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Features

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Cosmetics in Nanocups – The Smallest Beauty Cases in the World

With the growing wellness trend, highly active ingredients, such as vitamins have been playing a greater role in anti-aging agents and anti-wrinkle creams. However, the major drawback of all these substances is that they decompose easily when exposed to light and air, and thereby lose their effectiveness. WACKER has developed a way of protecting sensitive substances like these: each molecule is packaged in a tiny "sugar cup" just millionths of a millimeter high and is selectively released only when it makes contact with skin moisture.

Boom in anti-aging agents

Most of us would like to remain healthy as we grow older. Already, a third of Germany's population is over 60 and the proportion is rising. But the trend is towards arresting the symptoms of aging at the earliest possible stage. The 30-50 year-old target group, in particular, spends a lot on looking good. Food supplements, skin care products (cosmetics for internal and external use are all the rage), healthy nutrition and exercise are all part of the wellness trend. Cosmetic products with additional benefits, such as vitamins (preferably natural vitamins, and therefore from renewable sources) or essential oils, are extremely popular. As the European

cosmetics industry association, Colipa, states on its web site, the European cosmetics market was worth 60 billion euros in 2005, with a growth of 3.9 % in the principal personal care products alone.

Many substances lose their effectiveness in air and light

In recent years, a wide variety of vitamins, co-enzymes and oils have proved to be highly effective ingredients in such creams, but they suffer from a major disadvantage, namely they are sensitive to UV radiation and elevated temperatures, and some, such as retinol (also known as vitamin A), are even unstable in atmospheric oxygen. When exposed unprotected to light and air, these substances rapidly decompose and lose their effectiveness.

Ingenious idea: wrap each molecule individually

Marlies Regiert, responsible at WACKER FINE CHEMICALS for the development and marketing of cyclodextrins for the cosmetics and perfume sector, recalls how it all began. “Several years ago, when one of the top cosmetic companies was extremely keen on using the most stable retinol possible in its products, I thought that it ought to be possible to individually package these molecules in tiny capsules that would not only protect them, but also selectively release them again on the skin.” Ms. Regiert then went on to prove that this actually works in practice and that the desired product can be made to a very high quality level when she invented cyclodextrin-retinol complexes – which she fondly calls “the smallest beauty cases in the world.”

Patented by WACKER, these and similar molecular

Patented molecular complexes

complexes are now found in a wide variety of anti-wrinkle creams – and this is only the beginning. “The method we have developed for protecting sensitive substances and selectively releasing them again at the target site is so successful that we keep finding more uses for them – even inserts for shoes can be given a pleasant odor and treated with anti-bacterial substances.

Like nanometer-sized waffles

At the heart of this development are cyclodextrins, which are the natural decomposition products of starch (cyclodextrin basically means “a ring of dextrin sugar”). They are ring-shaped molecules that resemble sawn-off ice-cream cones, i.e. they are hollow. They can host guest molecules in their cavity much like a cone holds a scoop of ice-cream. But, whereas the ice-cream melts, the guest molecules remain perfectly secure for a long time inside the cyclodextrins, without the need for strong chemical bonds. The explanation of the mechanism behind this host-guest relationship earned the 1987 Nobel Prize in chemistry for Donald J. Cram, Jean-Marie Lehn and Charles Pedersen.

Tiny amounts of water release the active ingredients

Cyclodextrins prefer to host guests that have an aversion to water, such as fat-soluble vitamins, oils and the fragrances in perfumes. These guests remain inside their hosts until they are flushed out again by an excess of water. The water molecules attach themselves to the outside of the cyclodextrin-active ingredient complexes, and this changes their three-dimensional structure enough to terminate the relationship between host and guest molecule. “All it takes to release the guest

molecules is the small quantities of moisture that each one of us has on our skin," she adds. And so, what she set out to achieve has in fact been accomplished. The active ingredients, e.g. retinol, are safely tucked away inside the cyclodextrin contained in the creams and thus protected against environmental influences until they are released on the skin where they can unfold their healing action.

WACKER is the world's leading cyclodextrin manufacturer

A number of challenges had to be negotiated before this success was achieved. Thus, researchers and developers at WACKER had to devise ways of producing the cyclodextrins in a pure form and slashing their production costs. WACKER is now the world leader in the production of cyclodextrins. For the last eight years, these have been made by biotechnological processes and sold as active ingredient complexes to customers all around the world under the names CAVAMAX® for naturally occurring cyclodextrins and CAVASOL® for chemically modified ones (e.g. cyclodextrin-retinol).

Ice-cream cones just 0.8 nanometers high

Since cyclodextrins are natural decomposition products of starch, they can also be made by this process. In WACKER's bioreactors, specific enzymes snip out tiny segments from, say, cornstarch and combine them to form cyclodextrin molecules. These come in three sizes, alpha, beta and gamma, which contain six, seven and eight glucose units respectively. The diameter of the cavity inside the "molecular ice-cream cone" varies from 0.47 to 0.83 nanometers from

alpha to gamma-cyclodextrin, and the depth of the “cone” is around 0.8 nanometers. A nanometer is a millionth of a millimeter or fifty thousand times thinner than a hair diameter, but it is still large enough for each cyclodextrin molecule to trap and “neutralize” at least one of the even smaller molecules of vitamins or oils.

A beauty case for vitamin A

Finding out which cyclodextrins are best suited to which substances and how to produce the corresponding host-guest complexes are some of the most important tasks facing Marlies Regiert and her colleagues. For the cyclodextrin-retinol complex, they hit upon a particularly elegant solution. Although the retinol molecule fits very well inside gamma-cyclodextrin, it is such a long molecule that it sticks out at the end. So it was simply protected with two cyclodextrins that “close around the retinol like the two halves of a tiny suitcase,” says Ms. Regiert, describing the complex’s three-dimensional structure. In the case of vitamin F, which is an even longer molecule, it takes as many as four cyclodextrins in a row to envelop and protect it.

Retinol levels virtually unchanged, even after more than a year

This approach works so well that, for example, only three percent of a cyclodextrin-vitamin F complex is chemically decomposed by UV radiation and heat on a hot sunny day, whereas a mixture of unprotected vitamin F would be totally destroyed within the same period. Packaging the retinol inside the cyclodextrin suitcase works just as beautifully. When cyclodextrin-retinol complexes are stored in plastic tubes at room temperature, the retinol content is almost unchanged

after a year, whereas a mixture containing unprotected retinol has hardly any retinol left after just a few months because it has been chemically destroyed.

Aside from their longer shelf life, cyclodextrin complexes enjoy other major advantages:

More active ingredient per dose

- The active ingredients are released slowly and selectively over hours, and sometimes days, at a rate governed by the skin moisture level. For this reason, it only takes small amounts to achieve huge effects.

... and no unpleasant odors

- Manufacturers can also increase the quantity of active ingredient in a cream without having to worry about harmful side-effects caused by chemical decomposition products.

Stable for years on end

- Tea tree oil reveals a further benefit of cyclodextrin-complex packaging, which masks the oil's intense, resinous odor that otherwise might deter purchasers.

Dermatologically safe

In all these applications, it is naturally important that the cyclodextrins be absolutely dermatologically safe. So far, tests have failed to reveal any negative or even allergic reactions on the skin. This is why, for example, beta-cyclodextrin has been an EU-approved food additive for several years.

Various applications

"We have now developed cyclodextrin complexes for the most important anti-aging active ingredients, and our customers, the cosmetic manufacturers, have also been

using them in various products," says Ms. Regiert. "For example, linoleic acid can at last be used in cosmetic preparations."

Awarded concept

Until now, this fatty acid's skin-care and restorative properties had hardly been used in cosmetic formulations because it rapidly develops an intense rancid odor on exposure to air and light. "Our new α-cyclodextrin-linoleic acid complex protects and stabilizes the linoleic acid to the extent that it can be used in many different personal-care products," says Marlies Regiert. The idea has even won an award: The European Innovation Prize for Cosmetics and Chemical Raw Materials, which was awarded in October 2006 at the SEPAWA Congress in Würzburg, placed the cyclodextrin-linoleic acid complex in the "Most Innovative Natural Raw Material Concepts" category.

Background information on how anti-aging agents work

Skin aging is influenced by many factors. These can be harmful substances in our diet or the environment, along with UV radiation from the sun and the free-radicals that form in our bodies as harmful byproducts of vesicular breathing. The cells will repair the damage themselves for many years, but will not always be 100 percent successful. Over time, the skin is no longer provided with enough nutrients, and loses its suppleness and moisture. Anti-aging products attempt to supply the missing substances from the outside:

- Vitamin A (retinol) stimulates cell production in the skin and promotes shedding of dead skin cells. It also reduces acne and helps in the treatment of psoriasis.
- Vitamin E (tocopherol) and the coenzyme Q10 (ubiquinone) produced in our body mop up free-radicals and prevent them from doing damage. Q10 is also important for vesicular breathing and the energy metabolism of the skin.
- Linoleic acid is an essential fatty acid for humans and is a regular component of human skin. Its skin-care and restorative properties can counteract skin irritation, chronic light damage and age spots. It reduces the transepidermal water loss of the skin and is particularly effective when applied externally.
- Tea tree oil, whose principle active ingredient is the readily volatile terpinene-4-ol, is very good for treating greasy skin and acne because of its anti-bacterial, disinfecting action.

Cyclodextrin complexes produced so far by WACKER

CAVAMAX® W8/retinol complex: stable, highly effective vitamin A, tolerated by the skin
CAVAMAX® W8/tocopherol complex: UV-stable antioxidant
CAVAMAX® W6/linoleic acid complex: odorless vitamin F, stable to oxidation
CAVAMAX® W7/tea tree oil complex: stable, natural, reduced-volatility, odorless/low-odor essential oil with biocidal action
CAVAMAX® W8/menthol complex: low-odor, reduced-volatility cooling agent
CAVAMAX® W7/menthol complex: low-odor, reduced-volatility cooling agent
CAVAMAX® W7/citral complex: stable, reduced-volatility citrus fragrance
CAVAMAX® W6/biotin complex: improved water soluble vitamin H

General application areas of cyclodextrins

Generally, cyclodextrins can be used to modify the properties of other substances, such as to enhance their solubility or stability or to reduce their volatility.
Concrete examples are (already in existence or in preparation):
Pharmaceuticals: Molecularly encapsulated active ingredients. The substances are more stable and can be more easily dosed. Disagreeable odors or tastes, such as occur with garlic tablets, are masked (a large number of drugs are marketed, mainly in Japan; Europe is also a strong contender: prostaglandins, antiphlogistic agents, fungicides).
Cosmetics: Active ingredients in cyclodextrins do not decompose as quickly and do not have an unpleasant smell. Perfumes would be another interesting application area, because the cyclodextrins can ensure that the readily volatile substances persist on the skin and that all components of the perfume are emanated at the same time. The technological challenge here would be to incorporate the several hundred individual perfume ingredients into cyclodextrin complexes.
Food: Here, too, cyclodextrins are already in use to increase the stability – i.e. shelf life – of vegetable oils, vitamin A and aromas, to mask smells (e.g. fish oil), to remove bitter substances and to convert liquid substances such as honey and fruit juices into powder form.
Household / **textiles:** Use of cyclodextrins in fabric fresheners (spray on), masking odors, sweat, smoke on clothing, curtains, bed linen, etc. Cyclodextrins as stabilizers for perfumes, and depots for fragrances or anti-fungal agents.
Construction industry Inclusion in cyclodextrin makes it possible for the first time to use fragrances in different, non-hydrophobic applications within the building sector, such as coatings and surfacing. For instance, the fragrances may inhibit or kill bacteria, molds and fungi, or act as animal and insect repellents.

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The company in brief:
WACKER is a globally active chemical company with some 14,700 employees and annual sales of around €3.34 billion (2006).
WACKER has 22 production sites and over 100 sales offices worldwide.

WACKER SILICONES
Silicone fluids, emulsions, rubber and resins; silanes; pyrogenic silicas; thermoplastic silicone elastomers

WACKER POLYMERS
Dispersible polymer powders and dispersions for applications in the construction industry; PVAc-solid resins; VC copolymers; polyvinyl butyrals and acetates

WACKER FINE CHEMICALS
Fine chemicals, biologics and other biotech products, such as cyclodextrins and cytokine

WACKER POLYSILICON
Polysilicon for the semiconductor and photovoltaics industries

SILTRONIC
Hyperpure silicon wafers and monocrystals for semiconductor devices