Color and Protection from UV, Vis and IR Radiation

ADP COSMETICS HAS DEVELOPED MULTIFUNCTIONAL MINERAL FILTERS FOR SKIN CARE AND SUN CARE FORMULATIONS.

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The solar radiation reaching our skin involves three components: UV, Visible (Vis) and IR light. Their depth of penetration and damage depends on their wavelength and energy. The UVB radiation (290-320nm) acts primarily on the epidermis, the most superficial layer, and partially penetrates the dermis. It is the most energetic radiation and it causes erythema (sunburn). The UVA radiation (320-400nm) passes through the dermis and is responsible for photo-aging and pigment darkening. Both UVB and UVA radiation induce delayed tanning and are associated with cellular damage (through direct or indirect DNA damage) and with potential risk of skin cancer.

Visible light (from 380 to 700nm) penetrates the skin passing through the epidermis and dermis to the subcutis layer. It can induce pigmentation in skin types IV–VI[1] (darker and more sustained than pigmentation induced by UVA[2]) and reactive oxygen species (ROS) generation. The most energetic visible light is blue light (BL) or High Energy Visible (HEV) light (380-500nm). Nighttime exposure to BL from computer screens disrupts circadian rhythms and sleep, which may lead to diabetes, obesity and heart diseases,[3] DNA damage, cell and tissue injury, eye and skin barrier damage, and photoaging.[4]

IR radiation is divided into IR-A (760-1400nm), IR-B (1400-3000nm) and IR-C (3000nm-1mm). IR-A can reach subcutaneous tissues whereas IR-B and IR-C are absorbed mostly in the epidermal layers and increase skin temperature.[5] IR radiation may damage skin collagen and dermis integrity by ROS radicals generation and by increasing the matrix metalloproteinases MMP-1 and MMP-9 activity. IR may induce premature skin aging (photoaging).[6]

At the same time, sun exposure promotes vitamin D synthesis, immune response, cardiovascular health and well-being feelings. Exposure to visible and IR-A radiation in early morning and late afternoon prepare the skin for the less beneficial effects of the mid-day UV radiation.[7] Moderate sun exposure throughout the year allow beneficial effects whether protection is included mainly from UVB, UVA, HEV radiation.

Titanium dioxide and zinc oxide are Generally Recognized As Safe and Effective (GRASE) for use in OTC sunscreens to protect from UV radiation. These mineral filters are usually commercialized as nanoparticles to minimize whiteness on the skin. However, the less visible/more transparent the filter is on the skin, the less effective in protecting against the UVA radiation. Besides, iron oxides when included in cosmetic formulations to obtain tinted formulation, may block HEV light and suppress Vis light-induced pigmentation.[8,9] Increasing the number of ingredients can hinder and lengthen formulations development, so multifunctional ingredients are preferred. This way simpler, cheaper and more sustainable formulas are achieved in accordance with market trends.

COLOR & UV, VIS & IR PROTECTION

In this context, a range of mineral filters composed of titanium dioxide and iron oxides (CI-77492, CI-77491, CI-77499)

are evaluated. The first reference is white while the rest of them present different brown shades depending on the INCI (see Table 1). All of them are characterized by a balance size larger than 100nm and remarkable broad-spectrum UV radiation protection properties.[10]

Reference	Color	Quantitative INCI (wt%)				
enhanceU	Shades	Titanium dioxide*	Silica	CI-77492	CI-77491	CI-77499
T	white	91 - 97	2–5	N/A	N/A	N/A
T-light	light-brown	88 - 95	2–5	1 - 3	0,5 - 1,5	N/A
T-medium	light-brown	82 - 90	2–5	6 - 8	1 - 3	0 - 2
T-warm	brown	72 - 78	1–5	13 - 17	1 - 5	0 - 3
T-tan	brown	67 - 73	1–5	13 - 18	4 - 8	1 - 5
T-rich	brown	61 - 67	1–5	15 - 19	5 - 9	4 - 8

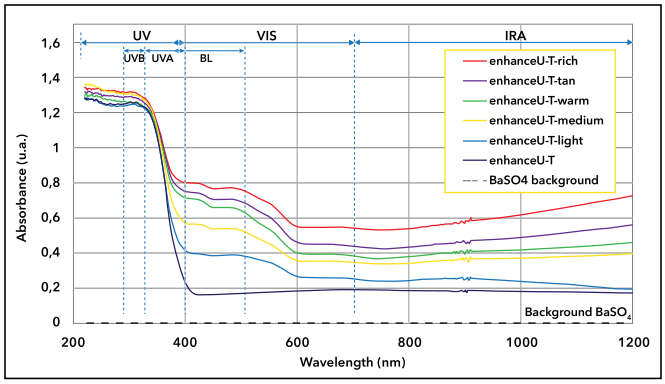
*Determination by ICP-OES technique (USP <730> validated method)

Table 1. Color and INCI of Mineral Filters

The absorbance properties of enhanceU filters in UV, Vis and near-IR regions were analyzed with a Shimadzu UV-2600i UV-Vis spectrophotometer with integrating sphere. The absorbance curves at increasing wavelength (Graph 1) confirm important UVB and UVA radiation protection (wavelengths 290-320 and 320-400nm respectively) for all the filters. From enhanceU-T to enhanceU-T-rich the iron oxides content increases (see quantitative INCI in Table 1) and so does the area under the absorbance curve (the curve is at higher values in this region) and thus the protection properties of these filters from UVA radiation.

This trend continues in the visible region (from 380-700nm), where the absorption of blue light, BL (380-500nm), is especially remarkable and proportionally increases with the iron oxides content of the filter (from enhanceU-T-light to enhanceU-T-rich, see Table 1). Thus, enhanceU-T-rich showed the highest absorbance of BL (and Vis) radiation explained by its higher iron oxides content. Interestingly, all color filters absorb in the near-IR region (from 700nm) with two main observations: the absorbance increases with iron oxides content and the curves tend to rise for all colored filters except for enhanceU-T-light, which does not contain black iron oxide CI-7499 in its composition. Although the wavelength stopped at 1200nm, it is deduced that the absorbance will continue to rise for the filters containing the three iron oxide pigments CI-7492, CI-7491 and CI-7499 in their composition thus protecting from IR radiation with higher wavelength.

In the other side, the absorbance curve of non-colored filter (enhanceU-T) showed important UVB and UVA protection (up to 400nm). In contrast, the absorbance of visible radiation



Graph 1. Absorbance Spectra of Mineral Filters

(380-700nm) and IR radiation (from 700nm) is much lower because there are not iron oxides in its composition. However, there is a residual contribution to the protection in these areas (0.2 u.a. with BaSO4 as background) due to the titanium dioxide particles size (>100nm).

In summary, enhanceU mineral filters have shown remarkable absorption of electromagnetic spectrum radiation up to wavelength of 1200nm which includes UVB, UVA, Vis and IR-A, and potential absorption at longer wavelengths.

PIGMENTS BOOST PROTECTION

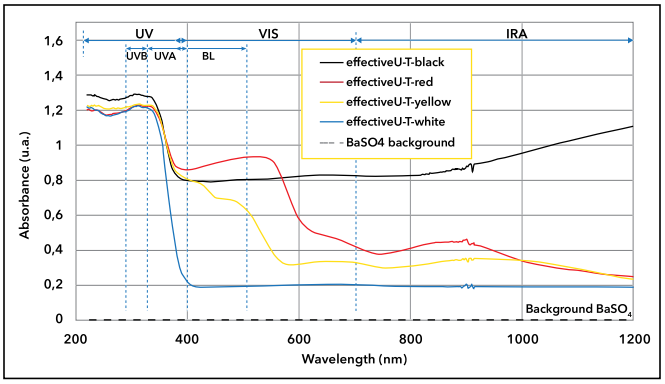
A range of mineral pigments developed to provide color and an increased protection against broad-spectrum UV radiation[11] is also evaluated. These pigments are composed of titanium dioxide and iron oxides, with balance size larger than 100nm responsible of the UV protection boosting properties (see Table 2).

Reference	Composition/quantitative INCI (wt%)				
effectiveU	Titanium dioxide*	Silicon dioxide	CI-77492	CI-77491	CI-77499
T-white	94 - 99	0–5	N/A	N/A	N/A
T-yellow	63 - 69	0–5	25 - 29	N/A	N/A
T-red	63 - 69	0–5	N/A	28 - 32	N/A
T-black	63 - 69	0–5	N/A	N/A	28 - 32

*Determination by ICP-OES technique (USP <730> validated method)

Table 2. Quantitative INCI of Protection-Boosting Mineral Pigments

The absorbance properties in UV, Vis and near-IR regions were analyzed with a Shimadzu UV-2600i UV-Vis spectrophotometer with integrating sphere. The absorbance curves at increasing wavelength (Graph 2) confirm important UVB and UVA radiation protection properties (wavelength 290-320 and 320-400nm, respectively): the absorbance curve is kept at values higher than 0.8-0.9 (u.a.) for the yellow, red and black pigments showing higher absorption of UVA radiation than



Graph 2. Absorbance Spectra of Protection-Boosting Mineral Pigments

the white pigment. The absorbance profile from 380nm is different for each sample. Thus, the white pigment only shows residual absorbance in Vis and IR regions (0.2 u.a. with BaSO4 as background, wavelength 380-700nm and 700-1200nm, respectively) due to the titanium dioxide particles size (>100nm). The color pigments showed important absorbance in Vis and IR regions (wavelength 380-700nm and 700-1200nm, respectively). More specifically, effectiveU-T-red showed remarkable blue light, BL (380-500nm), absorption while effectiveU-T-black showed the most important absorbance of Vis light of higher wavelength (570-700nm) and IR (from 700nm). In general, absorbance UV-Vis profiles were in agreement with iron oxides profiles reported in literature.[7] Interestingly, the BL absorption properties of effectiveU-T-red are more remarkable than those of effectiveU-T-black. Besides, the absorbance of effectiveU-T-black increases progressively after 400nm (in Vis and near IR regions) and it follows that it will remain after 1200nm. This was also observed with colored enhanceU filters that contain CI-7499 pigment in their composition.

CONCLUSION

The need to ensure protection from UV, Vis and IR radiation has been explained in the literature review at the beginning of this article. For this reason, skin care cosmetics with protection must be used throughout the year. By facilitating the work of formulators, ADPCosmetics' goal is to help increase the cosmetic formulas available in the market to protect the users and the environment. The mineral enhanceU filters and effectiveU pigments presented here have shown unusual protective properties from UV-Vis-IR radiation in one single ingredient. Efficacy can be explained by an outstanding combination of chemical composition (titanium dioxide and iron oxides), balance particle size (higher than 100nm) and physical structure. To get SPF30 and SPF50 daily creams and sunscreens only 15% by weight filter concentration is needed. Designed for natural formulations (100% natural origin content, ISO 16128), Cosmos- and Ecocert-certified and Coral-safe. Both enhanceU and effectiveU active ingredients are FDA registered and manufactured under GMP. ■

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