Skin compatible Microemulsions obtained by a new PIT-Nano-Technology Approach

Jörg Schreiber, Ulrich Kux, Anja Eitrich, Klaus-Peter Wittern and Yvonne Cierpisz

R&D cosmed, Beiersdorf AG, Hamburg, D-20245, Germany

E-mail address: joerg.schreiber@beiersdorf.com

Synopsis

A new technology to achieve o/w microemulsions allows the formulation of transparent products with low surfactant content. The PIT Nanotechnology approach gives cosmetic/pharmaceutical o/w microemulsions in one step with a broad variety of surfactants, cosurfactants and oil phases.

Keywords

Phase Inversion Temperature, Microemulsion, PIT Nanotechnology, PIT Microemulsions

Introduction

Microemulsions are thermodynamic stable, clear optically isotropic dispersions of two immiscible liquids (water and oil) containing appropriate amounts of surfactants and cosurfactants [1,2]. One can distinguish between O/W, W/O and bicontinous microemulsions. The droplet size of O/W microemulsions ranges from 10-100 nm. These systems offer several advantage compared to other cosmetic/pharmaceutical delivery systems like increased solubility for lipophilic acitves, increased bioavailability etc [3]. High-pressure homogenization of emulsions is one suitable method to produce the corresponding transparent products, but it is an expensive method. This article describes an alternative method by which o/w microemulsions are produced at the Phase Inversion Temperature (PIT), enabling the formulation of transparent products with low surfactant content.

PIT Emulsions

When mixtures of ethoxylated surfactants, cosurfactants, oil and water are heated, they show a phase inversion from an o/w emulsion to a w/o emulsion [4]. The temperature (which is actually a temperature range) where this inversion occurs is called the phase inversion temperature (PIT). Cooling a suitable w/o emulsion to room temperature from 60-85°C produces another phase inversion that yields a finely dispersed bluish-white o/w emulsion (PIT emulsion). The droplet sizes are typically from 90 to 260 nm [5].

Careful studies on the nature of the PIT area showed that the interfacial tension between the oil and water phase is very low (10^{-4} mN/M) [4]. One explanation is the formation of a microemulsion or a lyotropic lamellar liquid crystal at 60-85°C, leading to the high solubilization capacity for water and oil and the final stability of the PIT emulsion [6,7]. After cooling, the interfacial tension of the resulting PIT emulsion is 10^{-2} mN/M [8]. Unfortunately, the microemulsion formed in the PIT area does not survive at room temperature with the process described. The resulting products are white or bluish-white emulsions but not microemulsions.

We developed a new o/w microemulsion technology, which we call the PIT Nano Technology approach, that allows us to formulate transparent products with low surfactant content [9,10]. This approach gives cosmetic and pharmaceutical o/w microemulsions in one step with a broad variety of surfactants, cosurfactants and oil phases.

Insert Figure 1

Method and Materials

Equipment

Determining the phase inversion temperature:

A change in electrical conductivity characterizes the inversion of the w/o emulsion to the o/w microemulsion. We measured conductivity as a function of temperature with a conductivity meter[a] at 50/60 Hz, 230 V and 10 VA. The cooling rate was approximately 1°C/min.

[a] WTC Microprocessor Conductivity Meter LF 539, Wissenschaftlich-technische Werkstätten, Weilheim, Germany

Measuring the droplet size distribution:

The droplet size distribution was determined at 23°C by Photone Correlation Spectroscopy.[b] For this purpose, the microemulsions were diluted with water to an appropriate concentration.

[b] N4 Plus, Coulter Electronics GmbH, Krefeld, Germany

Preparing PIT Microemulsions:

We tested a variety of surfactants, cosurfactants and oil phases with water and glycerol in the eight formulations shown in Table I and prepared one kilogram of each microemulsion according to the procedure shown in the table.

Insert Table I

Results and Discussion

When mixtures F1-F7 were cooled from 85°C to room temperature, we observed a dramatic change of the properties of the initial w/o emulsions. The different formulations, which are typically white at high temperatures, show an increased transmission of light when prepared by the PIT Nano Technology approach, as opposed to the PIT technology approach (Figure 1).

We tested several oil phases of different polarity, molecular weight and structure (ester oils, triglycerides, ethers, cyclic alcanes, branched long chain alcohols, silicone oils). We observed formation of microemulsions with coco-caprylate/caprate, caprylic/capric triglycerides, dicaprylyl ether, diethylhexylcyclohexane, octyldodecanol, cyclomethicone. Oils like heptane and octane that have an irritation potential can now easily be replaced by more skin-friendly lipids.

We tested different surfactant/cosurfactant combinations for their ability to form o/w microemulsions. Numerous combinations are possible. Among the surfactants and cosurfactants were Isoceteth-20, PEG-25 Stearate, PEG-20 Sorbitan Stearate, Glyceryl Isostearate and Sorbitan Isostearate.

Figure 2 shows the conductivity of the heated F1 mixture as its temperature is allowed to fall. The phase inversion occurs from 75°C to 70°C. An observer will notice that the mixture becomes transparent in the temperature range from 70°C to 65°C, and from 65°C to room temperature it remains transparent.

Insert Figure 2

Measuring the droplet size distribution

The droplet size was determined at 23°C by Photone Correlation Spectroscopy. The resulting droplets are extremly small (37-67 nm).

Insert Table II

It is interesting to note that changing, for example, the surfactant/cosurfactant ratio or the oil volume of the formulations gives the typical bluish-white PIT emulsions. For example, whereas Formula 1 gives a transparent microemulsion; the slightly different Formula 8 gives a bluish-white PIT emulsion (100 nm).

Insert Figure 3

These "magic w/o emulsions" at higher temperatures, that show an inversion to o/w microemulsions after cooling, were obtained with the broad variety of surfactants and oil phases listed in Table 1.

Above the phase inversion area the mixtures are very viscous because they contain a large amount of the internal phase (water). They can be regarded as high internal phase emulsions (HIPE) where densely packed water droplets exist. This explains the high viscosity of the different formulations. The PIT of a microemulsion for commercial purposes should, for practical reasons, lie between 60°C and 85°C. Otherwise, the system is transformed into other colloidal phases (w/o emulsions, liquid crystals) at room temperature and a loss of transparency is possible in this case.

The formation of nanodroplets with a low surfactant content is usually achieved by other technologies, such as high-pressure homogenization. Our approach avoids this expensive preparation method.

This simple approach to PIT microemulsions or PIT emulsions by changing the surfactants, oil phases, and ratios of surfactants and cosurfactants gives the formulator more flexibility to design unique mixtures with the same ingredients. Furthermore, raw materials costs for different cosmetic/pharmaceutical products can be reduced using this concept.

Mechanism of Microemulsion Formation

Based on these data, we propose that the formation of o/w microemulsions occurs via the following steps during cooling of the mixtures (Figure 1):

1. Formation of a w/o emulsion
2. Phase inversion
3. Formation of an o/w emulsion
4. Formation of an o/w microemulsion

The temperature where the different steps occur depends, of course, on the choices of the raw materials, surfactant/cosurfactant ratios, lipids and other additives.

Other researchers have been unable to form microemulsions with a low emulsifier content. One possible explanation for this statement is the fact that commercial surfactants are not pure; they consist of a polydisperse distribution of both ethylene oxide units and hydrophobic alkyl chains with different chain lengths. Therefore, looking for new microemulsions with commercial surfactants is often akin to finding a needle in a haystack.

Applications with Actives

The incorporation of actives (lipophilic, hydrophilic) in microemulsions was studied in detail for the new nanoemulsification technology. Sprayable bluish-white PIT technology-based emulsions are already being used in marketed sun sprays, body sprays and deodorants. The deodorants

incorporate skin-friendly deodorizing actives such as wool wax acid, glyceryl monocaprylate and aluminum chlorohydrate.
The new PIT Microemulsion Technology enables incorporation of actives in transparent products. The disadvantage of hydroalcoholic transparent products (such as eau de toilettes, hair tonics, face tonics, sun sprays and deodorant pump sprays) is their alcohol content, which reportedly causes dry skin, enhanced penetration and stinging in the shaved axilla of some consumers. Since transparency is often desired for cosmetic/pharmaceutical products, alcohol-free microemulsions represent an interesting alternative. Other advantages of microemulsions from the PIT nanotechnology approach are shown below.

Advantages of the PIT Nano Technology Approach

- Ease of preparation
- One-step process to new low-viscosity o/w microemulsions
- Fresh sensation after topical application
- Good spreadability
- Sprayable
- Broader variety of cosmetic oils and lipids compared to other systems
- Formulation of alcohol-free products
- Encapsulation of lipophilic actives in the nanodroplets
- Controlled release of actives
- Low surfactant content
- Skin care
- Inexpensive formulations
- Good skin compatibility

One example is a skin-friendly microemulsion for a deodorant pump spray with actives (e.g. glyceryl caprate, aluminum chlorohydrate). Personal Care products (Basis pH, Nivea) were introduced in 1996 and 2003 respectively into the European market. Incorporating both actives and a fragrance did not affect the product's transparency.
Another example is a self-tan spray recently introduced under the Nivea brand. This product contains dihydroxyacetone (DHA) in an o/w microemulsion based on the PIT Nano Technology approach.

Summary

The new PIT-Nanotechnology Approach allows the formation of transparent products. Furthermore, by changing the surfactant/cosurfactant ratio, the oil phase and/or preparation method, one can obtain finely dispersed o/w macroemulsions (PIT emulsions) with the same ingredients. Short-chain surfactants and oil components with an irritation potential can be avoided with this process.

The microemulsion formation requires a smaller amount of surfactants/cosurfactants than other published systems. The technology offers flexibility in choosing different surfactants/cosurfactants and oil phases. Furthermore it could be demonstrated that upscaling up to five tons (5 t) was successfull.

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of PIT- Microemulsions and PIT- Emulsions

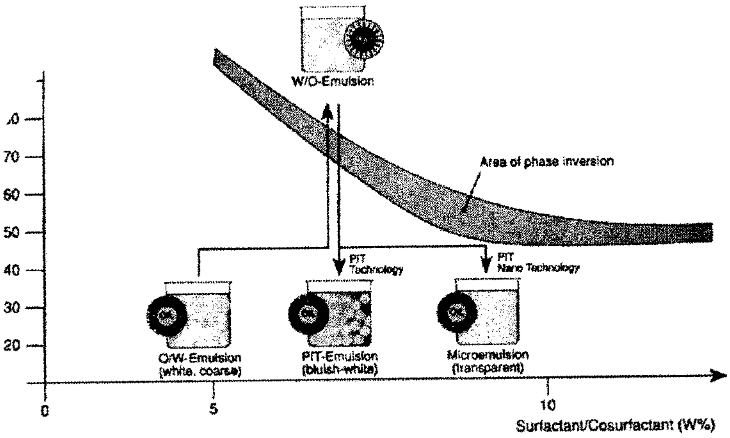

Figure 1 Preparation Method

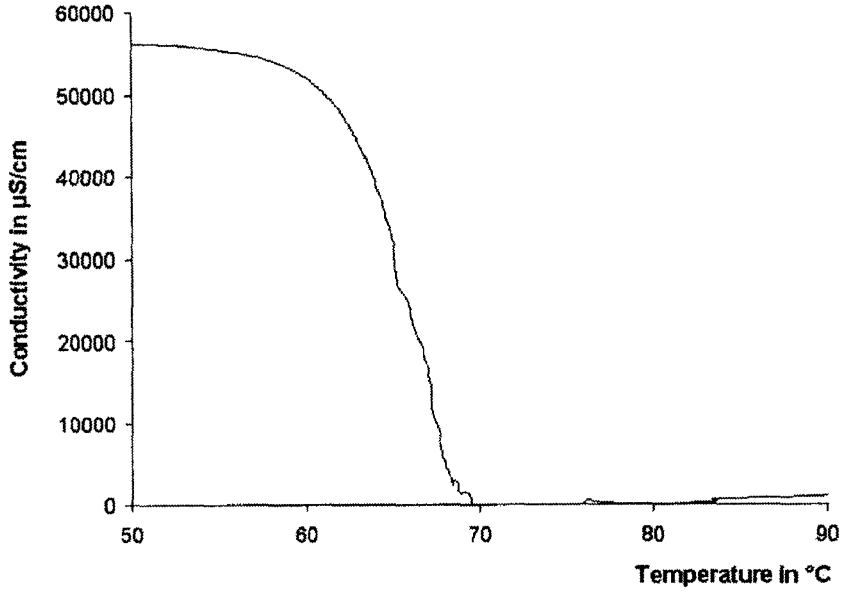

Figure 2 **Conductivity curve**

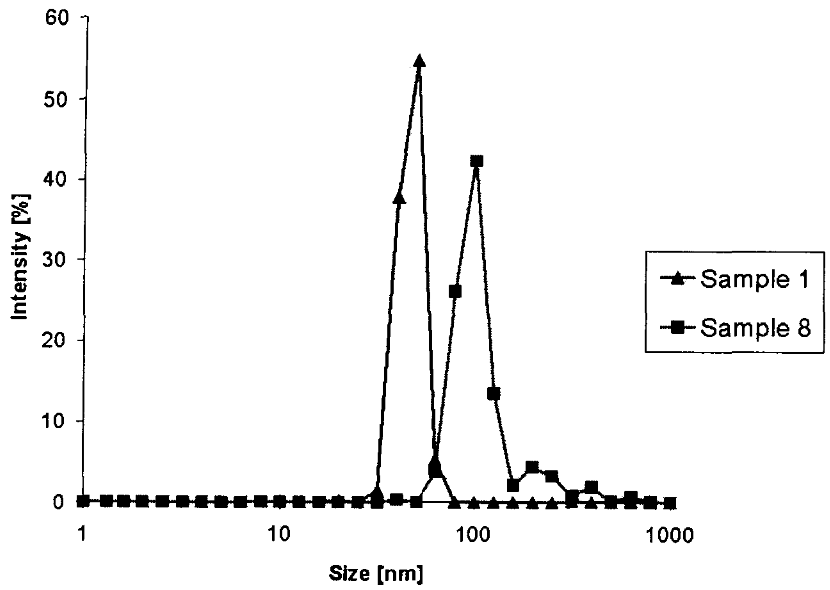

Figure 3 Droplet size distribution curve

Table I. The tested formulations (wt %)

	Ingredient	F1	F2	F3	F4	F5	F6	F7	F8
A	*Oil phase*								
	Isoceteth-20	4.6	4.6	4.6	4.6	4.6			4.6
	PEG-25 stearate						4.6		
	PEG-20 sorbitan isostearate							4.6	
	Glyceryl isostearate	2.4	2.4	2.4	2.4	2.4	2.4		2.4
	Sorbitan isostearate							2.4	
	Dicaprylyl ether	5.0	5.0				5.0	5.0	15.0
	Cyclomethicone	5.0					5.0	5.0	
	Caprylic/Capric triglyceride			5.0					
	Diethylcyclohexane				5.0				
	Coco-Caprylate/Caprate					5.0			
B	*Water phase*								
	Glycerol	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
	NaCl	5.0							
	Water	75	85	85	85	85	80	80	75

Procedure: To prepare 1 kg of each microemulsion, heat A and B separately to 85°C. Add B to A with mixing. Cool to room temperature. The cooling will be accompanied by an increase in the transparency of the mixture
(F1 to F7; in comparison: F8: white formulation).

Table II. Droplet size (nm) of the tested formulations

	F1	F2	F3	F4	F5	F6	F7	F8
Particle size	47	32	45	30	38	38	67	100

IFSCC2003 Seoul 22-24 Sept. Seoul, Korea

ABSTRACT SUBMISSION FORM

Submission Deadline: Dec. 20, 2002

Date : Dec. 16. 2002

■ Author's Information

First Name	MAN-SEOK		Last Name	SEO	
Title	□ Prof. □ Dr. ■ Mr. □ Ms. □ Other		Position	Senior Researcher	
Institution	COSMAX R&D Center		Department	MAKEUP R&D	
Address	902-4,Sang Sin Ri,Hyang Nam Myeon,Wha Sung Si,Kyeong Ki Province Korea				
City	Wha-Sung	Zip Code	445-922	Country	Korea
E-mail	cedrik@orgio.net	Telephone	82-31-353-6070-212	Fax	82-31-353-6086

■ Co-Author

First Name	Last Name
K.H.	CHOI
K.J.	YOO
J.H.	BOO
C.K.	JUNG

■ Presentation Preference (Please check only one)

Oral		Poster	✓

■ Subject Classification

□ Advances in skin/hair-care research/Active Ingredients

■ Advances in Formulation Technology

□ Advances in Evaluation techniques for efficacy and safety

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C/O Co & Ex Co., Ltd.
5Fl. Seam Bldg., 184-4 Sukcheon-dong, Songpa-gu, Seoul 138-844, Korea
Tel: +82-2-416- 3672, 416-3673 Fax : +82-2-424-5675
E-mail: ifscc2003@ifscc2003.or.kt
Homepage: www.ifscc2003.or.kr

Powder Surface Treatment using Oxygen(O_2),Argon(Ar) Plasma

M. S. Seo[1], K. H. Kwon[1], K. J.Yoo[1] and C. K.Jung[2], J. H.Boo[2]

[1]*R & D Center, Cosmax INC, Wha-Sung 445-922, Korea*

[2]*Dept. of Chemistry, Sungkyunkwan University.Suwon 440-746 Kyung-gi, Korea*

A lot of powders including organic, inorganic, etc are using in cosmetic industry. Among them, Nylon powder has key role in improving sensory feeling. So Nylon powder has been used all over the world. But, this one is hydrophobic so, it's very hard to use in water-dispersing cosmetic products. We think that if neutralized and ionized oxygen is incorporated into Nylon powder, we can easily use it. We make it possible using atmospheric plasma treatment equipment. We could change it hydrophobic into hydrophilic. Moreover we can find that treated Nylon is subject to have more moisturizing effect.