“Novel Non-Penetrating Sun Protection Technology Significantly Reducing UV filter Concentrations, their Environmental Footprint, and Human Systemic Absorption"

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1. Introduction

The global suncare market and the fast-growing share of personal care and make-up products claiming a UV protection, is under growing scrutiny from both regulators and consumers due to concerns about environmental impact[1,2,3] and potential toxicity[4]. While topical sun protection is widely acknowledged as a critical public health measure, its increasing year-round use has raised systemic toxicity concerns. Additional concerns include potential endocrine disruption, skin sensitization, and environmental issues such as persistence and marine ecotoxicity.

This paper introduces a novel patented encapsulation technology designed to address these challenges. This technology has been designed to prevent systemic absorption of UV filters while enhancing sun protection efficacy (namely SPF yield[5]) and minimizing environmental impact. Interestingly, the encapsulated structures also provide a soft-focus effect on skin, also improving the sensory experience during application.

The technology utilizes interfacial cross-linking of polyurea derivatives to create sub-micron spherical biodegradable matrices (mean size: 400 nm) that encapsulate UV filters. These structures combine UV-scattering and UV-absorbing properties, resulting in significantly enhanced Sun Protection Factors (SPFs).

2. Materials and Methods

Materials & methods

2.1 Test compounds
Encapsulated blend of UV Filters (Homosalate-Octyl salicylate-Avobenzone) (E-HOA)
Corresponding blend of free UV filters HOA

2.2 Materials
2.2.1 SEM analysis of polyurea crosspolymer-9 submicronic structures (Zeis)
2.2.2 PSD by laser diffraction (Malvern)
2.2.3 SPF and UVA PF responses to E-HOA concentrations in O/W formulation vs non encapsulated HOA (UV-2600 240V IVDD spectro-photometer (manufacturer: SHIMADZU) and Lambda 1050+ (manufacturer: PERKINELMER) equipped with an integrating sphere between 290 and 400 nm)

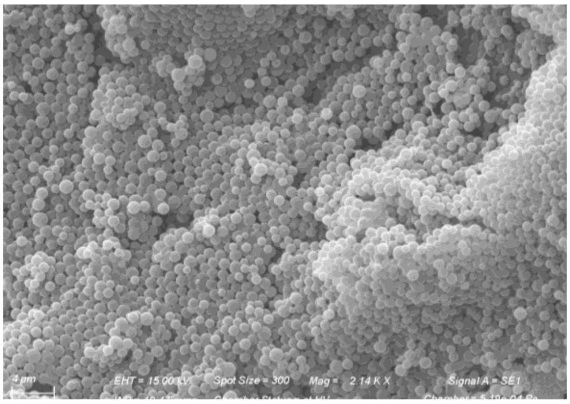
2.3 Methods
SPF response to E-HOA concentrations in O/W formulation vs non encapsulated HOA
Modified In Vitro test method:
The results are obtained using our internal in vitro tests inspired by ISO 24443:2021, specifically designed for the determination of the Sun Protection Factor (SPF) (HelioTest™ 1)*, UVA protection (HelioTest™ 2)*, and the calculation of the Critical Wavelength (CW) (HelioTest™ 3). To conduct these tests, the Helio+™* method is applied (developed for products containing water-soluble filters).

- A quantity of 30 mg is applied to sandblasted polymethyl methacrylate (PMMA) (1.2 mg/cm²).
- The test samples are applied to the rough side of the plate using a bare finger pre-saturated with the product to obtain the most homogeneous film possible.
- A series of 16 measurements is then carried out using a UV-2600 240V IVDD spectro-photometer (manufacturer: SHIMADZU) or Lambda 1050+ (manufacturer: PERKINELMER) equipped with an integrating sphere between 290 and 400 nm.
- An average of the absorbance measurements is then calculated, allowing the determination of the SPF, UVA, and CW photoprotection indices."

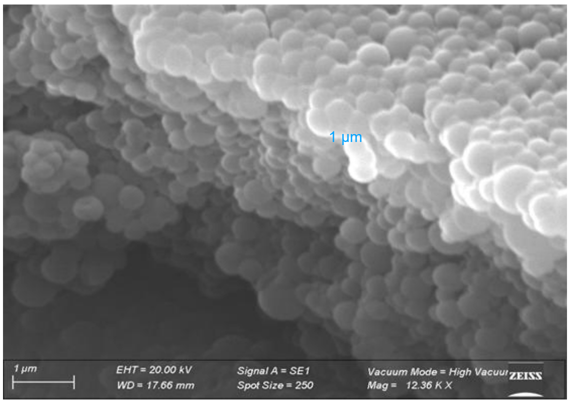
In Vivo SPF measurement as per ISO 24444 method[6] (test on 5 volunteers)

3. Results

3.1.1. Scan Electron Micrograph on submicronic capsules of polyurea cross polymer-9 loaded with a blend of UV Filters (E-HOA)



Polyurea capsules loaded with
UV Filters blend (HMS/ OS/ BMDBM)



Dried layer 2 mg/sqm2
on a PMMA plate

Figure 1. The left image displays monodisperse submicron capsules with particle sizes falling within the UV-visible light range. The right image shows a dried film on a PMMA substrate, demonstrating structural adhesion and the formation of a cohesive optical layer—resembling the expected behavior of a sunscreen film upon skin application.

The polyurea cross-polymer demonstrates strong resistance to physical stress, as evidenced by its structural integrity under high vacuum conditions during scanning electron microscopy (SEM), indicating the robustness and compactness of the capsules. Additional tests confirmed that these nanostructures withstand exposure to cosmetic emollients, water, surfactants, mechanical stress, and high shear forces. This stability is essential to prevent the release of UV absorbers into the skin layers."

3.1.2 Particle Size Distribution by laser diffraction

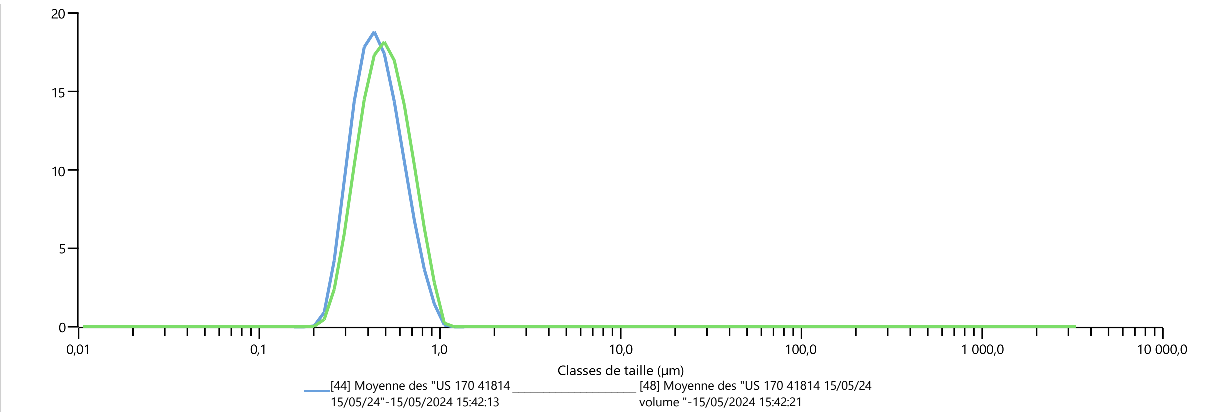


Figure 2. Particle size analysis and SEM

Ds (10) 0,305 µm

D [3;2] 0.470 µm

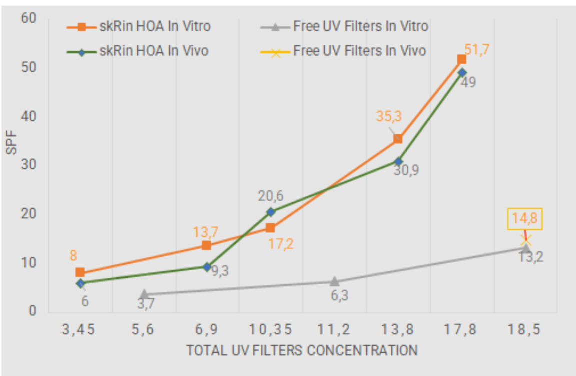
Ds (50) 0,443 µm
Ds (90) 0,673 µm

Observations: Approximately half of the capsule population exhibits diameters within the UVB/UVA wavelength range, while the remainder falls within the visible light spectrum.

3.1.3 In Vitro and In Vivo SPF and UVA protection performance

Phase	Commercial Names	INCI Names	%
A	DI water	Aqua	qs 100
A	Xanthan FEDCS-PC	Xanthan gum	0,1 – 0,5
A	Vivapur® CS TEX Sun	Microcristalline cellulose (and) Cellulose gum	0,2
B	Eumulgin® SG	Sodium stearoyl glutamate	2
B	Silicone 350	Dimethicone	1
B	Crodamol™ IPP	Isopropyl palmitate	7
B	Unimer U-6	Triacontanyl PVP	1,5
B	Xiameter™ 2cst	Dimethicone	3
C	Bioxan SFT50	Tocopherol (and) Helianthus annuus seed oil	0,5
C	Euxyl™ 9010	Phenoxyethanol (and) Ethylhexyl glycerin	1
D	SkRin™ HOA	Water (and) Homosalate (and) Ethylhexyl salicylate (and) Butyl methoxydibenzoylmethane (and) Polyurea crosspolymer 9 (and) Tocopherol acetate (and) Polysorbate 20	tbd

Figure 3: Oil-in-water sunscreen screening formula used with variable concentrations of E-HOA (skrin HOA)



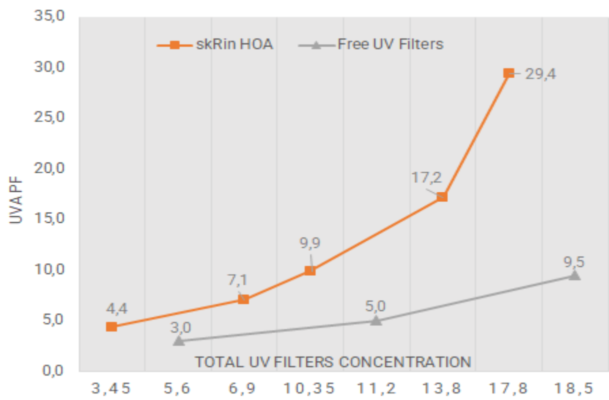


Figure 4: Left : In vitro and in vivo UVB protection factors in accordance to E-HOA concentrations in O/W formulation vs non encapsulated HOA . Right : in vitro UVA protection factors in accordance to HOA concentrations in O/W formulation vs non encapsulated HOA

Observations: The HelioTest™ protocol, adapted to assess the UVB protection factor of formulations containing different concentrations of microcapsules, demonstrates a strong correlation with in vivo SPF values measured according to ISO 24444.

A marked increase in the protection factor associated with E-HOA is observed once the concentration of UV filters reaches approximately 10%. This inflection point indicates a critical threshold in capsule content, beyond which optical coverage becomes significantly more effective. The subsequent exponential rise in protection suggests enhanced light-scattering or absorption efficiency. However, this increase plateaus due to the intrinsic loading capacity limit of the dispersion within the cosmetic formulation. The critical wavelength established for each formulation range between 370 and 377 nm

4. Discussion

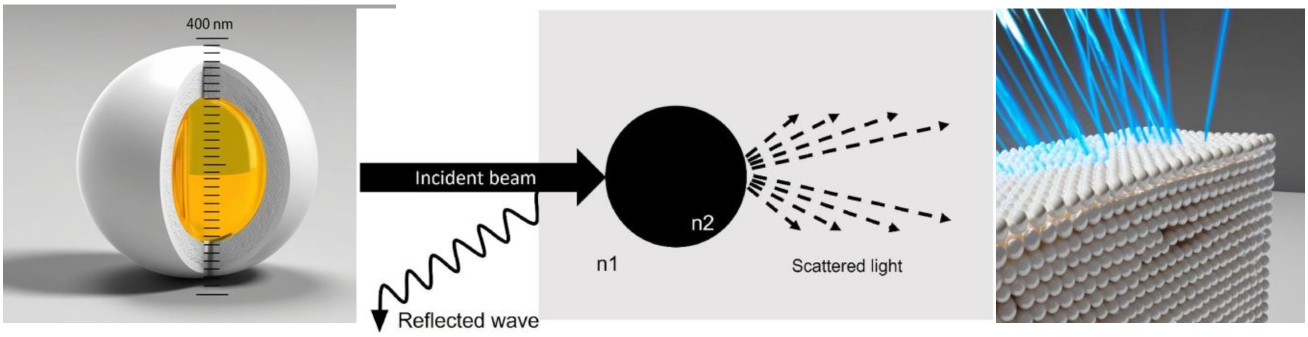


Figure 5. Modeling of an average submicronic composite, Electromagnetic radiation interaction with a translucent material

Mathematical modeling estimates that applying 2 mg/cm² of an SPF 50 formulation containing submicron microcapsules results in the deposition of approximately 10 to 20 billion capsules per square centimeter of skin. This corresponds to the formation of roughly 25 stacked layers of nanostructures on the skin surface. Particle size distribution (PSD) analysis revealed a specific surface area of 12 300 m² per kilogram of microcapsules—equivalent to approximately 1.7 football fields.

Optimizing nanostructure dispersity—through control of size enables absorption and scatering in the UV range while minimizing absorption in the visible spectrum. The optical properties of nanostructures, particularly their absorbance spectra, are strongly influenced by their size and shape. In general, smaller nanostructures preferentially absorb shorter wavelengths, including UV light.

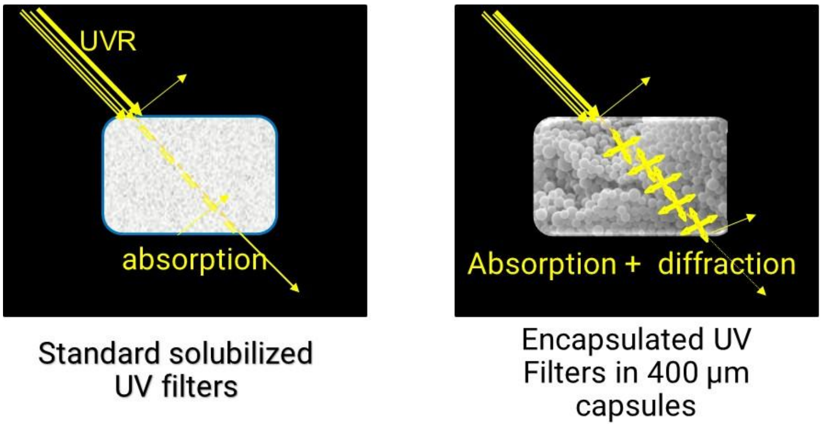


Figure 6: Theoretical Framework for the Proposed Physical Mechanism Underlying the Synergistic Reduction of Photonic Absorption

5. Conclusion

Encapsulation of organic UV filters is not a novel concept[7–8]. However, no existing technology has yet achieved commercial success due to limited efficacy or unfavorable cost-to-SPF yield ratios. Most approaches rely on either non-biodegradable polymers such as PMMA—which fall under the definition of microplastics—or on delivery systems with insufficient structural integrity and particle sizes exceeding the micrometer scale.

Complementary studies on the polyurea crosspolymer encapsulation technology described in this paper confirm the polymer's ready biodegradability, its non-delivery profile, the photostabilization effect and the absence of skin penetration.

These findings suggest a low risk of chronic toxicity and a substantial reduction in the potential for allergic reactions to UV filters. Notably, the most significant observation is the pronounced enhancement of UV absorption, enabling a 3- to 7-fold reduction in the required concentration of UV filters, as demonstrated across multiple experiments with various active ingredients.

The significant enhancement in UVB and UVA protection arises from a synergistic mechanism: the overlapping absorption of UV photons (UVA and UVB) by entrapped UV filters, combined with the diffraction and scattering of these photons by particles whose sizes fall within the ultraviolet wavelength range. This dual action amplifies overall photoprotection efficacy. This enhanced SPF efficiency translates into meaningful environmental and consumer benefits. By achieving high levels of photoprotection with reduced quantities of UV filters, the overall chemical load required in formulations is significantly lowered. This reduction not only minimizes the potential for systemic absorption of UV absorbers through the skin--thus improving safety and reducing the risk of allergic reactions--but also decreases the environmental impact associated with the production, use, and eventual release of these compounds. As a result, this approach supports a lower carbon footprint and promotes more sustainable sunscreen formulations, while also improving sensory attributes such as skin feel and wearability for consumer.

Acknowledgements

HelioTest™ 1, 2 & 3 are modified methods developed by Helioscience, Marseille France.

Literature

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