ILE Osaka

Manupilation of microstructure of ultralow-density TPX foam using coagulant alcohol

Keiji NAGAI, Takayoshi NORIMATSU, Tatsuhiko YAMANAKA

Target Group, ILE Osaka

ultralow-density foam

ILE Osaka

Cut-off density of plasma for 530 nm laser

$\sim 4 \times 10^{21}$ electrons/cm^3

1×10^{-2} g/ cm^3

ultralow-density foam = under cutoff density foam

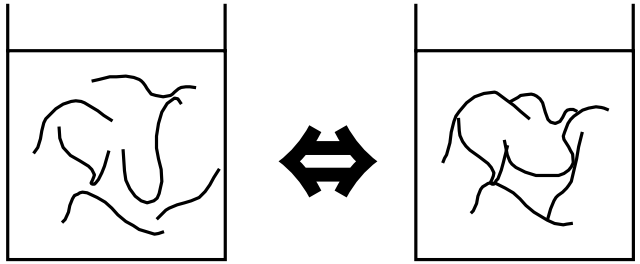
microstructure of foam

Low density foam has a microstructure.
microstrcture of foam ⟷ character of laser plasma ?

How to prepare with manupiration of the microstructure?

sol ⇔ gel

ILE Osaka



crosslinked polymer
translation motion

x polymer
o solvent

polymer chain

polymer solvates with solvent.
Microbrownian motion of polymer is possible.

Fabrication of low density foam

ILE Osaka

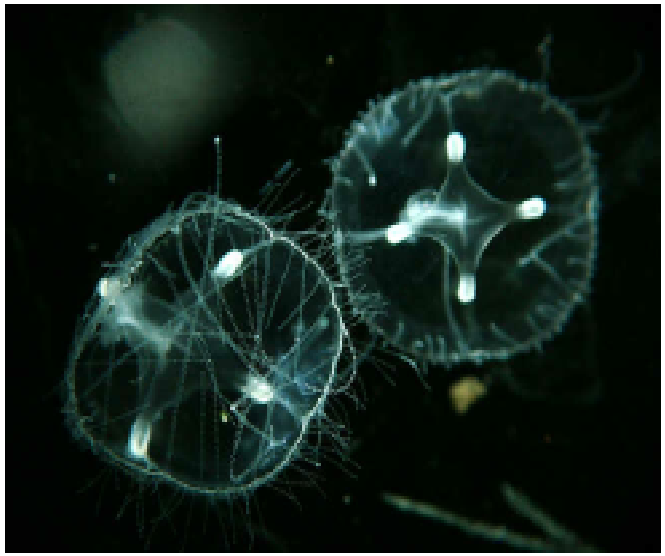
1) Foam polyurethane, polystyrene
   - x They have larger structure than focus spot.

2) Freeze-Dry PMP
   - x Relatively large structure (~10μm)
   - o Ultralow density

3) Aerogel
   - o Fine structure
   - x not applicable for hydrocarbon (such as PMP)

1) Is it possible to prepare a mummy of jellyfish with its original shape?

ILE Osaka

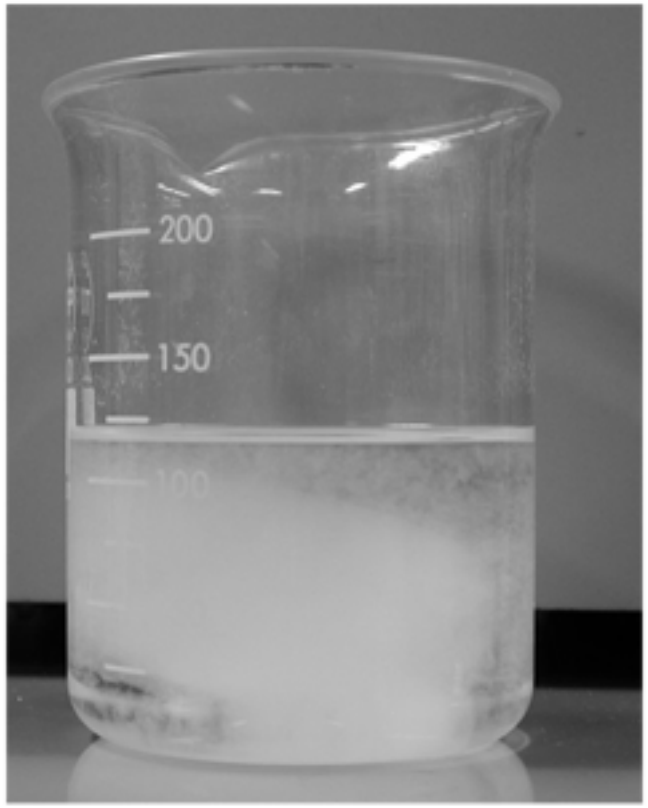


-> Yes.

extraction using supercritical fluid

2) A jellyfish contains 99 % water.
Is it possible to prepare a jellyfish containing 99.9% water?

ILE Osaka



PMP in 2-ethyl-1-butanol

-> I do not know the answer.

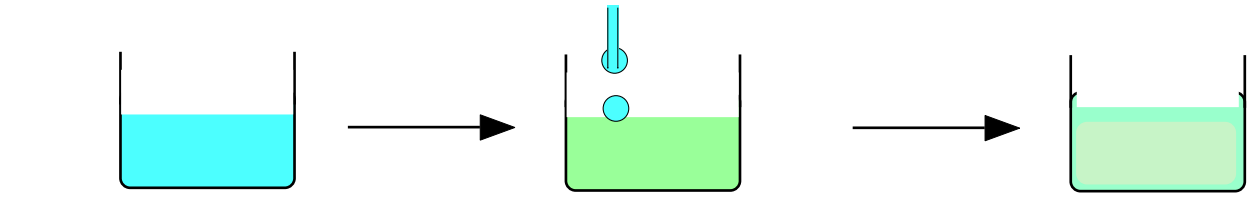
But it is possible to prepare a gel containing 99.9 % solvent,

by density matching of polymer and solvent.

PMP	0.83 g/cc
2-ethyl-1-butanol	0.83 g/cc
2-methyl-pentanol	0.82 g/cc
1-hexanol	0.82 g/cc

Preparation of ultralow density foam

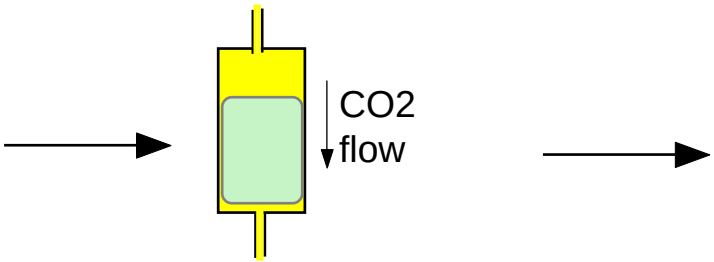
ILE Osaka



poly(4-methyl-pentene) (PMP) cyclohexane solution

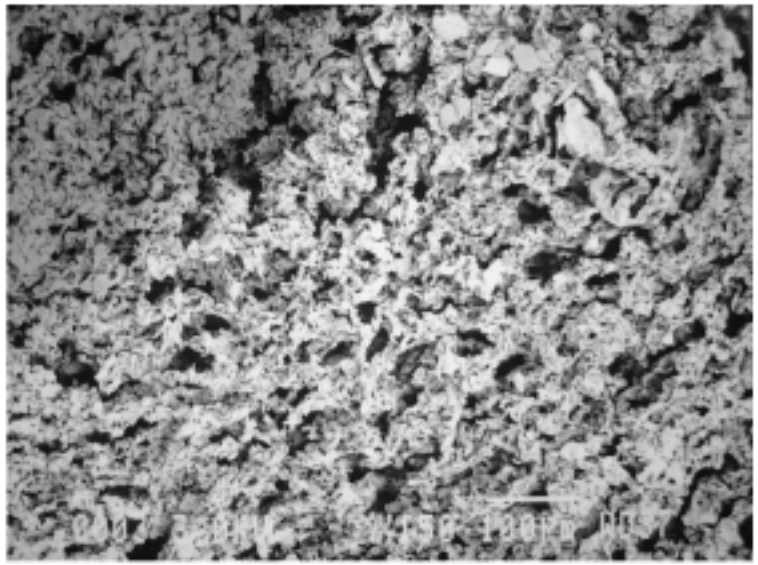
mixed with boiled alcohol

gelation

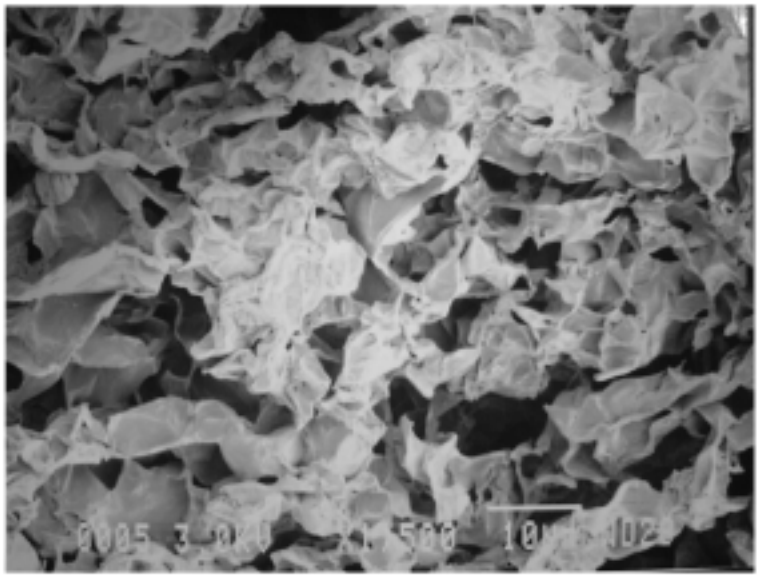


extraction using supercritical CO2

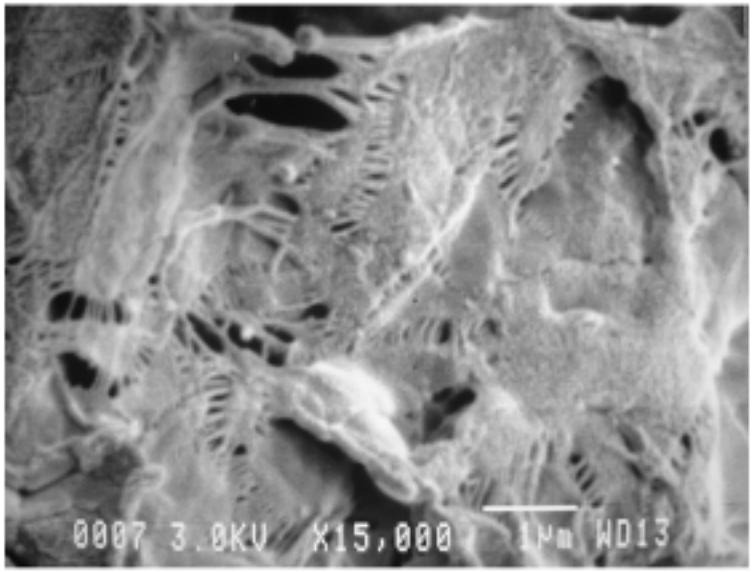
ultralow density PMP



100 μm



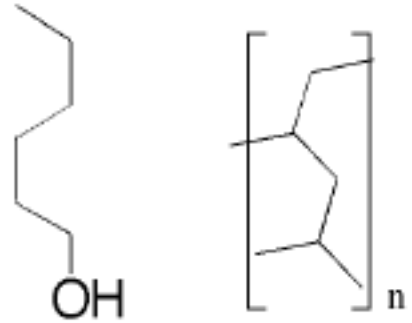
10 μm

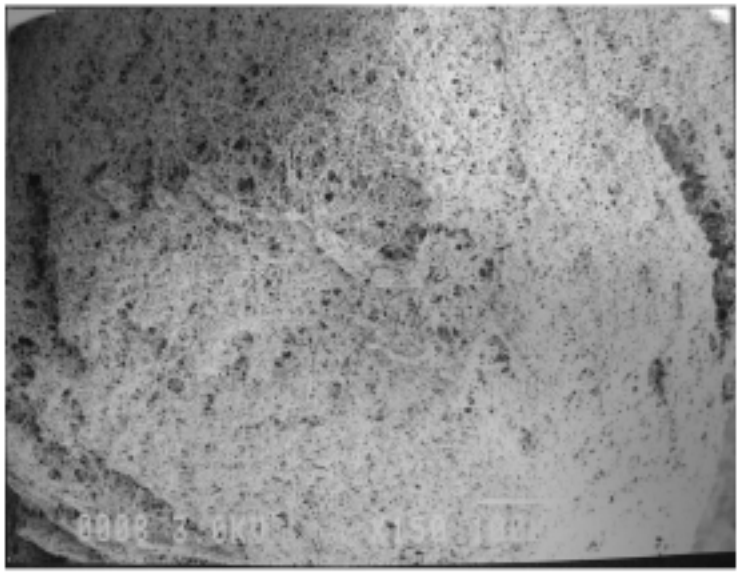


1 μm

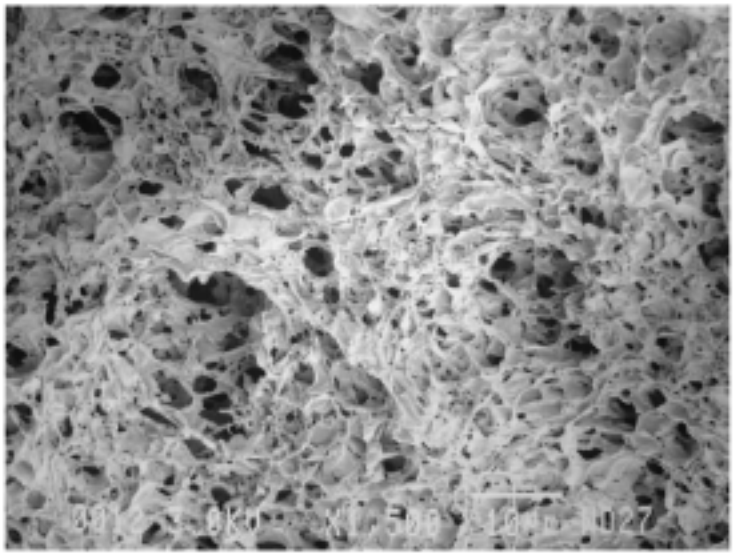
SEM images of poly(4-methyl-1-pentene) prepared from 1-hexanol solution

d = 12 mg/cc

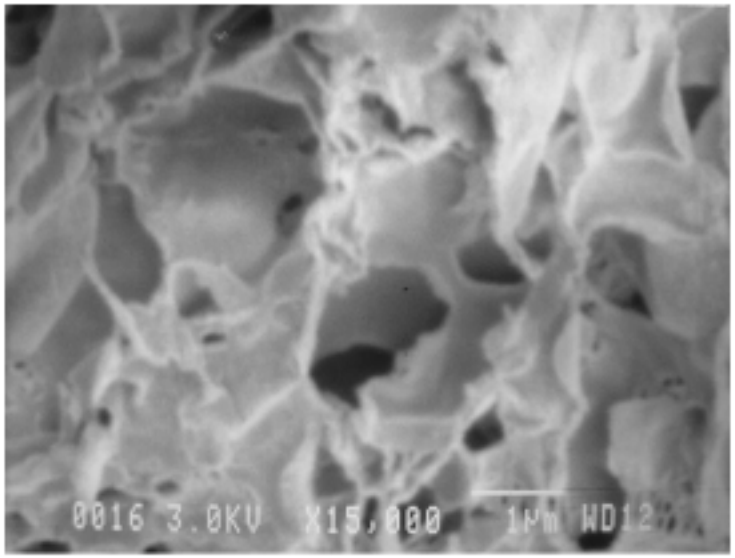




100 μm



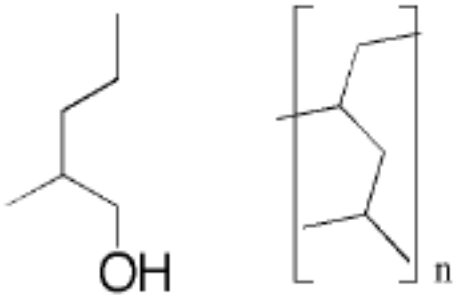
10 μm

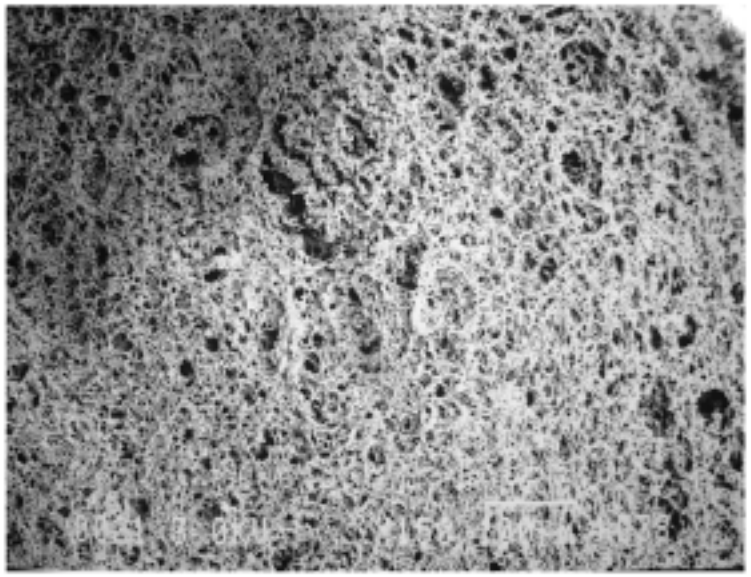


1 μm

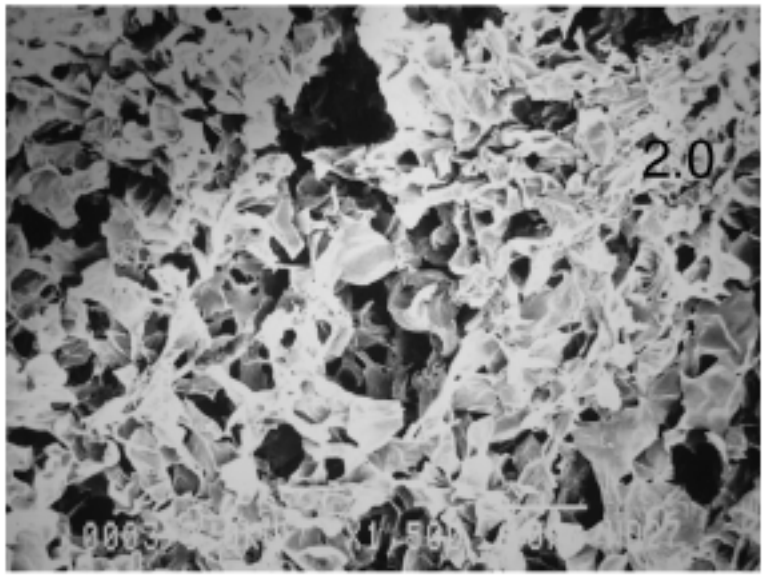
SEM images of poly(4-methyl-1-pentene) prepared from 2-methylpentanol solution

d = 5.0 mg/cc

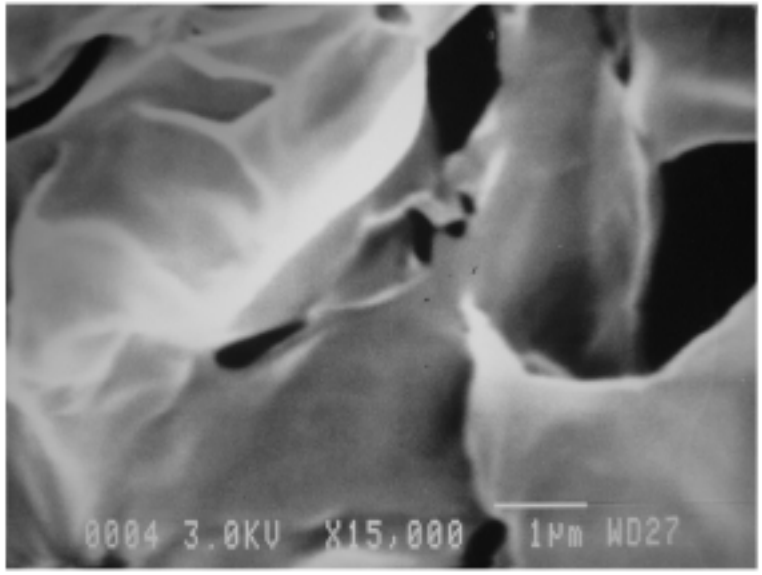




100 μm



10 μm



1 μm

SEM images of poly(4-methyl-1-pentene) prepared from diethylethanol solution

d = 2.0 mg/cc

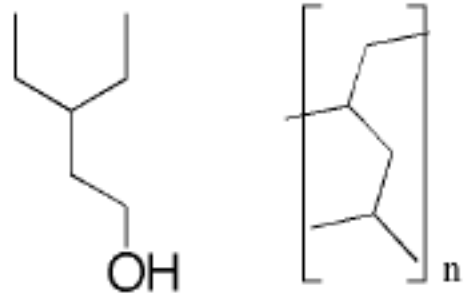


Table I. Characteristics of low-density poly(4-methyl-1-pentene) foam prepared from hexanolic gel.

ILE Osaka

coagulant	foam density (mg/cm3)	disk size (μm)	corresponding cutoff laser wavelength (μm)
1-hexanol	12	~10	0.55
2-methyl-1-pentanol	5.0	~3	0.84
2-ethyl-1-butanol	2.0	~6	1.3

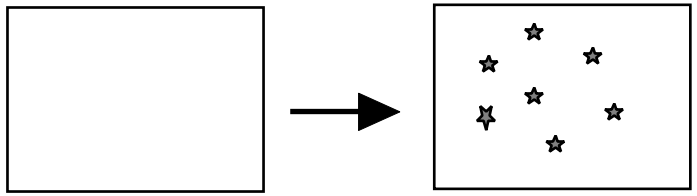
How to construct the microstructure (gelation process) kinetics

nuclear formation -> growth of lamella

ILE Osaka

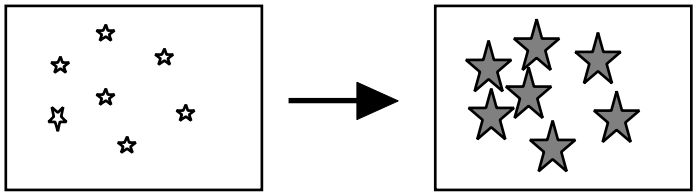
rate of nuclear formation

faster -> more nuclear



growth rate

faster -> larger lamella



Character of foam depending on hexanol derivatives

ILE Osaka

Solubility of PMP (Similarity of chemical structure)

2-methyl-1-pentanol > 2-ethyl-1-butanol > 1-hexanol

lamellar size

2-methyl-1-pentanol < 2-ethyl-1-butanol < 1-hexanol

3 μm 6 μm 10μm

foam density

2-ethyl-1-butanol < 2-methyl-1-pentanol < 1-hexanol

2 mg/cc 5 mg/cc 12 mg/cc

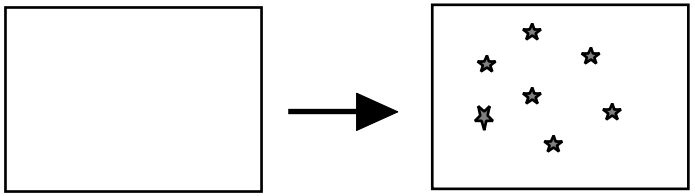
How to construct the microstructure (gelation process) kinetics

nuclear formation -> growth of lamella

ILE Osaka

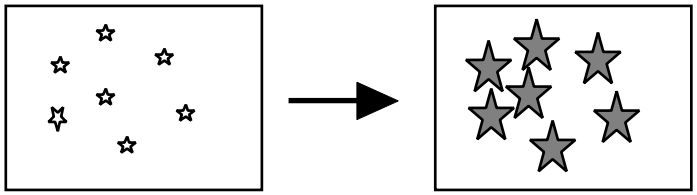
rate of nuclear formation

faster -> more nuclear



growth rate

faster -> larger lamella



experimental results

higher affinity between hexanol/PMP

X -> more nuclear

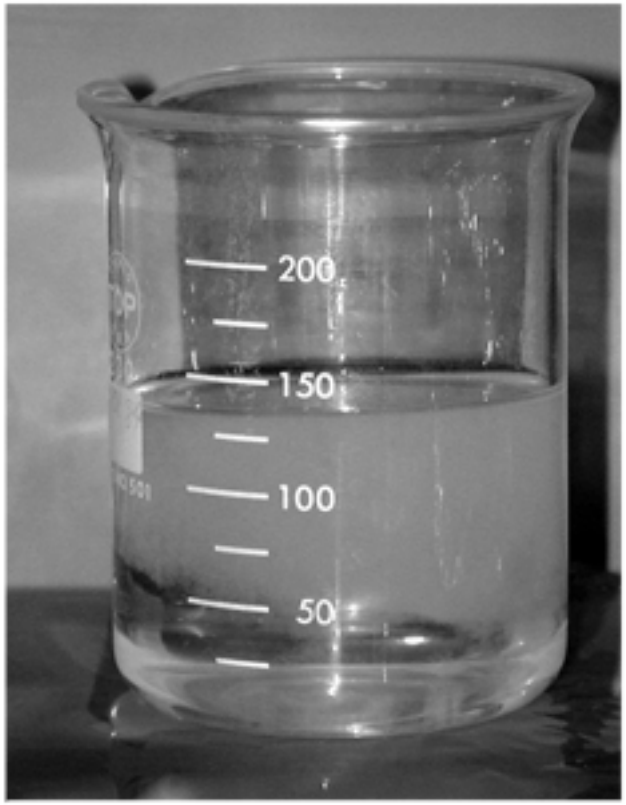
.....?

higher affinity between hexanol/PMP

O -> smaller structure

→ Chemical affinity of hexanol governs lamella growth , but does not nuclear formation.

After several days,
the PMP density becomes lower than hexanol derivatives

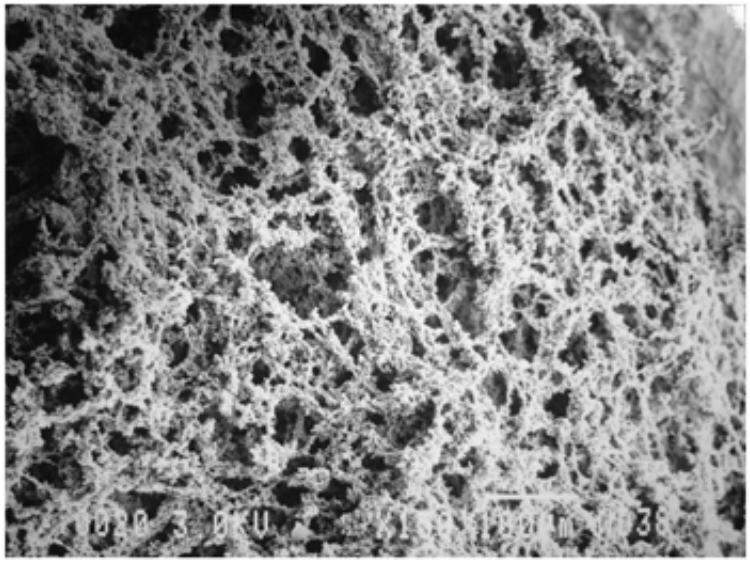


PMP in 2-ethyl-1-butanol

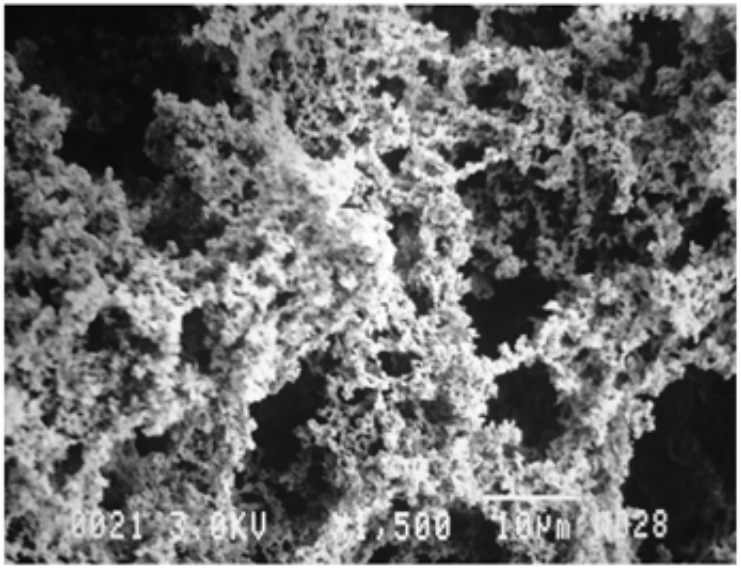
ILE Osaka

We have chosen slightly lower density alcohol of butanol derivatives.

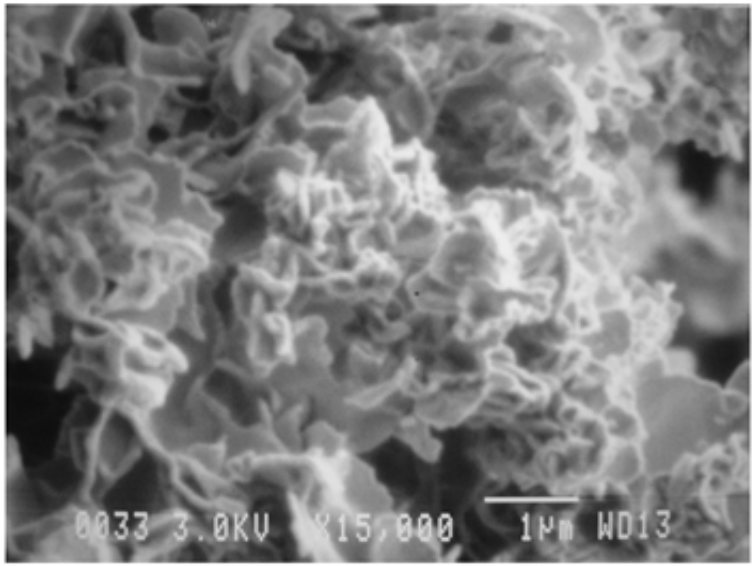
PMP	0.83 g/cc
1-butanol	0.81 g/cc
2-butanol	0.81 g/cc
2-methyl-1-propanol	0.78 g/cc



100 μm

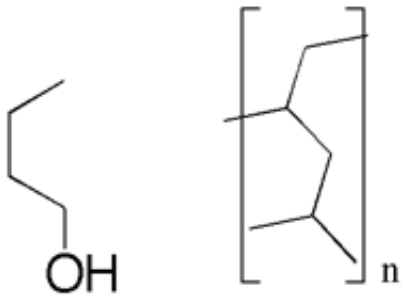


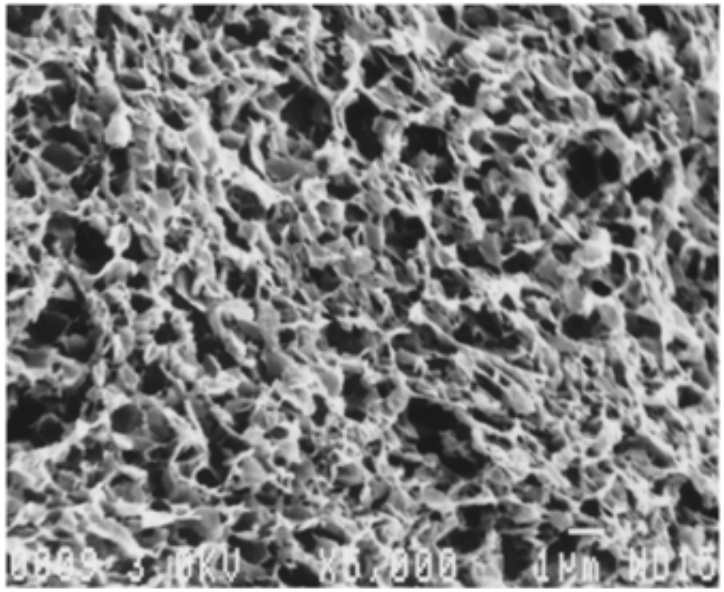
10 μm



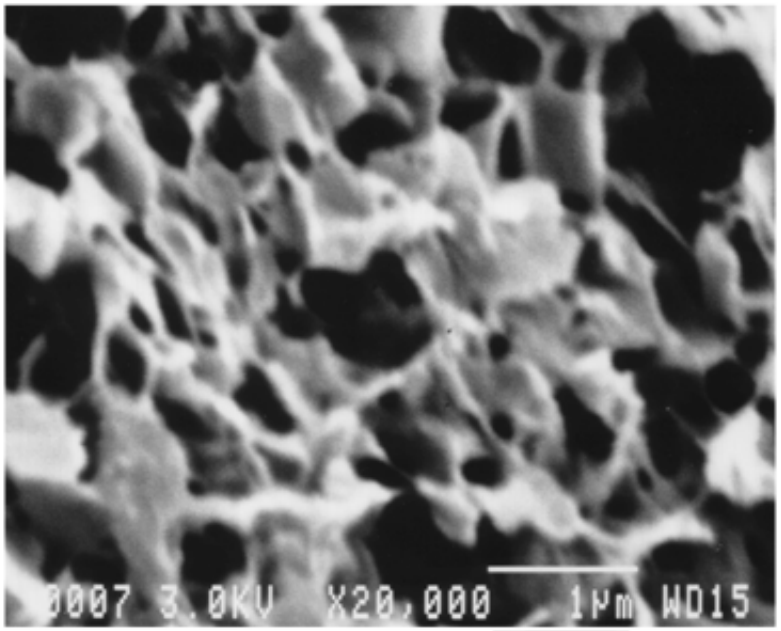
1 μm

SEM images of poly(4-methyl-1-pentene) prepared from 1-butanol solution



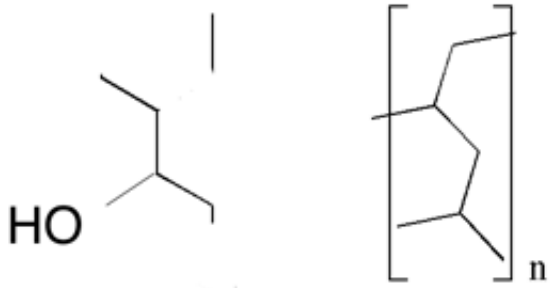


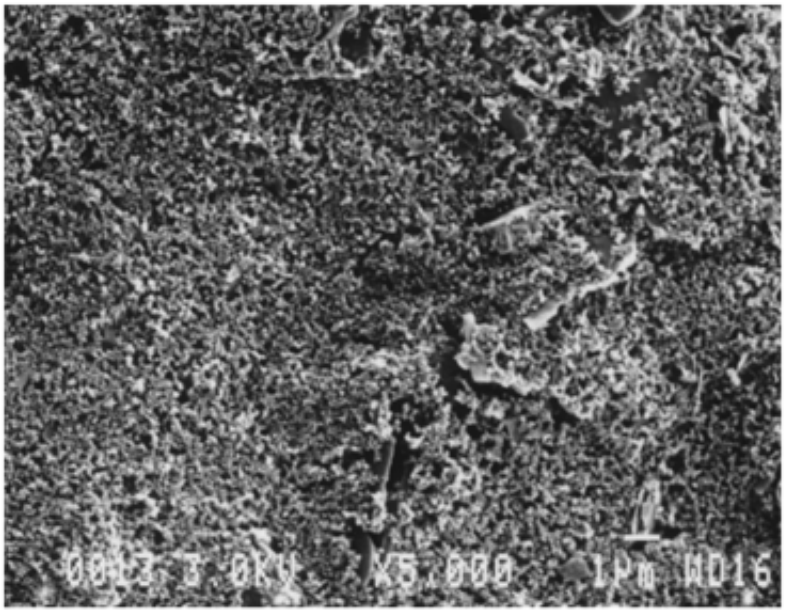
3 μm



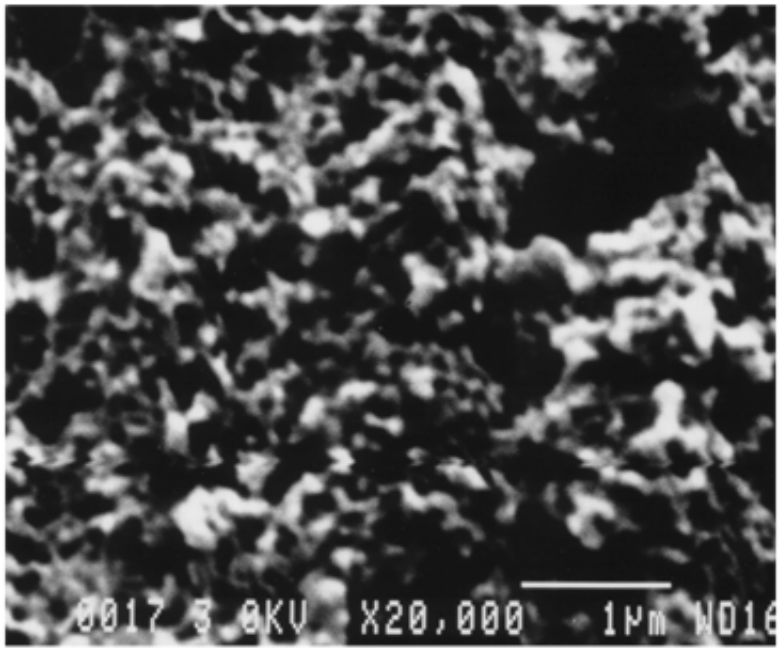
1 μm

SEM images of poly(4-methyl-1-pentene) prepared from 2-butanol gel



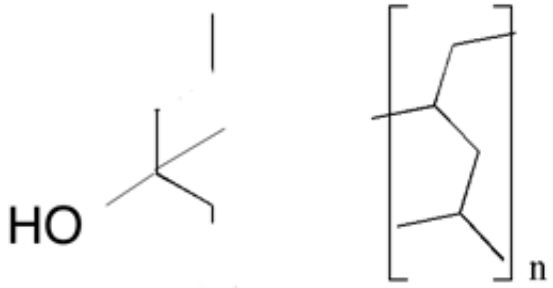


3 μm



1 μm

SEM images of poly(4-methyl-1-pentene) prepared from 2-methyl-2-propanol gel



Summary

ILE Osaka

We have prepared ultralow density PMP foams via density matched hexanol gel.

Lowest density reached to **twice of the air density**.

How to manupirate.

1) Microstructure was fine with **high affinity** between alcohol and PMP.

2) Sudden gelation using **butanol** derivatives induced fine microstructure (nanostructure).