INTELLIGENT MATERIAL

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

SMP Technologies Inc.

Introduction

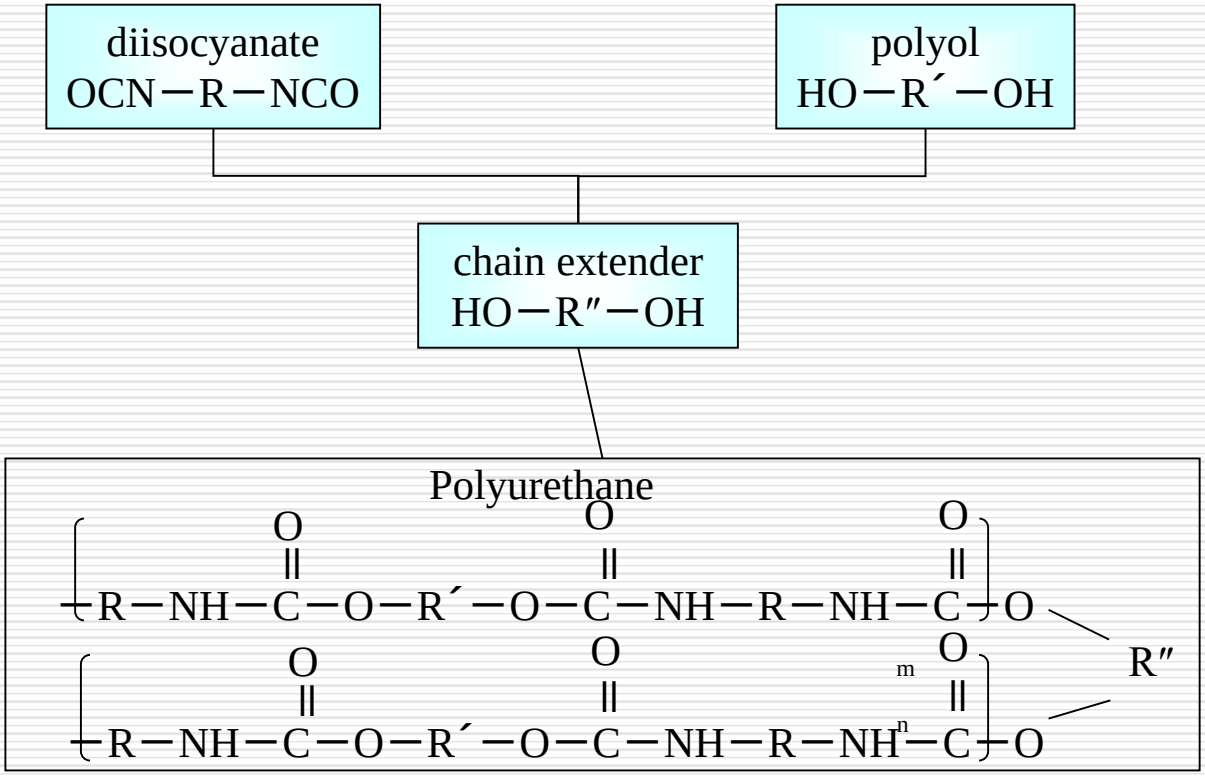
Shape Memory Polymer(SMP)

"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 (Tg)** is unique to **SMP**.

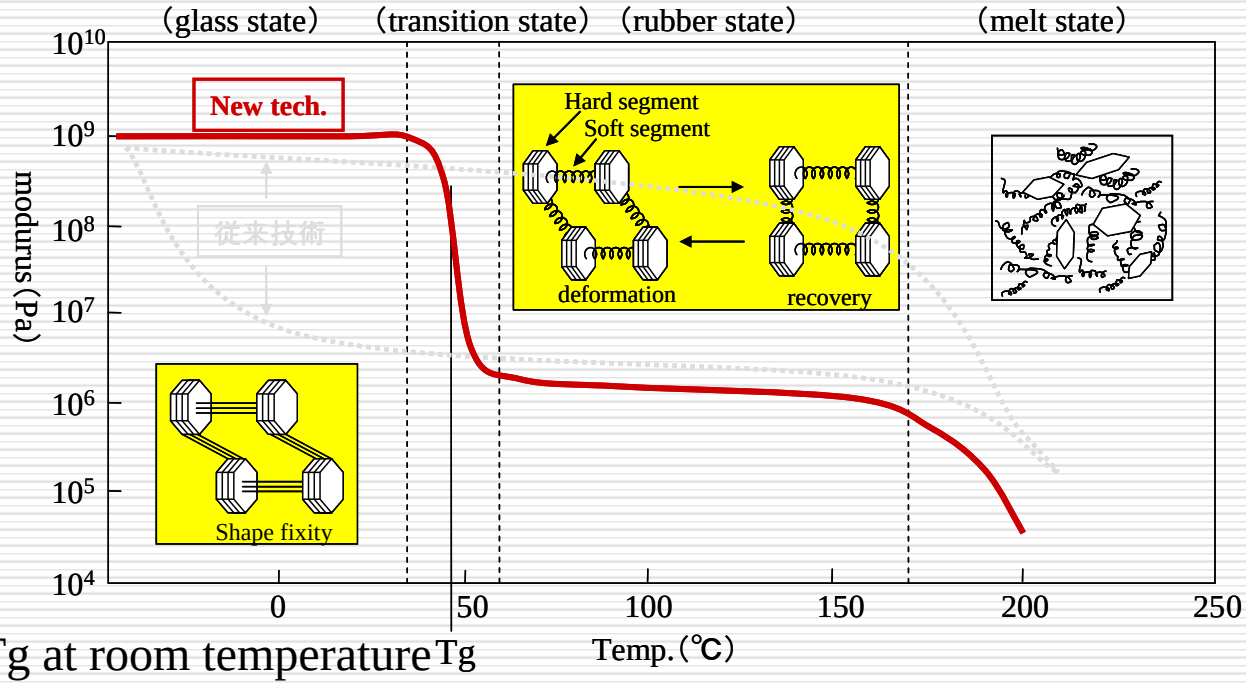
2. A wide range of new applications for the **SMP** materials are expanding in such fields as a space exploration, medical, clothing, food packaging , health care, toys, and more.

SMP based on Polyurethane



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

What's SMP

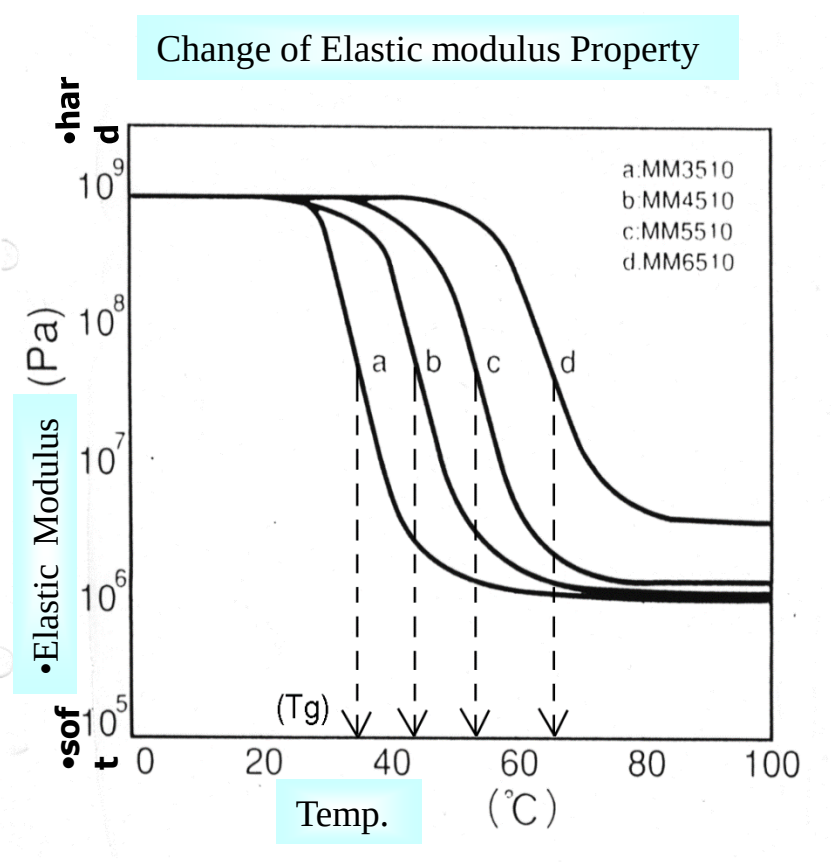


- Tg at room temperature
- Narrow transition state
- Drastic change of properties at transition state

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 (**Tg**)
  - **Tg** setting of the material can be designed at the desired temperature between

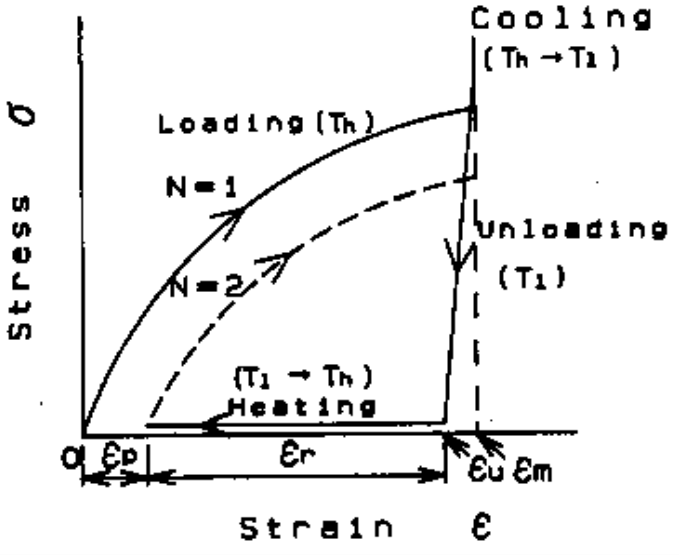
    -40 C ~90 C. (-40F ~194F)

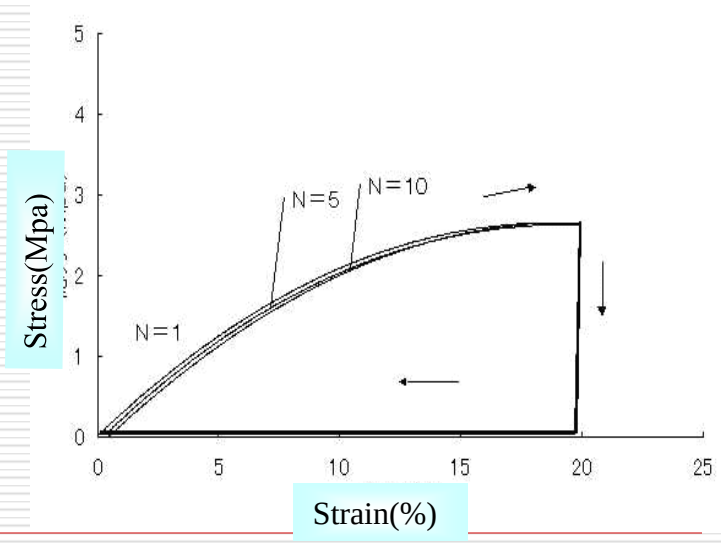


Property of DiAPLEX(2)

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

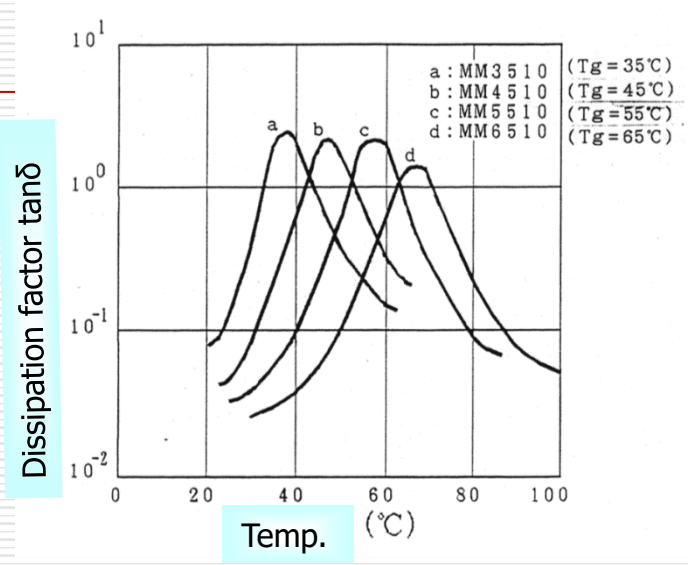
    To remove the external force at the low temperature (<Tg) the formed shape is retained.
  - To heat **SMP** with no external force from a low temperature to a temperature higher than **Tg**. It eliminates the strain, resulting in recovery of its original shape.
  - **SMP** allows the maximum strain can be applied up to **400%.**





Property of DiAPLEX（3）

- **Energy dissipation property**
  - Energy dissipation factor defined by tanδ change with the temperature and becomes very large compared to ordinary elastic material.（These material's tanδ are in the range of 0.2～0.4）
  - The tanδ 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（tanδ）of human body

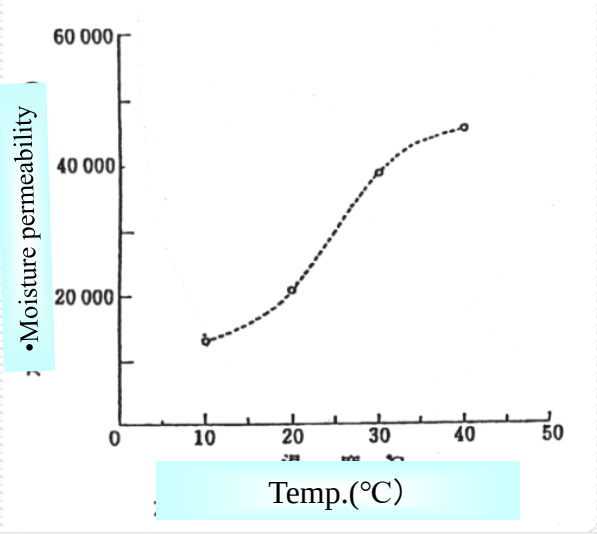
Lower arm	０．４３
forehead	０．５１
Palm	０．４１

高橋元次　高分子 33 巻１９８４

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 **Tg**, high moisture permeability,below Tg 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
1μm	Porous membrane	Staphylococcus（ 0.8μm）
0.5μm		Typhoid bacillus/cholera bacillus（ 0.6μm）
0.2μm		Smallpox virus（ 0.21μm）
0.1μm		Influenza virus（ 0.08μm）
0.05μm		
0.02μm		Gene（ 0.02×0.13μm）
0.01μm (100Å)		Polio virus（0.012μm）
50Å		Hemoglobin（ 30×50Å ）
20Å		DNA（20Å）
10Å	Non Porus membrane	Glutamine（ 5×8×16Å）
5Å		H_2O（ 3.5Å）
2Å		H_2（ 2.3Å）

Other properties of DiAPLEX

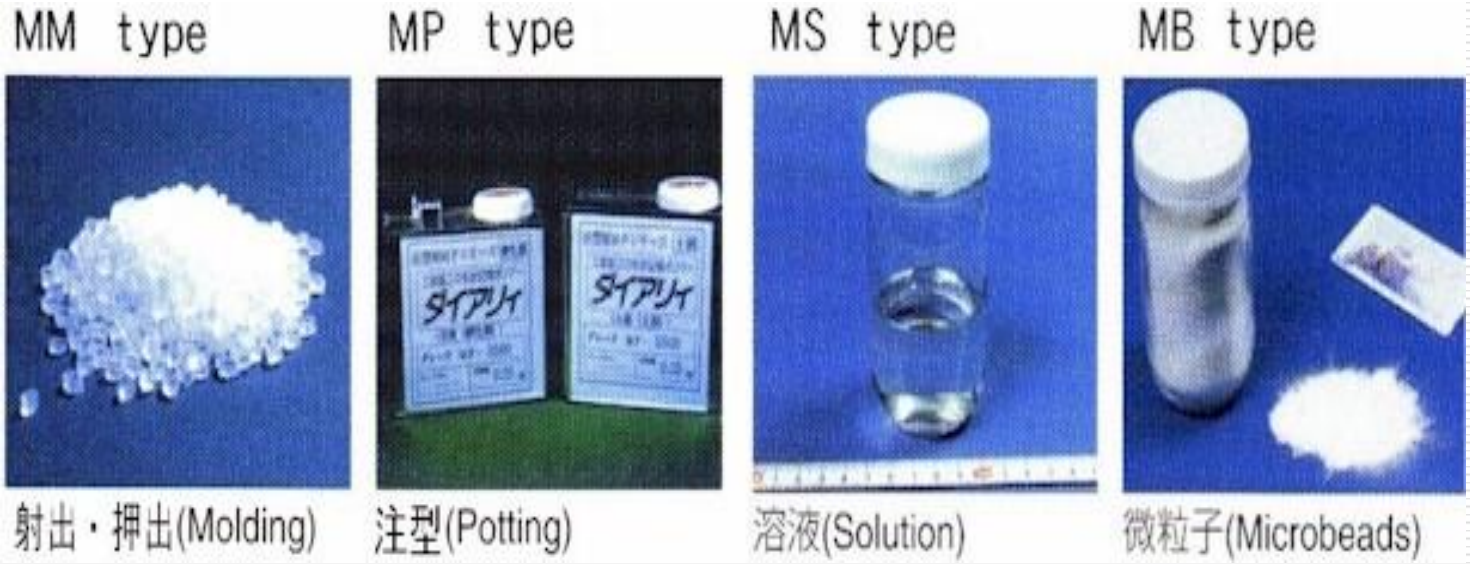
- **DiAPLEX can be applied to your body**.
  - DiAPLEX has been authorized by Japanese Ministry of Health and Welfare as follows;
  - Regulation standard on Food and Food additives
  - Food Hygiene law
  - Japanese Ministry of Health and Welfare notice No.370 in 1959.
  - The pharmaceutical affairs law

    No.145 in 1960, Article14, section 1.

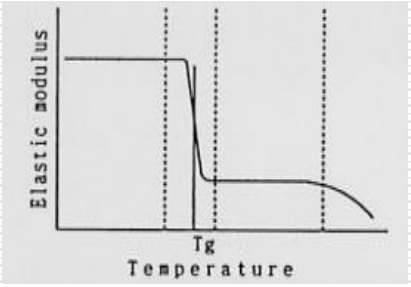
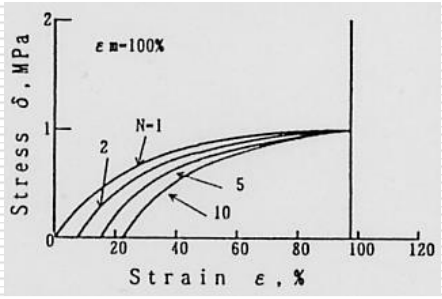
- **Molding Ability of DiAPLEX.**
- **Forming techniques include;**
  - Injection ,extrusion, and other ordinary forming techniques.
  - Material types available are Pellets, solution, foam, micro-beads ,fiber.

SMP Materials

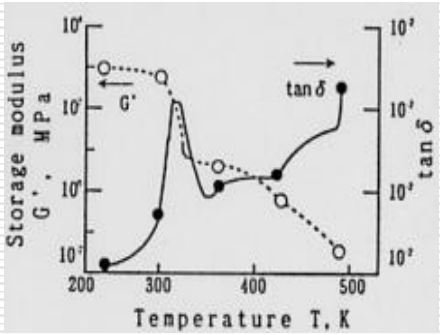
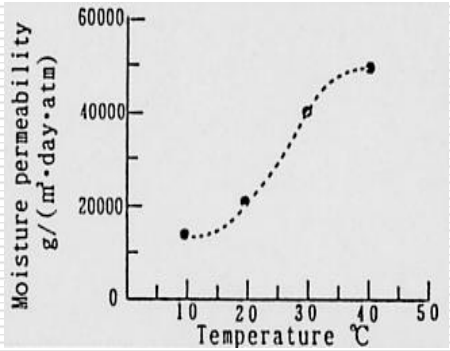
Index	Material	Molding	Packing unit
MM	Pellet	Injection・Extrusion	20Kg Bag
MP	Resin & Hardener	Potting	1Kg Can×2
MS	Solution	Coating	4Kg Can



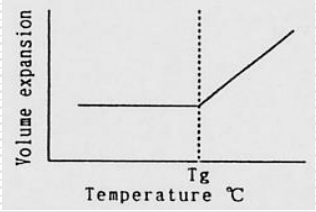
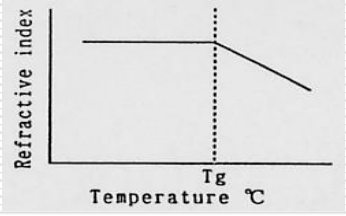
Properties and Applications of SMP

PROPERTIES		APPLICATIONS	
		Developed & Applied	Under Developing & Ideal Phase
Modulus		・Autochoke for Engine ・Intravenous Cannula	・Pressure sensitive switch
Shape Memory Property		・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	・Memory Material for CD ・Artificial Muscle ・Ski insole ・Shape Memory for natural fiber ・Shrink Film ・IC Tag

Properties and Applications of SMP

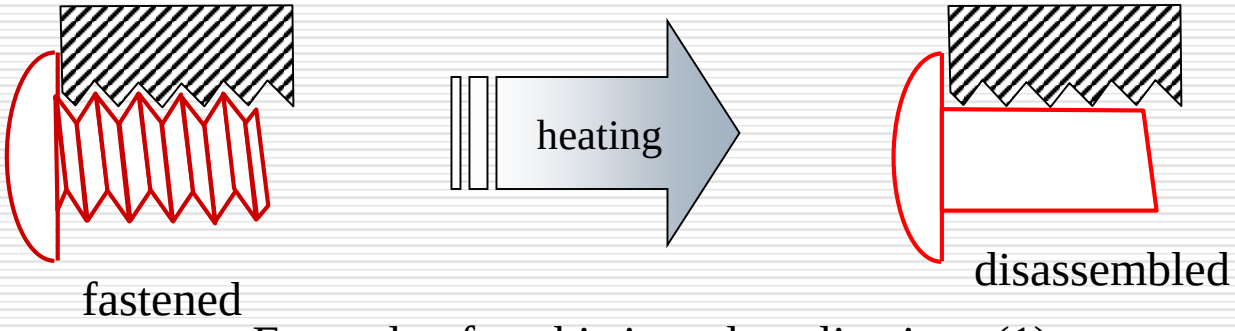
PROPERTIES		APPLICATIONS	
		Developed & Applied	Under Developing & Ideal Phase
Damping Property		・Lingerie generally (Bra cup) ・Glasses parts （Nose pad, ear pad） ・Damping Material ・Intravenous Cannula ・Inner Support of Mask ・Cosmetics Foundation ・Insole	・Lens ・Artificial Blood Vessel
Gas Permeability		・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	・Artificial Skin ・Gas Separator

Properties and Applications of SMP

PROPERTIES		APPLICATIONS Under Developing & Ideal Phase
Volume Expansion		・Thermo sensor ・Inflatable material ・Panel for Display
Recovery Force		・Binding Element ・Clamping pin ・Self-deployable structures
Refractive Index		・Lens ・Thermo sensor ・Optical Fiber
Dialectic Constant		・Thermo sensor

Example of sophisticated applications（1）Fastener-1

Easy disassemble using SMP by heating



Example of sophisticated applications (1)

Example of sophisticated applications（1）Fastener-2

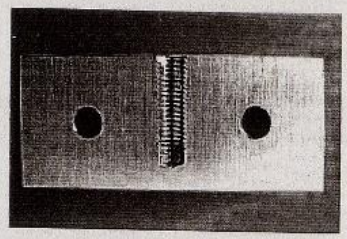


Figure 3. SMP Screw Post Forming Jig.

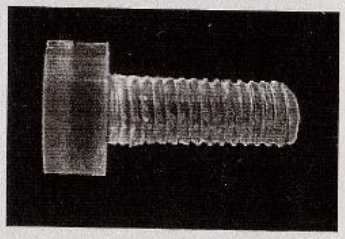
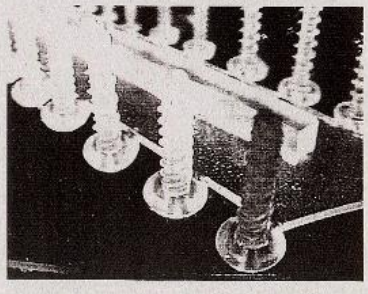


Figure 4. SME-SMP Screw after Post Forming / Jig.



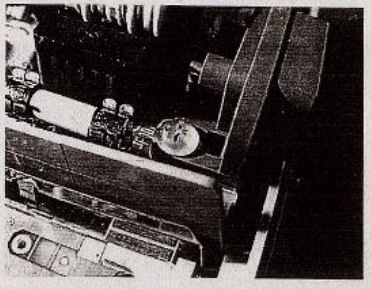


Figure 5. Concept SME-SMP Screw in a Product Assembly.

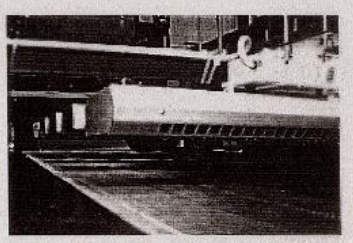


Figure 6. Infrared heaters over conveyor system for the mechanical property loss SMP experiments.

Example of sophisticated applications（1）Fastener-3

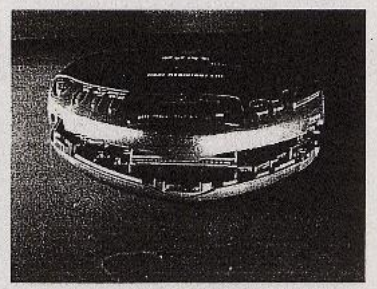


Figure 7. Successful active disassembly of the macro assembly of the Sony CD player.

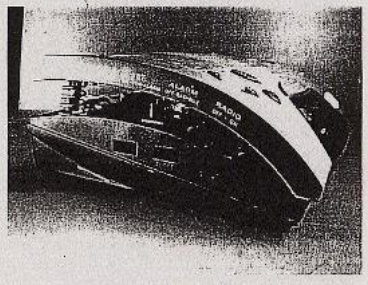


Figure 8. Successful active disassembly of the macro assembly of the Philips digital FM audio.

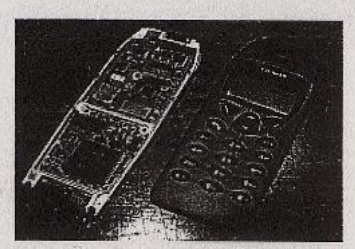


Figure 8. SME-SMP Nokia 6110 after successful ADSM.

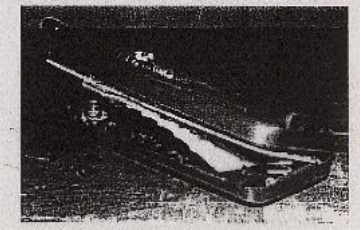
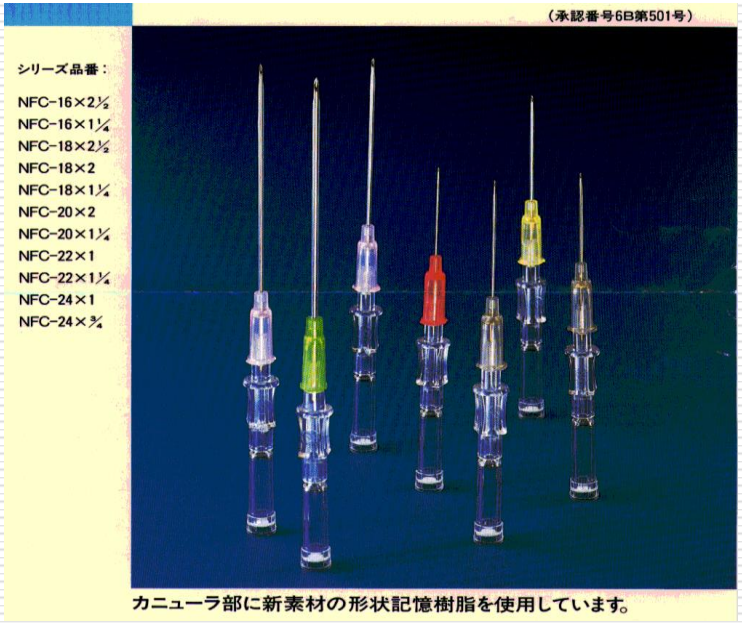


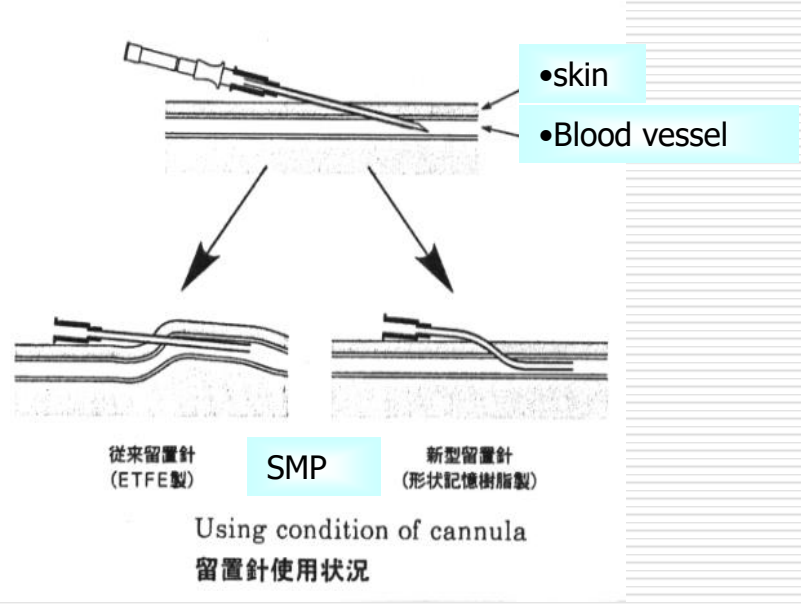
Figure 9. SME-SMP Motorola Populus after successful ADSM.

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.

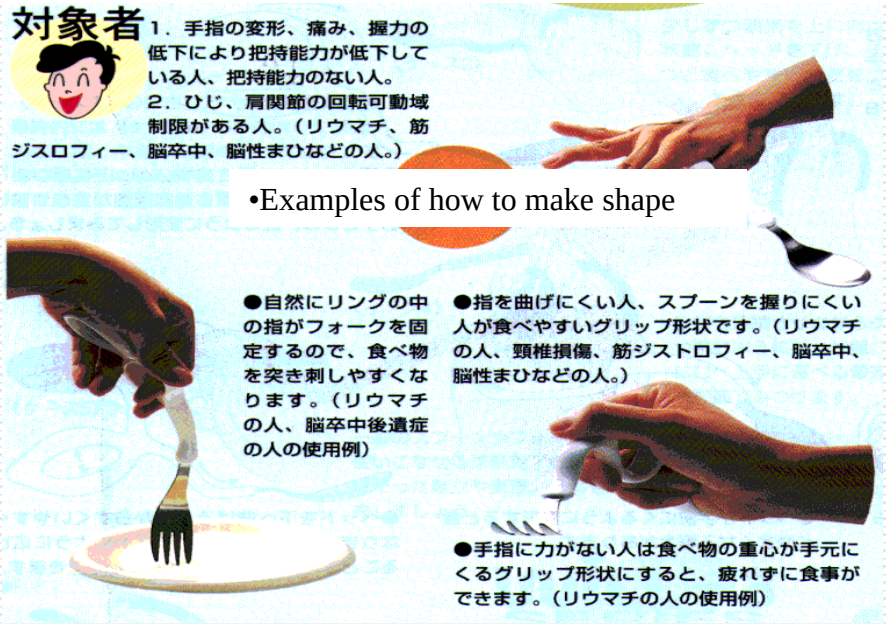




From Nipro

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）

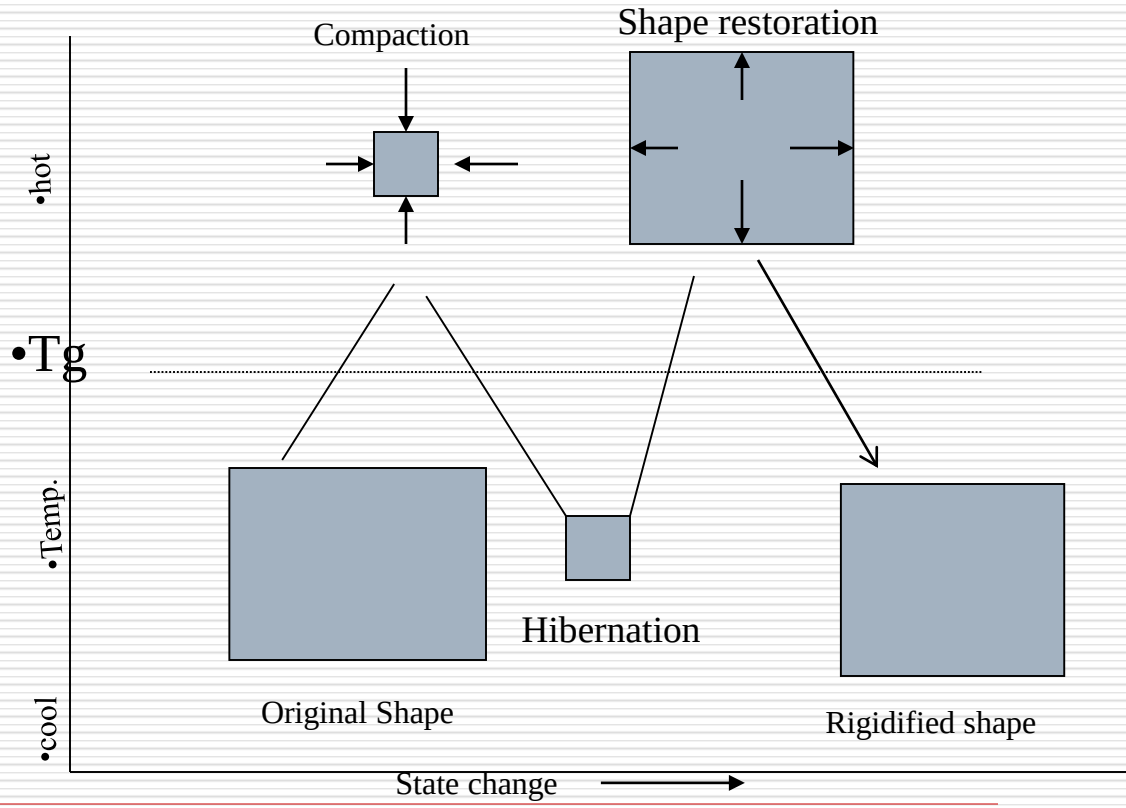
- **Ankle supporter** from properties (1), (2)
- A guard part utilizing FR-SMP(Fiberglass Reinforced Shape Memory Polymer) is available for transformation by heating.
- It can be changed into a shape fitting an ankle easily.

From Nippon Sigmax Co., Ltd.

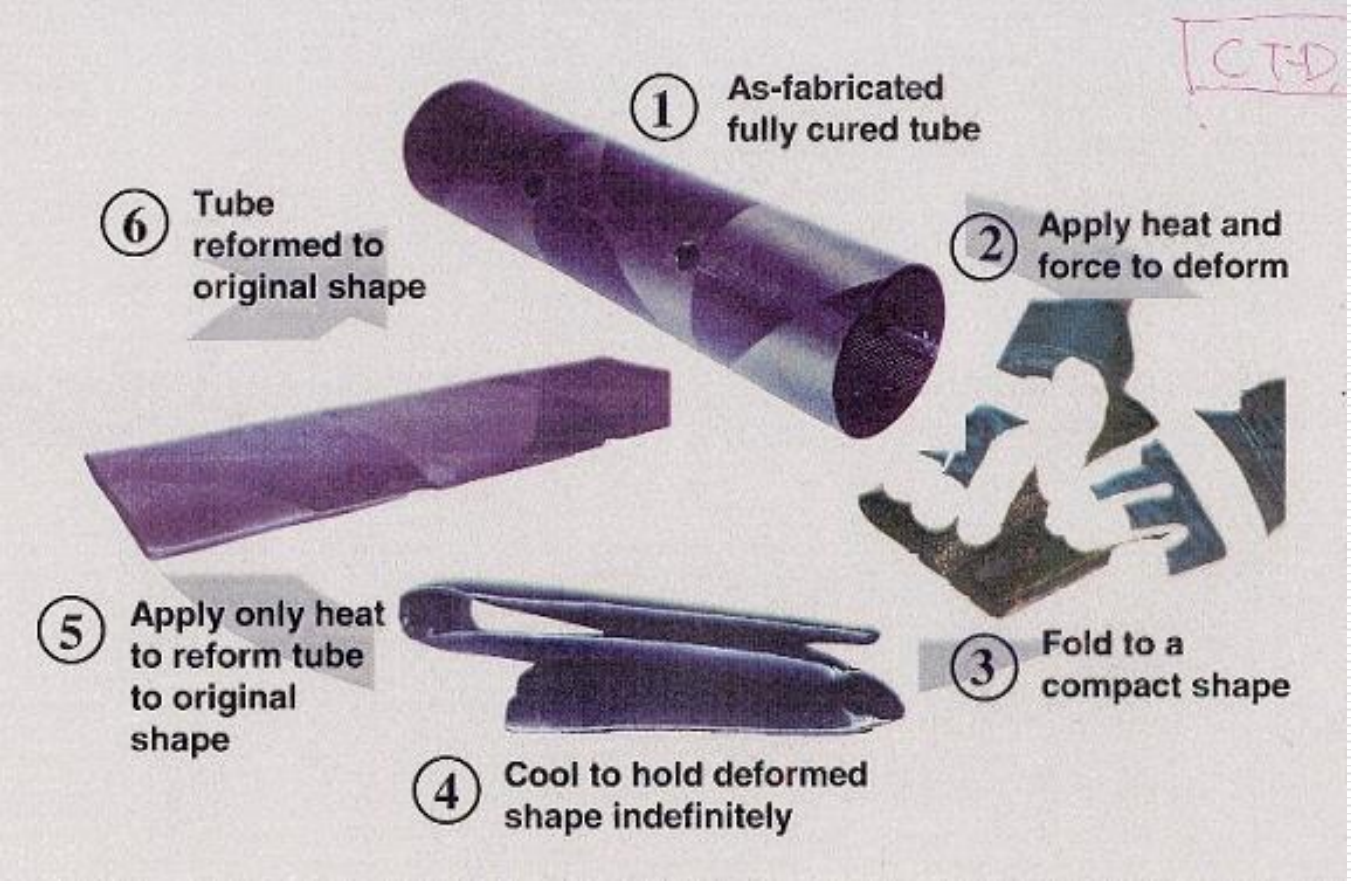
Example of sophisticated applications（5）

Inflatable Material for Aero-space Applications

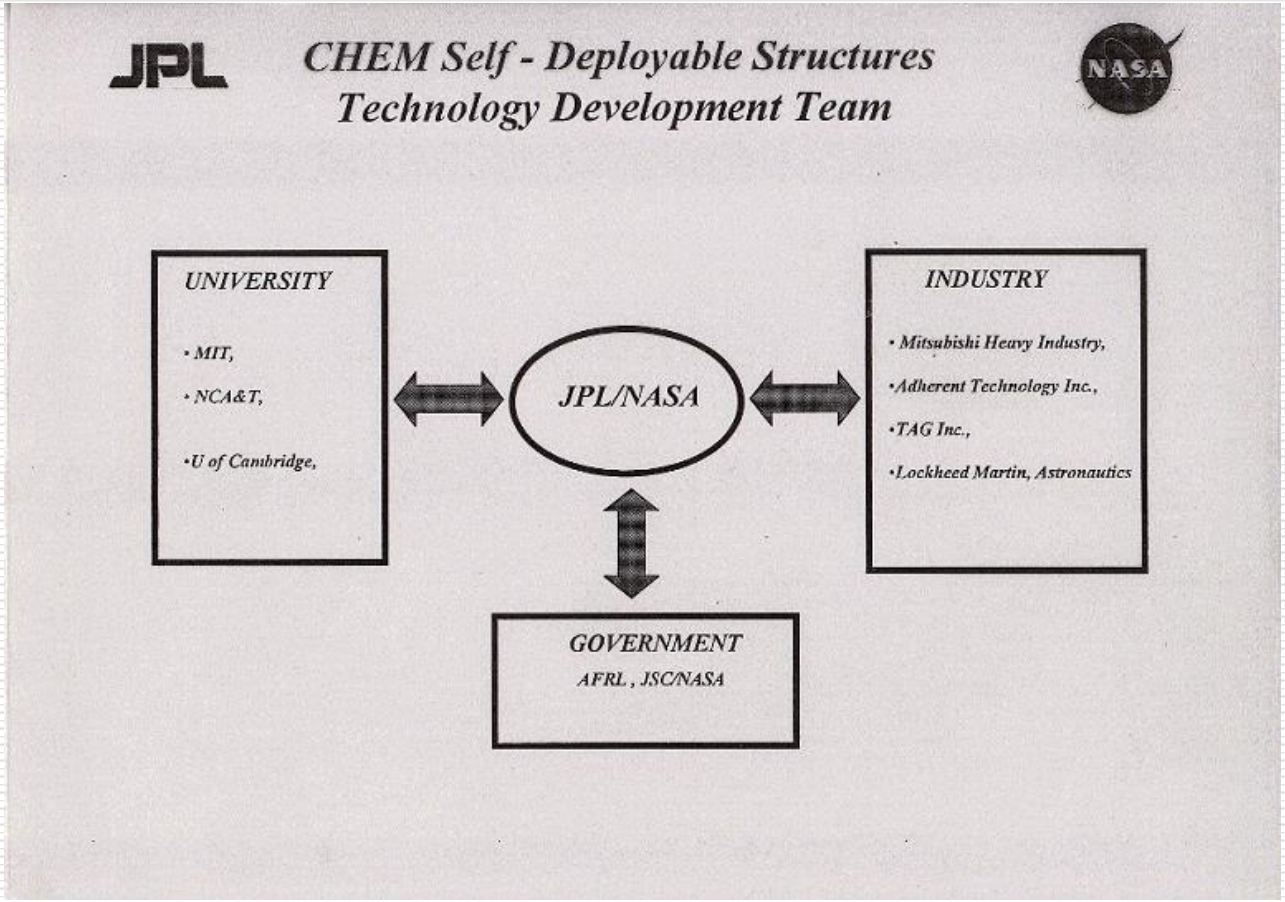
In foam structure, **full/stowed volume ratio of 30 ～40** has been realized.



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 δ and J-curve(stress-strain curve)

There behavior are very similar to human body.

Example of sophisticated applications（8）

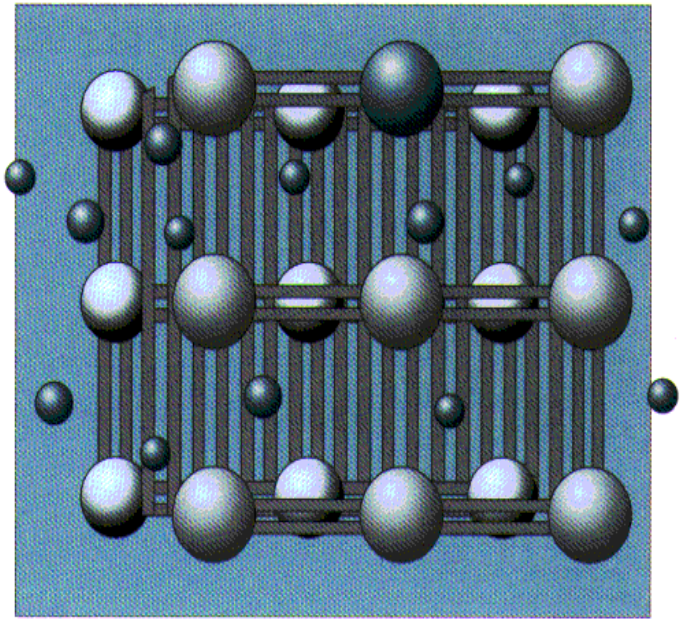
Nose guard for eye Glass

utilizing injection molded SMP

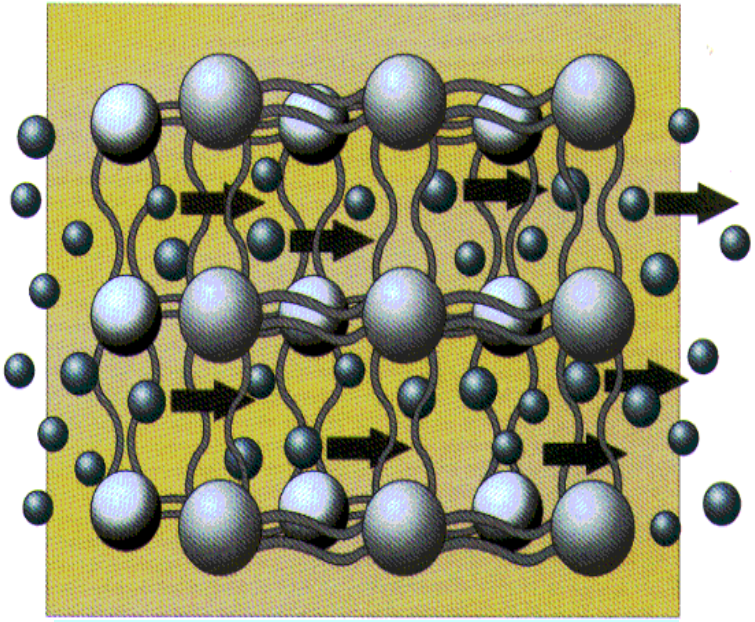
This nose guard has the same mechanical properties to nose

Example of sophisticated applications（9）

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



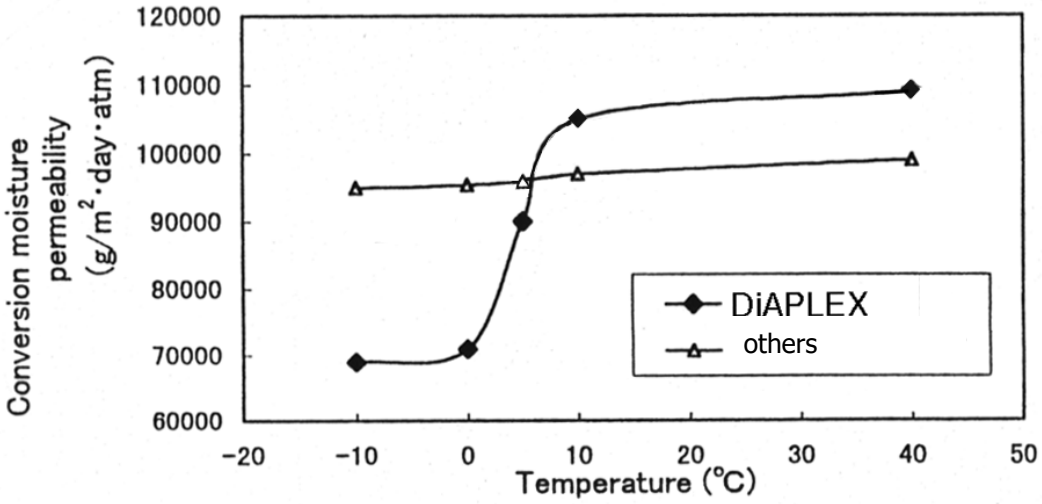
•At low temperature the polymer molecular chains stop the transfer of water vapor.



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

Example of sophisticated applications（9）

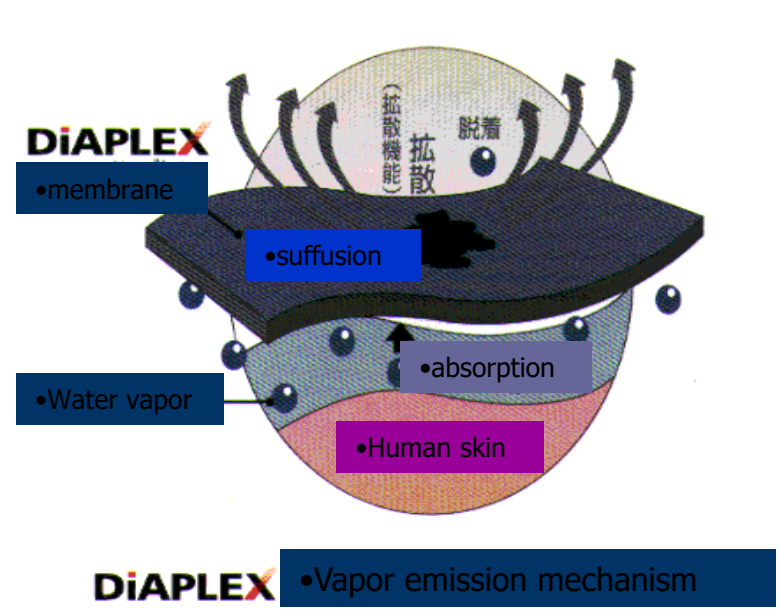
- This intelligent material memorizes conditions of comfort and responds to changes in environmental and ambient temperature.

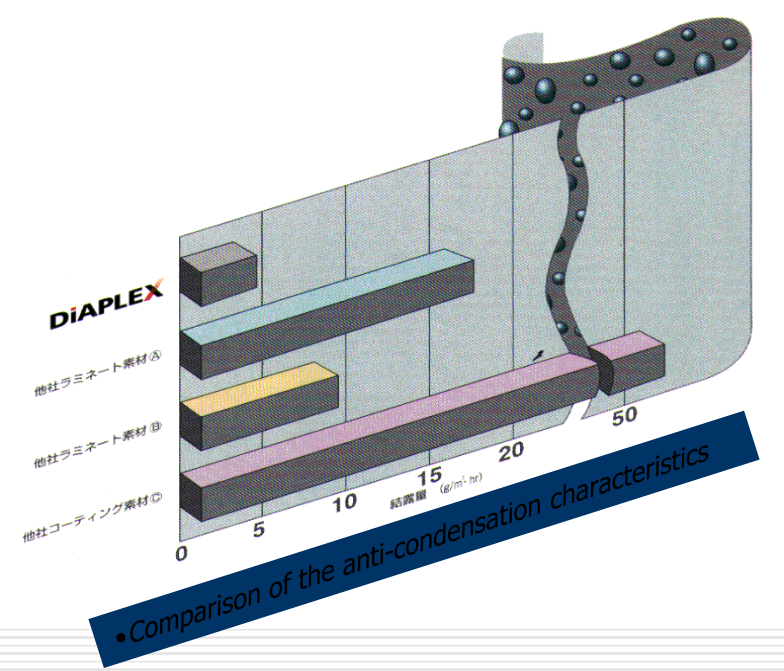


Change in moisture permeability above and below transition temperature

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
- （Tg＝0℃） water vapor resistance Ret 5.39 m^2.**Pa**/W
- others 2-layer 、70d×70d Taffeta total weight＝1.28Kg
- water vapor resistance Ret 5.67m^2.**Pa**/W

•Tg designed at 0℃

（ガラス転移温度 0℃設定）

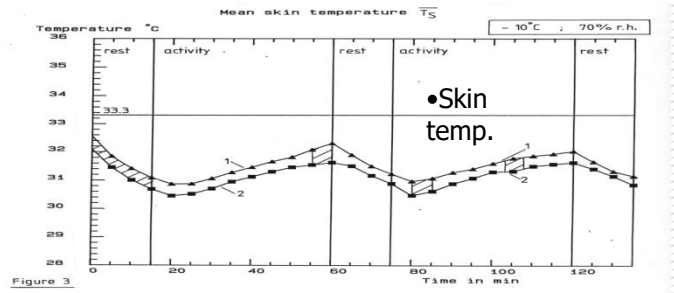
•Others（2-layer）

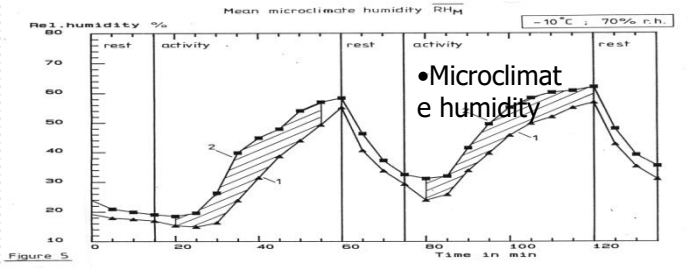
• Test chamber

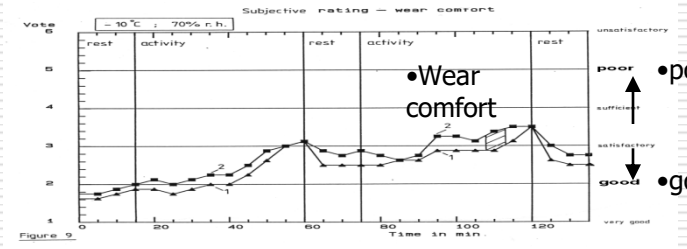
Example of sophisticated applications（9）

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.







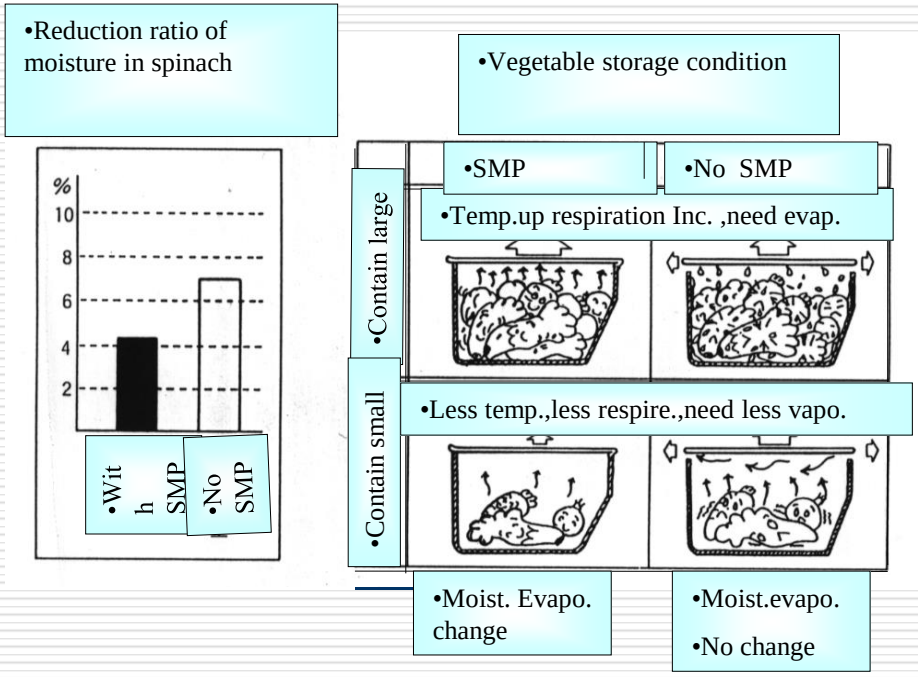
•グラフ1：Diaplex　グラフ2：他社多孔質膜

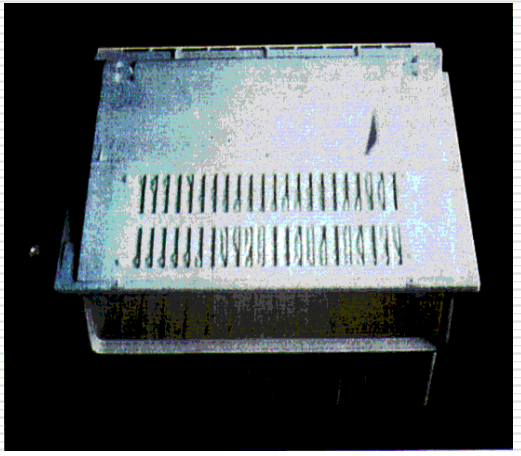
Example of sophisticated applications（10）

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

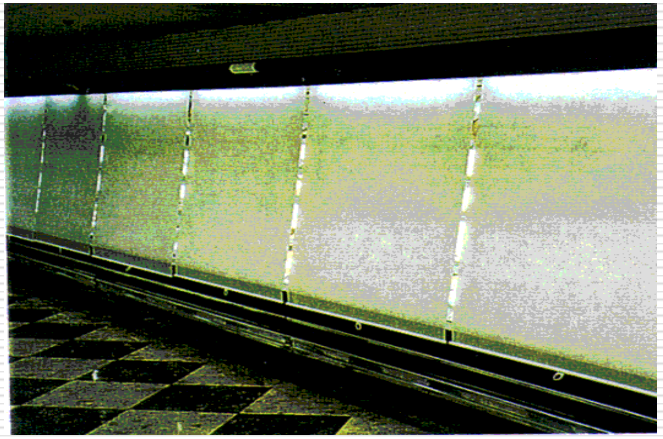
- Because of its waterproof and vapor permeable properties Diaplex can maintain proper humidity,helping to prevent clamminess or dryness within the showcase

•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

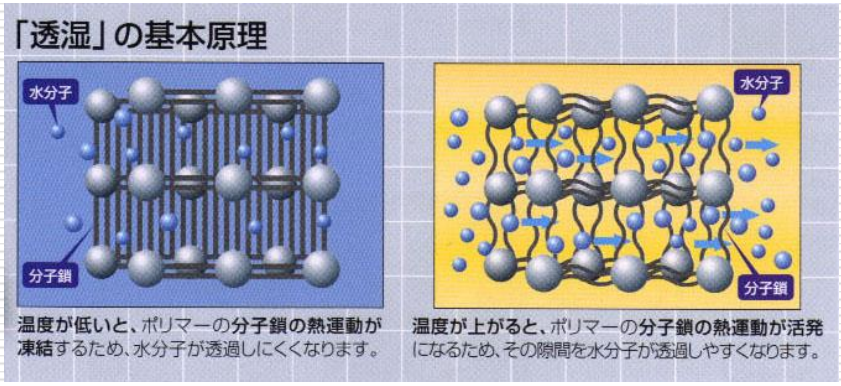
•Diaplex has been specially treated for removing odors such as ammonia,hydrogen sulfide and also possesses antibacterial properties.



•Covered by Diaplex screen at night

Example of sophisticated applications（12）

三菱重工の形状記憶ポリマー技術を応用したナノミストチューブを使用。温度が上がると分子運動が増加、ポリマー間隔が広がり、水分子が大量に透過。ファン送風でチューブ内へ透過した水分子を送り出すという画期的なしくみです。



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.