400%**.



Property of DiAPLEX(3)

□ Energy dissipation property

- Energy dissipation factor defined by $\tan\delta$ change with the temperature and becomes very large compared to ordinary elastic material. (These material's $\tan\delta$ are in the range of $0.2 \sim 0.4$)
- The $\tan\delta$ of the **DiAPLEX** in the transition region is very similar to that of human skin, providing a natural smooth feel when **SMP** is used in region touched by hand.



Dissipation factor ($\tan\delta$) of human body

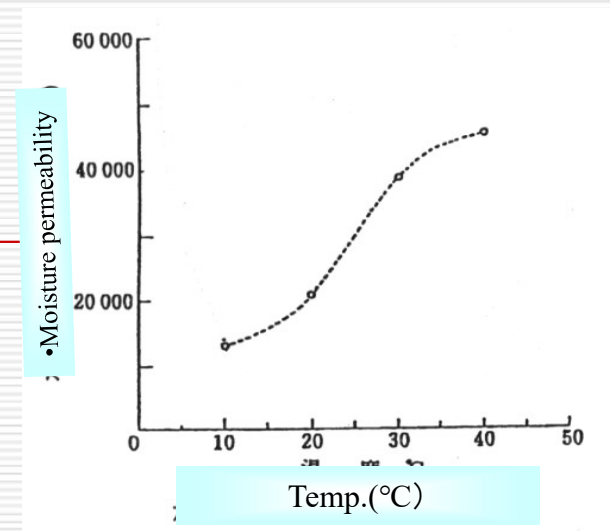
Lower arm	0.43
forehead	0.51
Palm	0.41

高橋元次 高分子 33 卷 1 9 8 4

Property of DiAPLEX (4)

Diaplex membrane

- Gas permeability property depending on temperature.
 - DiAPLEX membrane has large change in moisture permeability depending on temperature change.
 - Above **T_g**, high moisture permeability, below **T_g** small moisture permeability is realized.



Dia of passage in membrane and molecular dia

Size of path and transmitting substance

Path Size	Type Of membrane						Variety of particle size
1 μm	Porous membrane						Staphylococcus (0.8 μm)
0.5 μm							Typhoid bacillus/cholera bacillus (0.6 μm)
0.2 μm							Smallpox virus (0.21 μm)
0.1 μm							Influenza virus (0.08 μm)
0.05 μm							
0.02 μm							Gene (0.02×0.13 μm)
0.01 μm (100 Å)							Polio virus (0.012 μm)
50 Å	Non Porus membrane						Hemoglobin (30×50 Å)
20 Å							DNA (20 Å)
10 Å							Glutamine (5×8×16 Å)
5 Å							H ₂ O (3.5 Å)
2 Å							H ₂ (2.3 Å)

Other properties of DiAPLEX

☐ **DiAPLEX can be applied to your body.**

- DiAPLEX has been authorized by Japanese Ministry of Health and Welfare as follows;
- Regulation standard on Food and Food additives
- Food Hygiene law
- Japanese Ministry of Health and Welfare notice No.370 in 1959.
- The pharmaceutical affairs law No.145 in 1960, Article14, section 1.

☐ **Molding Ability of DiAPLEX.**

☐ **Forming techniques include;**

- Injection ,extrusion, and other ordinary forming techniques.
- Material types available are Pellets, solution, foam, micro-beads ,fiber.

SMP Materials

Index	Material	Molding	Packing unit
MM	Pellet	Injection • Extrusion	20Kg Bag
MP	Resin & Hardener	Potting	1Kg Can × 2
MS	Solution	Coating	4Kg Can

MM type



射出・押出(Molding)

MP type



注型(Potting)

MS type



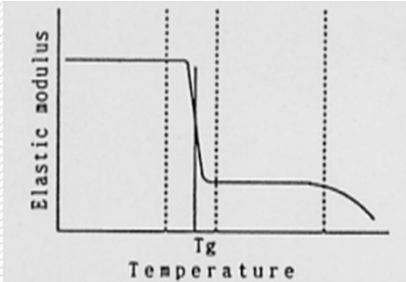
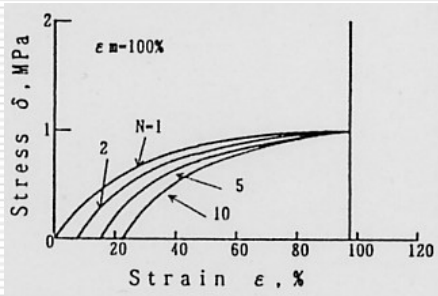
溶液(Solution)

MB type

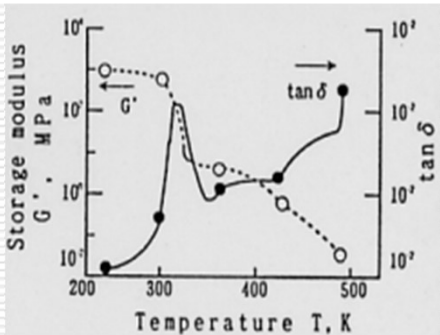
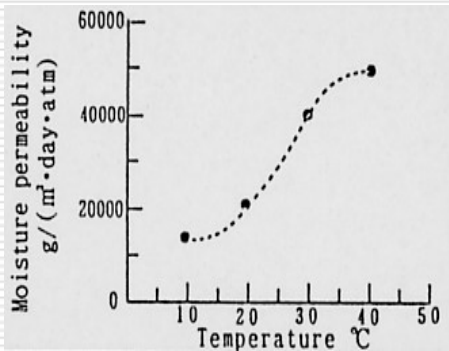


微粒子(Microbeads)

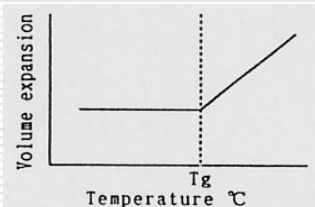
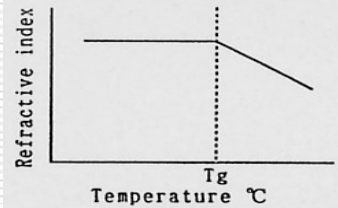
Properties and Applications of SMP

PROPERTIES		APPLICATIONS	
		Developed & Applied	Under Developing & Ideal Phase
Modulus	 <p>The graph shows the Elastic modulus on the y-axis and Temperature on the x-axis. A vertical dashed line marks the glass transition temperature T_g. The modulus is high and constant before T_g, then drops sharply to a lower, constant value after T_g.</p>	<ul style="list-style-type: none"> • Autochoke for Engine • Intravenous Cannula 	<ul style="list-style-type: none"> • Pressure sensitive switch
Shape Memory Property	 <p>The graph shows Stress δ, MPa on the y-axis (0 to 2) and Strain ϵ, % on the x-axis (0 to 120). Multiple loading curves are shown for different values of N (1, 2, 5, 10). The curves start at the origin and rise towards a plateau. A vertical line at $\epsilon = 100\%$ indicates the maximum strain. The curves for higher N values reach higher stress levels at lower strains.</p>	<ul style="list-style-type: none"> • Spoon, scissors, tooth brush and kitchen knife for Handicapped • Wig net • Dole Hair • Water-proofing film tape bandage • Printing for leather • Transforming photo to canvas • Surgical cast • Lining of Inner Pipe • Artificial Nail • Toys • Development structures for outer space • Readily decomposable Fasteners 	<ul style="list-style-type: none"> • Memory Material for CD • Artificial Muscle • Ski insole • Shape Memory for natural fiber • Shrink Film • IC Tag

Properties and Applications of SMP

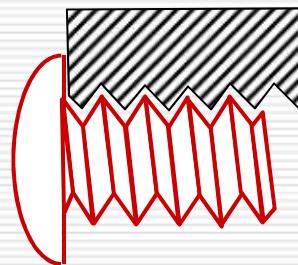
PROPERTIES		APPLICATIONS	
		Developed & Applied	Under Developing & Ideal Phase
<u>Damping Property</u>	 <p>Storage modulus G', MPa</p> <p>Temperature T, K</p> <p>$\tan \delta$</p>	<ul style="list-style-type: none"> •Lingerie generally (Bra cup) •Glasses parts (Nose pad, ear pad) •Damping Material •Intravenous Cannula •Inner Support of Mask •Cosmetics Foundation •Insole 	<ul style="list-style-type: none"> • Lens •Artificial Blood Vessel
<u>Gas Permeability</u>	 <p>Moisture permeability $g/(m^2 \cdot day \cdot atm)$</p> <p>Temperature $^{\circ}C$</p>	<ul style="list-style-type: none"> • Sports outfit •Water-proofing film tape bandage •Humidity Controlled Film •Diaper Cover •Water Proof Shoe •Sanitary Shorts •Wrapping Film •Amphibious clothes •Night cover for showcase 	<ul style="list-style-type: none"> •Artificial Skin •Gas Separator

Properties and Applications of SMP

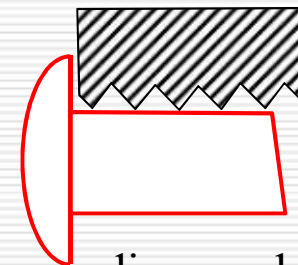
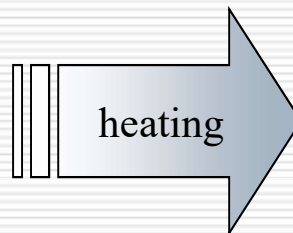
PROPERTIES		APPLICATIONS
		Under Developing & Ideal Phase
<u>Volume Expansion</u>	 <p>The graph shows Volume expansion on the y-axis and Temperature °C on the x-axis. A horizontal line represents the material's state before the glass transition temperature (Tg). At Tg, indicated by a vertical dashed line, the material undergoes a sharp increase in volume expansion, shown by a steep upward-sloping line.</p>	<ul style="list-style-type: none"> • Thermo sensor • Inflatable material • Panel for Display
<u>Recovery Force</u>		<ul style="list-style-type: none"> • Binding Element • Clamping pin • Self-deployable structures
<u>Refractive Index</u>	 <p>The graph shows Refractive index on the y-axis and Temperature °C on the x-axis. A horizontal line represents the material's state before the glass transition temperature (Tg). At Tg, indicated by a vertical dashed line, the material undergoes a sharp decrease in refractive index, shown by a downward-sloping line.</p>	<ul style="list-style-type: none"> • Lens • Thermo sensor • Optical Fiber
<u>Dialectic Constant</u>		<ul style="list-style-type: none"> • Thermo sensor

Example of sophisticated applications (1) Fastener-1

Easy disassemble using SMP by heating



fastened



disassembled

Example of sophisticated applications (1)

Example of sophisticated applications (1) Fastener-2

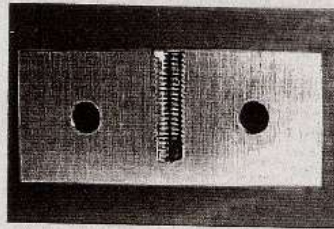


Figure 3. SMP Screw Post Forming Jig.

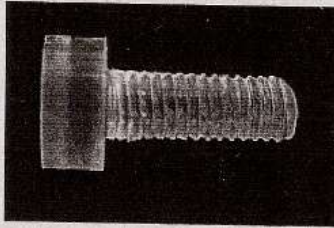


Figure 4. SME-SMP Screw after Post Forming / Jig.

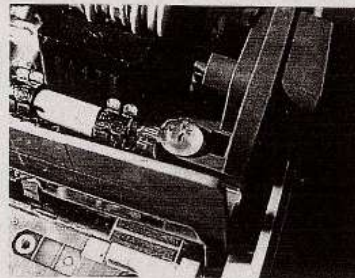
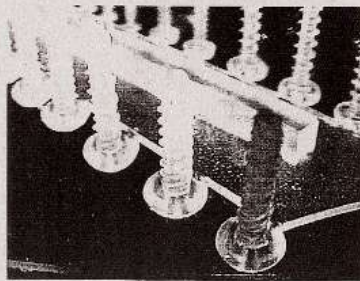


Figure 5. Concept SME-SMP Screw in a Product Assembly.

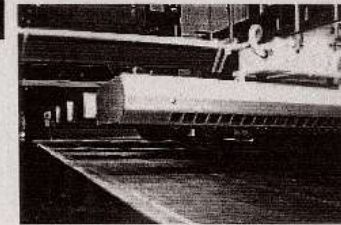


Figure 6. Infrared heaters over conveyor system for the mechanical property loss SMP experiments.

Example of sophisticated applications (1) Fastener-3

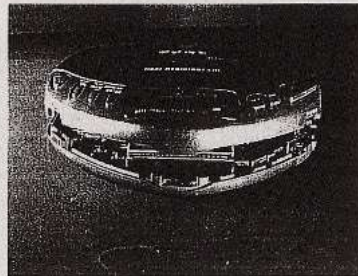


Figure 7. Successful active disassembly of the macro assembly of the Sony CD player.

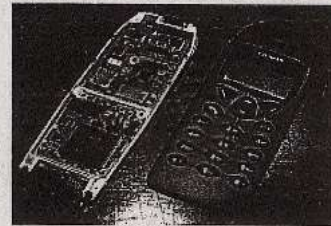


Figure 8. SME-SMP Nokia 6110 after successful ADSM.

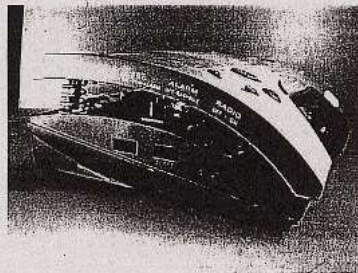


Figure 8. Successful active disassembly of the macro assembly of the Philips digital FM audio.

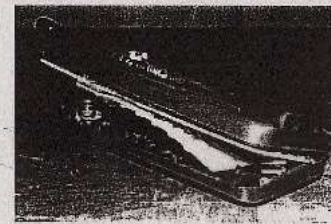
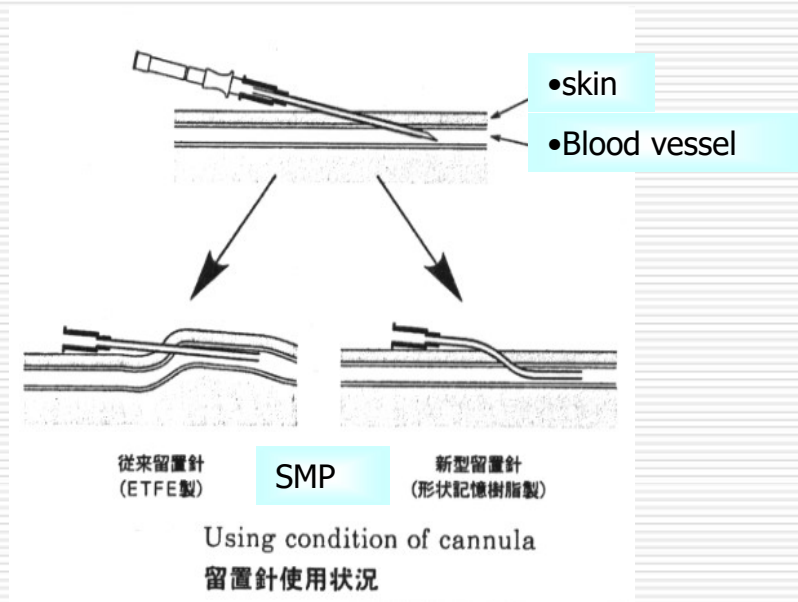
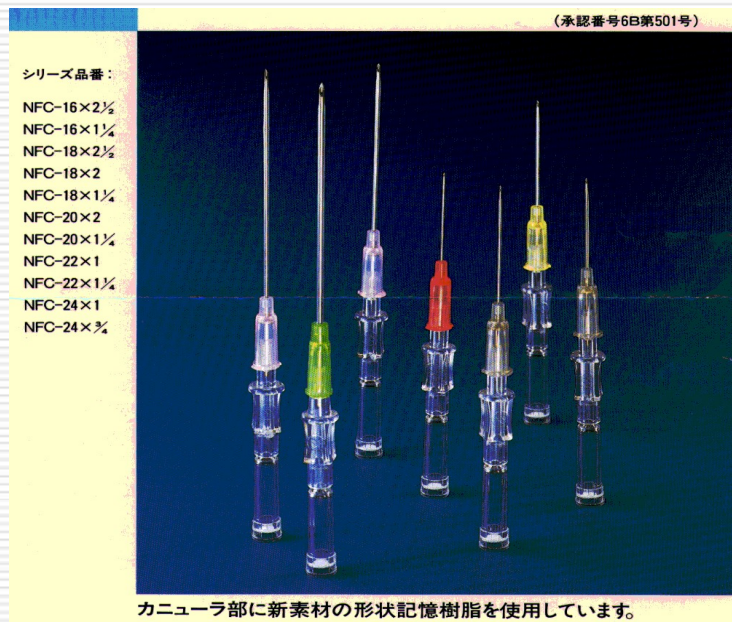


Figure 9. SME-SMP Motorola Populus after successful ADSM.

Example of sophisticated applications (2)

Intravenous syringe cannula

When injection is performed, it keeps its rigid state. Once under the Skin, it becomes flexible, resulting in greater comfort.



From Nipro

Example of sophisticated applications (3)

- ❑ **Barrier-free Utensil** from properties (1), (2)
- ❑ The physically challenged can perform basic necessities more easily.
- ❑ Examples; eating, brushing teeth, scissors and razor using with the unique shaping characteristics of SMP.



Spoon sold by Aoyoshi Co.,Ltd

Example of sophisticated applications (4)

- ❑ **Ankle supporter** from properties (1), (2)
- ❑ A guard part utilizing FR-SMP(Fiberglass Reinforced Shape Memory Polymer) is available for transformation by heating.
- ❑ It can be changed into a shape fitting an ankle easily.

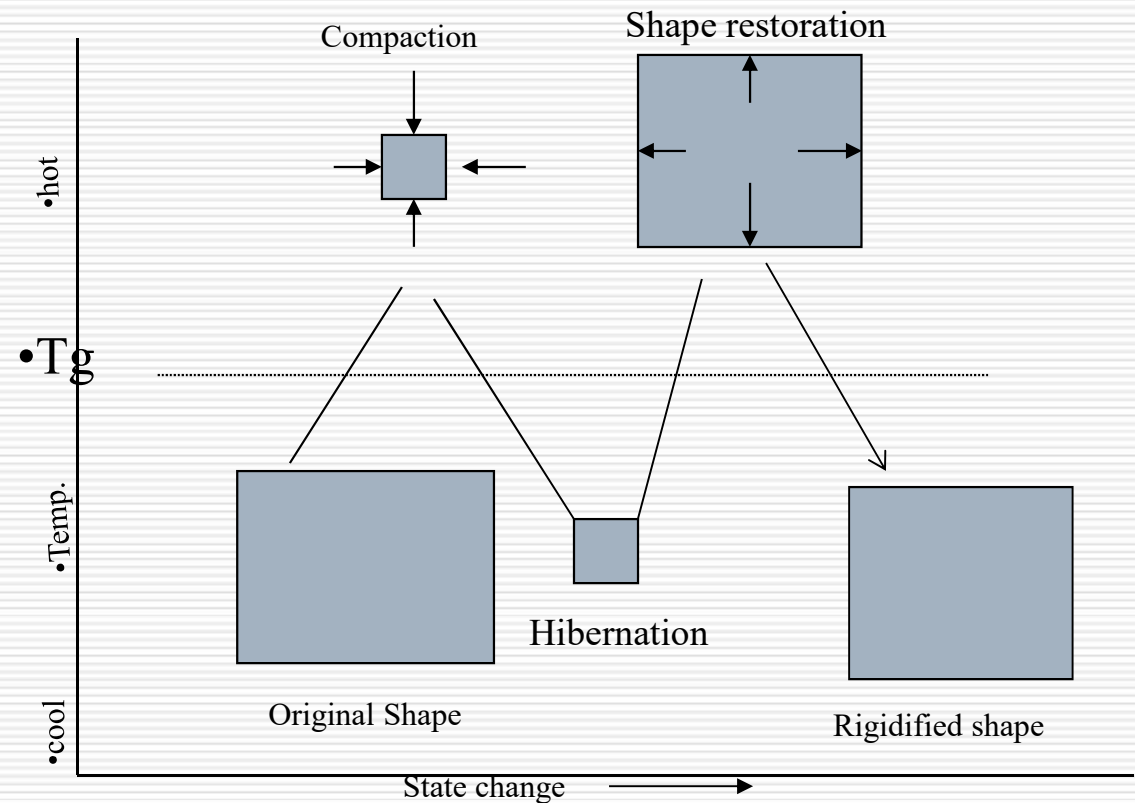


From Nippon Sigmax Co., Ltd.

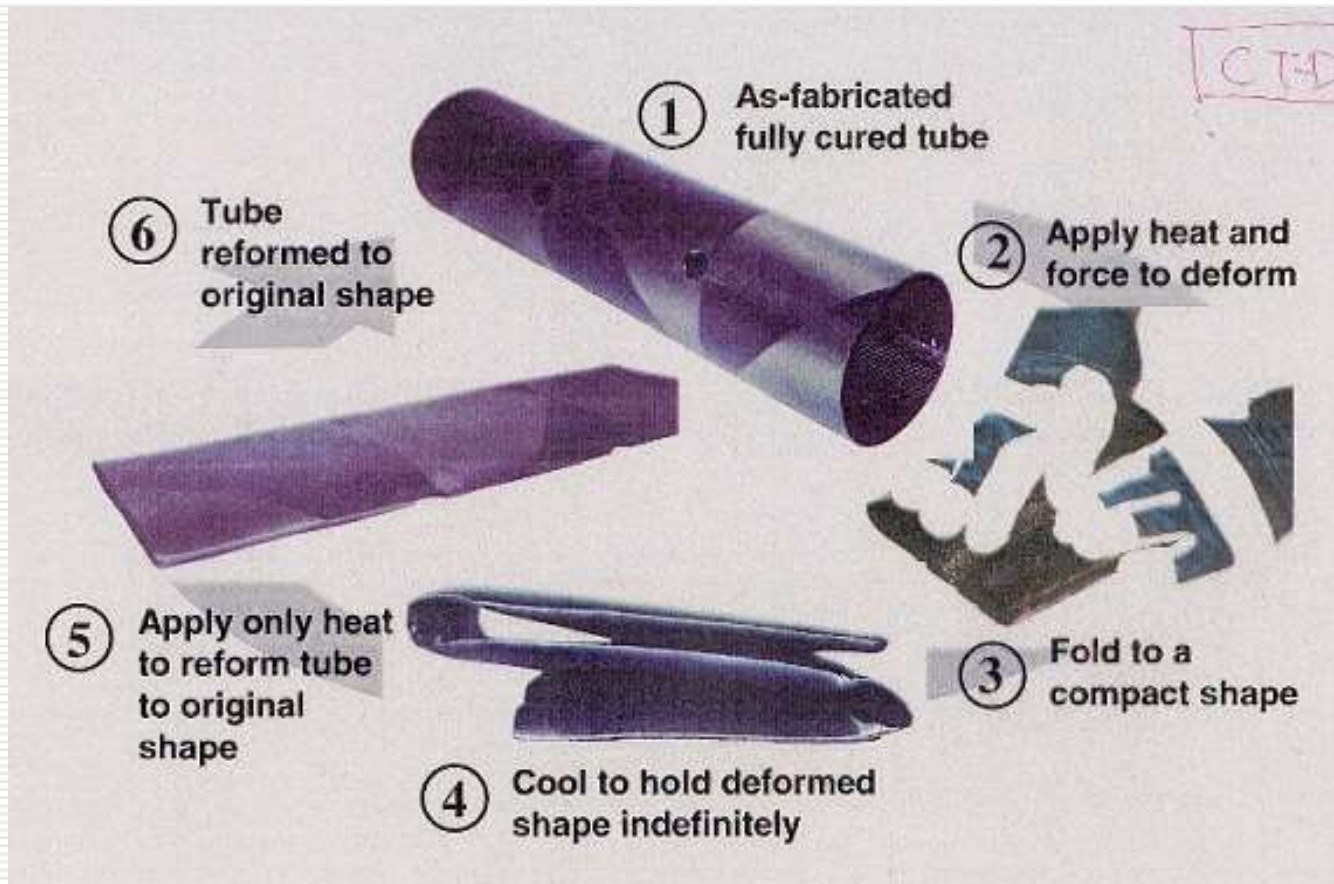
Example of sophisticated applications(5)

Inflatable Material for Aero-space Applications

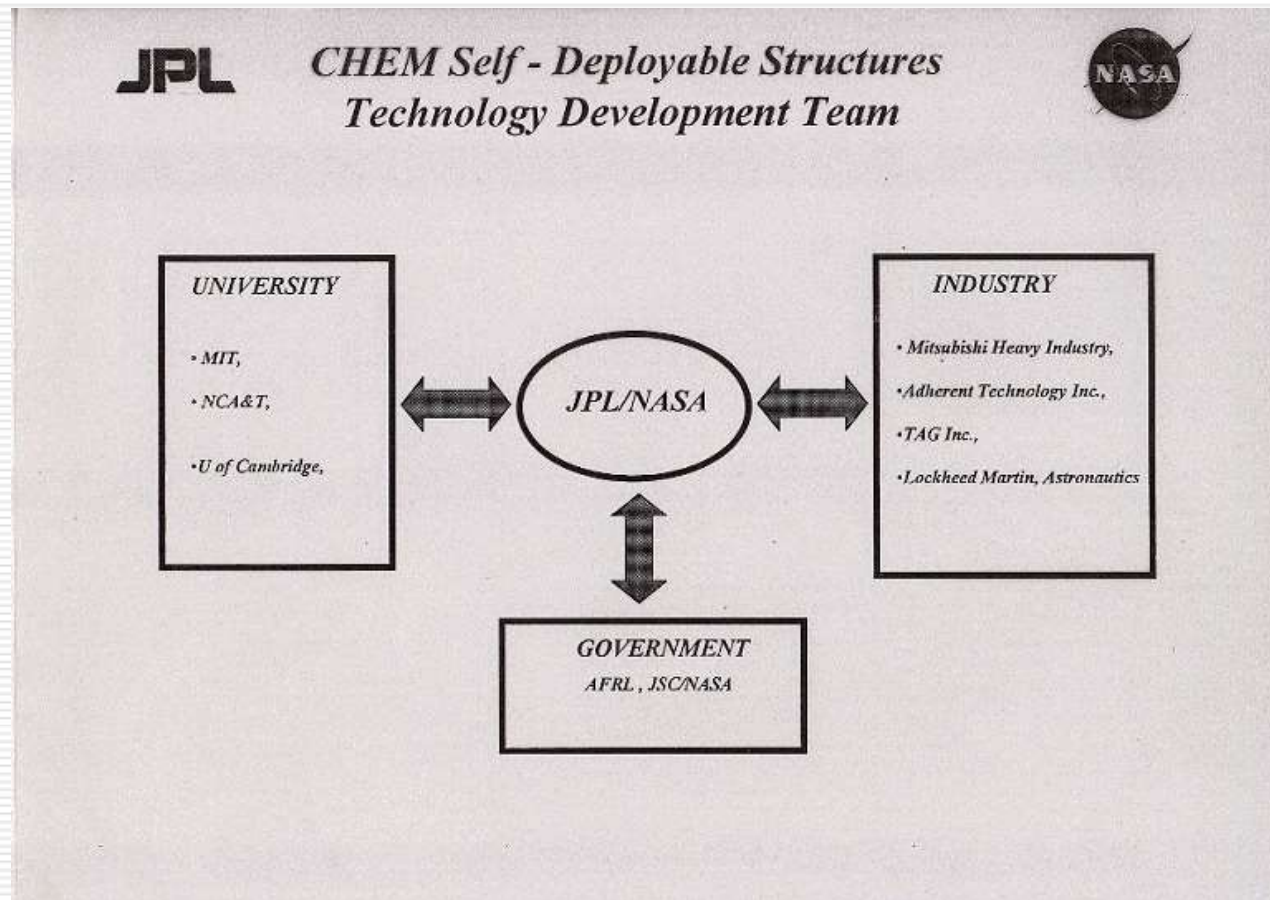
In foam structure,
full/stowed volume ratio
of 30 ~ 40 has been
realized.



Example of sophisticated applications (5)



Example of sophisticated applications (5)



Example of sophisticated applications (6)

☐ Doll hair

Denier of the filament of
50d,70d and more are available
2.Any color is available

•1



2



•3



•4



•The doll hair is now on the market from takara toy

Example of sophisticated applications (7)

□ Bra-Cup

utilizing SMP-Foam which has large dynamic $\tan \delta$ and J-curve(stress-strain curve)

There behavior are very similar to human body.



Example of sophisticated applications (8)

□ Nose guard for eye Glass

utilizing injection molded SMP

This nose guard has the same mechanical properties to nose

エスエムビー・パッド
SMP-Pad
形状記憶樹脂パッド

体温で変形していくので
鼻にピッタリと馴染んでいきます。

標準カーブ
よくあるカーブ
時々あるカーブ
めったにないカーブ

標準パターン
側面カーブの大きいパターン
側面に凹凸があるパターン

- SMP-Padは、SMP(形状記憶樹脂)で作られています。
- SMP-Padは、人の体温(約36度)で変形し始めます。
- SMP-PadのサイズはS、M、Lの3タイプです。
- このパッドは、ボックスタイプ(ネジ止め)です。
- このパッドは、フィッティング用としてご利用下さい。
- この材料は介護医療用にも使用されています。

注意：温度に反応しますので涼しい場所で保管して下さい。

体温で変形し始める

サイズ：S/M/L

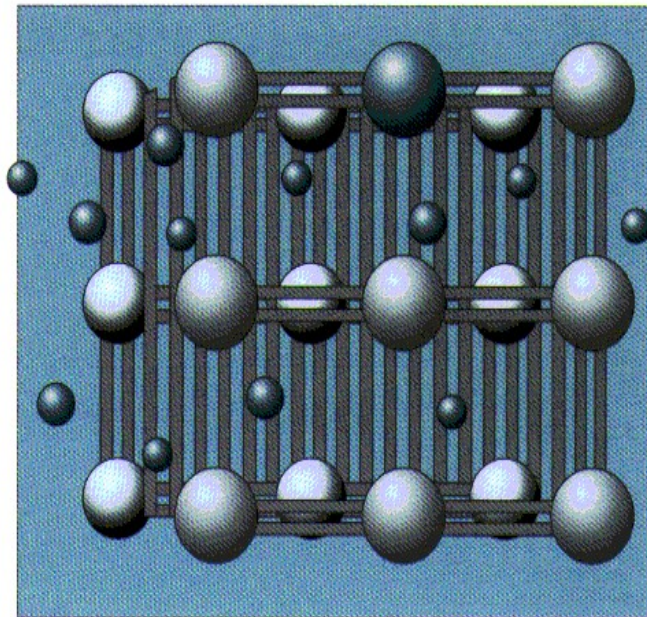
Sサイズ Mサイズ Lサイズ

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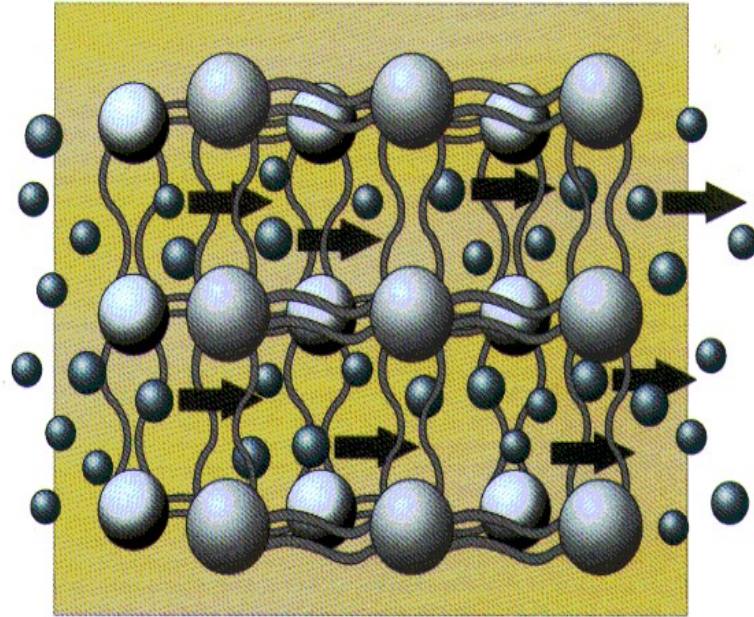
エスエムビー株式会社
〒016-0033 岩手県江刺市中野町49-7
TEL:0778-51-0807 FAX:0778-52-9308
http://www.smt.jp/ E-Mail:kakaku@smt.jp

Example of sophisticated applications (9)

- Micro-Brownian motion allows the nonporous polymer membrane to transfer molecules of water vapor



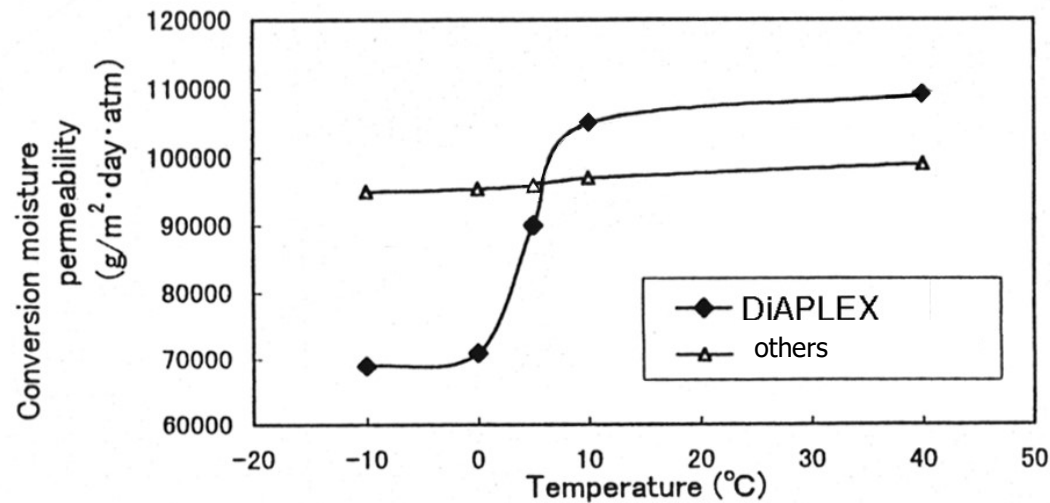
•At low temperature the polymer molecular chains stop the transfer of water vapor.



•As temperature increase, the formation of free space allows the transfer of water vapor.

Example of sophisticated applications (9)

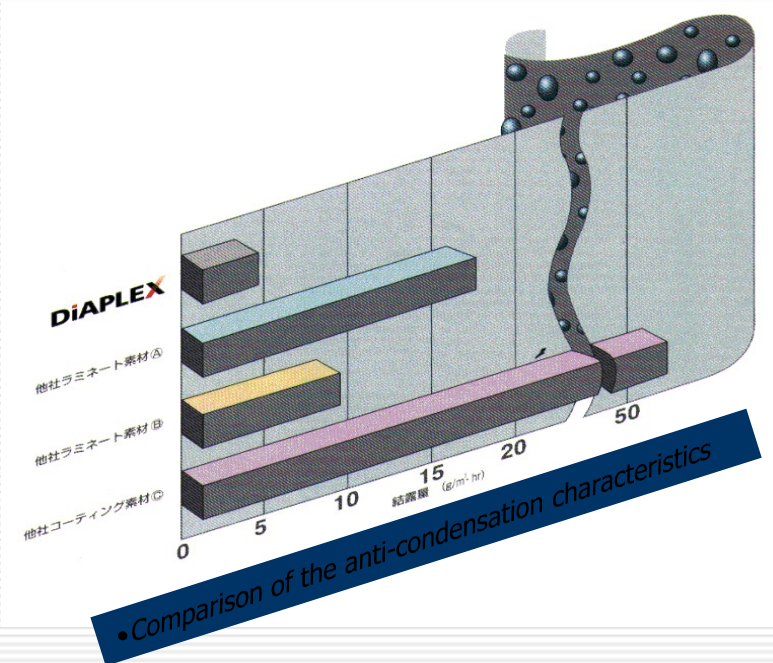
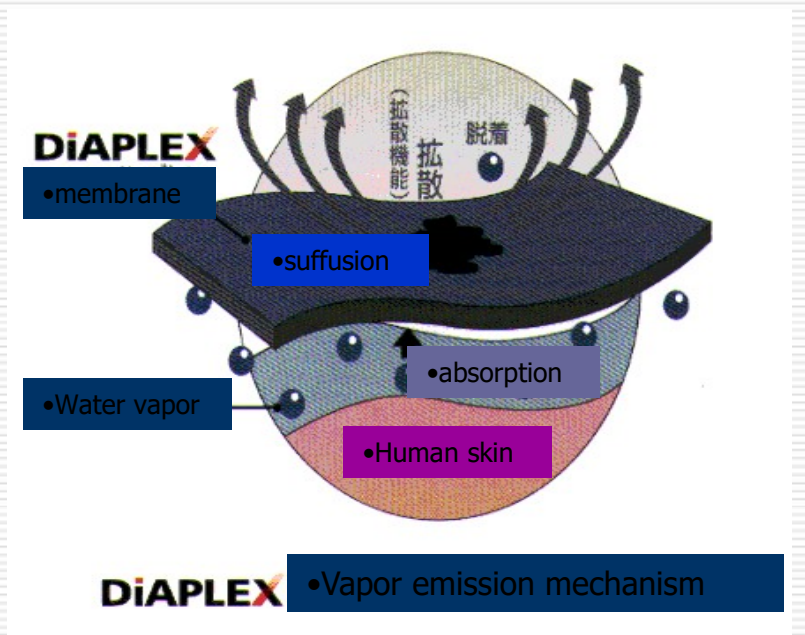
- This intelligent material memorizes conditions of comfort and responds to changes in environmental and ambient temperature.



Change in moisture permeability above and below transition temperature

Example of sophisticated applications (9)

Excellent waterproof, breathable, and anti-condensation are achieved.



Example of sophisticated applications(9)

FORSCHUNGSINSTITUT HOHENSTEIN TEST REPORT

Comparative wear trials with **DiAPLEX** garments

- Test Samples (garments)
- Diaplex2-layer 、70d×70d Taffeta total weight=1
- .18Kg
- (T_g=0°C) water vapor resistance Ret 5.39 m².Pa/W
- others 2-layer 、70d×70d Taffeta total weight=1.28Kg
- water vapor resistance Ret 5.67m².Pa/W



•T_g designed at 0°C

(ガラス転移温度 0°C設定)



•Others (2-layer)

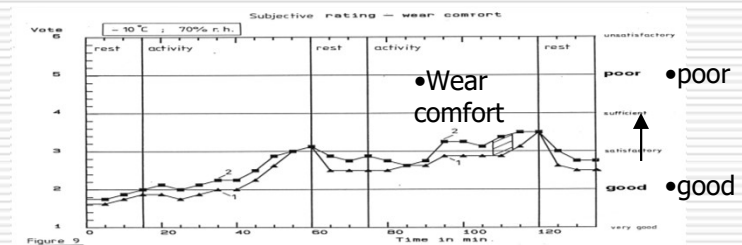
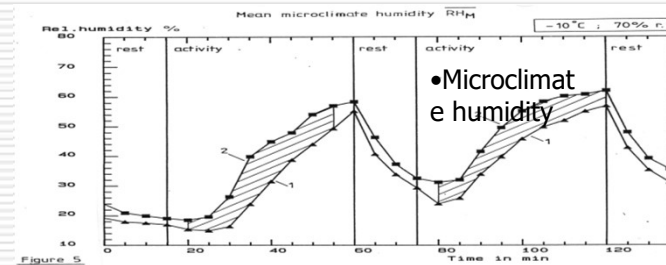
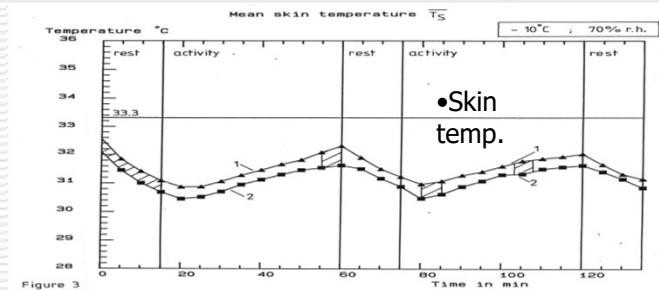


• Test chamber

Example of sophisticated applications (9)

Test results (performed with 4 test persons)

- Diaplex keeps subject warmer than the others.
- Microclimate humidity Diaplex keeps subject drier than the others.
- Superior comfort level is achieved.



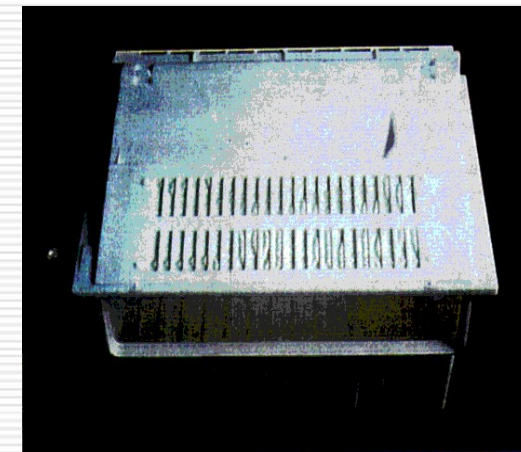
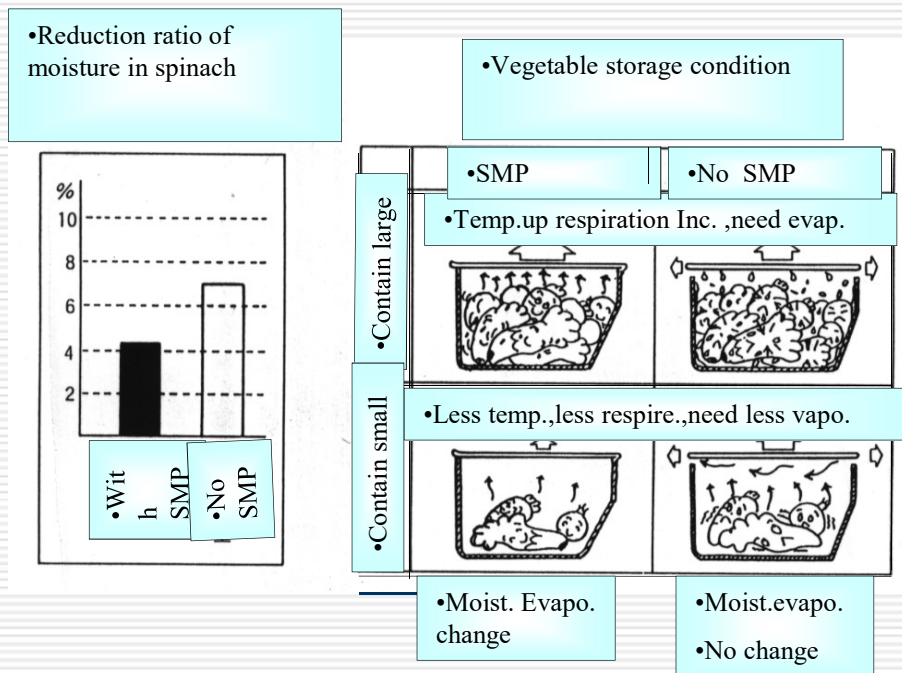
●グラフ1 : Diaplex グラフ2 : 他社多孔質膜

Example of sophisticated applications (10)

□ New vegetable container with SMP film

When temperature rises, perspiration rises, evaporation necessary.

SMP film performs to maintain the optimal condition in the container.



•National refrigerator “Tanto”

Example of sophisticated applications (11)

- Energy efficient and clean low dew condensation helps supermarket freezer unit stay cool and operate at maximum efficiency.

- Freshness retention

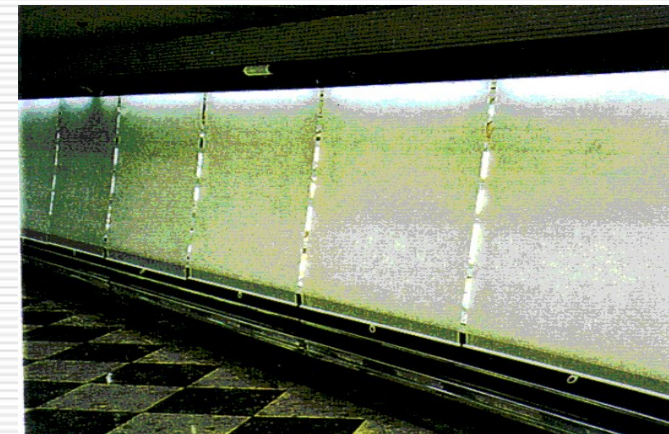
- Because of its waterproof and vapor permeable properties Diaplex can maintain proper humidity, helping to prevent clamminess or dryness within the showcase

- Energy conservation and anti condensation

Electric energy	51.4Kwh	37.1Kwh	26.4Kwh
Condensation	Observed	Observed	Not observed
Floor may become wet due to condensation.			

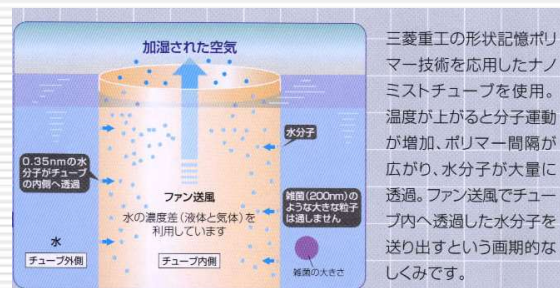
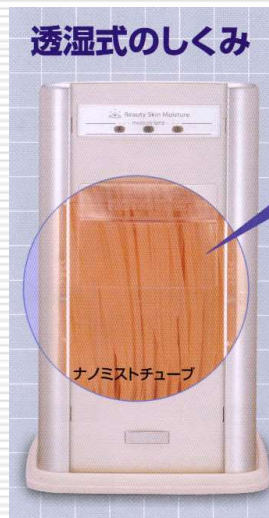
- Deodorizing, Antibacterial

- Diaplex has been specially treated for removing odors such as ammonia, hydrogen sulfide and also possesses antibacterial properties.

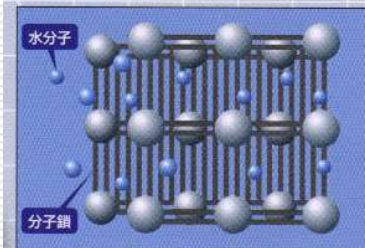


• Covered by Diaplex screen at night

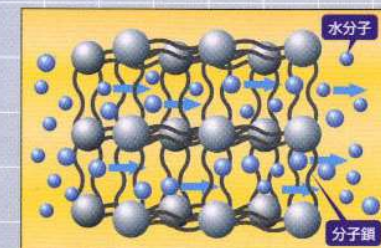
Example of sophisticated applications (12)



「透湿」の基本原理解



温度が低いと、ポリマーの分子鎖の熱運動が凍結するため、水分子が透過しにくくなります。



温度が上がると、ポリマーの分子鎖の熱運動が活発になるため、その隙間を水分子が透過しやすくなります。

DiAPLEX membrane for textile application

DiAPLEX is intelligent material able to adjust itself accordingly to ensure the highest level of comfort in garments.

Superior waterproof, breathable , and anti-condensation characteristics.

