

# The Sun Protection Factor of Sunscreen

## Application Note



### KEYWORDS

- Sun protection factor
- UV radiation
- Sunburn danger

### TECHNIQUES

- Transmission spectroscopy

### APPLICATIONS

- SPF determination
- Authentication

*While you might find stretching out on a beach towel in the sunshine wonderfully relaxing, for your skin this activity sends all dials to the red – literally. Sunburn is no longer just considered an annoyance; its dangers are by now well known, from accelerated skin aging to skin cancer.*

Fortunately, sunscreens can protect you and your skin from the dangers of the sun's ultraviolet radiation, as indicated by the sun protection factor (SPF) on the container. But what does this number really mean and how is it measured in the first place? Do sunscreens really offer all the protection they promise? In this application note we will answer these important questions using spectroscopy.

### Ultraviolet Radiation

The human eye is sensitive to light from the red end of the spectrum at around

780 nm through a rainbow of colors to violet at about 380 nm. Sunlight with shorter wavelengths is hence considered to be beyond violet and called "ultraviolet" (UV). Ultraviolet light is separated into the UVA band down to about 320 nm, the more energetic and dangerous UVB light (between 320 nm and 280 nm), and the high-energy UVC band at even shorter wavelengths. UVC is completely absorbed in the ozone layer, but significant amounts of UVB light still reach the Earth's surface, as shown in **Figure 1**.

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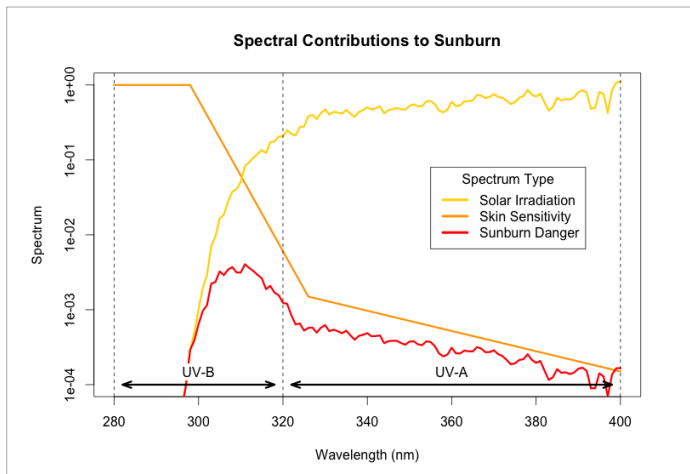
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**Figure 1.** Solar spectrum at the Earth surface, the sensitivity of skin to sunburn, and the product of the two, the relative sunburn danger, as a function of wavelength (Source: Wikipedia)

## The Sun Protection Factor (SPF)

A person's tolerance to sun exposure varies significantly, and depends on skin type. It may be as short as just five minutes for a person with fair skin, red hair, and blue eyes, or far longer for someone with dark skin and hair. Applying sunscreen extends this maximum exposure time depending on the sun protection factor. An SPF of 20, for example, should increase the fun time on the beach for a person of fair complexion by a factor of 20 minutes to about 100 minutes. Regardless of your skin type and SPF used, dermatologists recommend reapplying sunscreen every two hours.

In the past, the sun protection factor was measured in exactly this way: small patches of skin on the back of volunteers were exposed to increasing amounts of UV light, some areas protected with the sunscreen under test, some patches left unprotected as a control. The ratio of the exposure times that led to the first sign of reddening with and without sunscreen then gave the sun protection factor for the sunscreen. Not only does this method sound painful and not particularly accurate, but it is also more difficult to find volunteers now that the dangers of UV radiation are common knowledge.

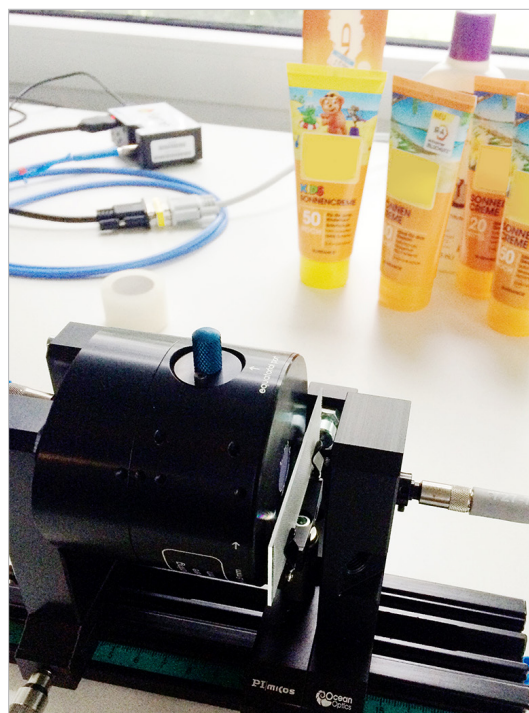
## Instrumental Determination of SPF

Once again, spectroscopy offers a much better solution to the problem. Sunscreen works by absorbing or reflecting UV light before it reaches the skin. White pigments, such as titanium dioxide used in high-SPF sun blockers, work in reflection mode. Most other ingredients, such as benzophenones, absorb a portion of the UV radiation. Of interest for the measurement of the sun protection factor is the percentage of the UV light that is transmitted and still reaches the skin.

Three different approaches are possible for sample preparation when measuring SPF spectroscopically. In the solution method, the active ingredients of the sunscreen are dissolved in a suitable solvent, the solution is decanted from the solids, and the transmission is measured with a cuvette in a standard absorbance setup. However, the solid pigments used often are ignored with this method. Alternatively, a thin film of the sunscreen can be evenly applied to a transparent holder with a shallow depression, allowing the transmission of the film to be measured with all ingredients present. In practice, however, we found it to be difficult to ensure the consistency of the film with this setup.

A third possible method is to apply the sunscreen to surgical tape (such as 3M Transpore) affixed to a microscope slide. This might sound like an unusual approach at first, but the regularly distributed pores of the surgical tape allow for a very even and reproducible application of the sunscreen onto the sample holder. As an added bonus, a typical sunscreen spread on this surgical tape has a coverage of about 1-2 mg per cm<sup>2</sup>, similar to what dermatologists recommend to protect your skin.

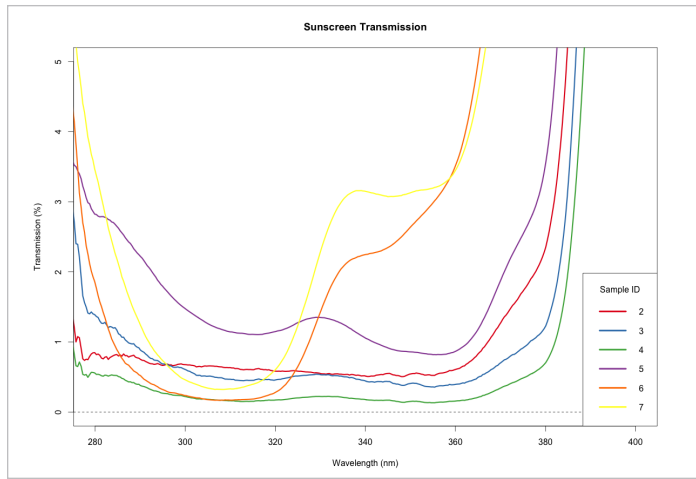
## Setup and Procedure



**Figure 2:** Setup employed to measure the UV transmission through sunscreen applied to a sample holder consisting of surgical tape on a microscope slide (center). UV light from a deuterium light source (DH-2000 BAL) enters the setup through a fiber on the left and an integrating sphere captures the transmitted light (left). An ACH-CUV-VAR lens holder was used to mount the input lens, sample holder, and integrating sphere.

A thin layer of sunscreen applied to surgical tape will scatter the incoming UV light, and thus a simple lens-to-fiber collector will not adequately collect all of the transmitted light. It is a better solution to collect all of the transmitted and scattered light with an integrating sphere placed after the sample, as shown in **Figure 2**.

The sample holders were prepared, numbered, and weighed (to later determine the amount of sunscreen applied). The transmission through the blank sample holders was determined using a separate, marked, microscope slide with surgical tape (but no sunscreen) as the reference.



**Figure 3.** UV transmission of various sunscreens with SPF varying from 20 to 50.

A thin layer of sunscreen was applied to the sample holders, scraped to create a thin, even layer with a clean microscope slide, then the sample slide was weighed again and left to dry for 60 minutes. After this drying period, the transmission through the scattering reference slide was set again as the 100% reference to account for any changes in the lamp output over time. Finally, the transmission through the actual samples with applied sunscreen was measured. Including the dark measurements, a total of eight spectra were recorded for a single sample to account for changes and differences in the spectrometer, sample holders, and UV source output. **Figure 3** shows the resulting averaged transmission spectra in the UV region of interest.

## Calculation of the SPF

The transmission spectrum (**Figure 3**) indicates what percentage of the incoming UV radiation reaches the skin. However, not all UV wavelengths are created equal; some are more dangerous than others, depending on the amount of incoming sunlight and the susceptibility of the skin to sunburn as a function of wavelength, as shown with the red curve in **Figure 1**. For example, radiation between 300 nm and 320 nm is the most dangerous of the rays reaching the Earth’s surface, which explains why sunscreens often predominantly absorb UV light in this region.

The sun protection factor is now the ratio of the total sunburn danger without sunscreen (as measured by the integral over the red curve in **Figure 1**) compared to the reduced sunburn danger due to the transmission diminished by the sunscreen (as measured by the integral over the product of the sunscreen transmission curves in **Figure 3** times the red curve in **Figure 1**). The results of these calculations are summarized in **Table I**.

**Table I – Results of SPF determination for six sunscreen samples**

Sample ID	Brand	Notes	SPF claimed	SPF measured
2	A	Regular	20	79
3	A	Regular	30	99
4	A	Regular	50	193
5	A	Baby	50	48
6	B	Hard to spread	45	32
7	C	Store Brand	30	34

## Results

Overall, we find that the sunscreens tested in this experiment kept their promises of good sun protection. Interestingly, the SPF determined for the regular sunscreens of brand A exceeded the claim by a factor of 3 to 4, while the “Baby” sunscreen from the same brand did not. Not surprisingly, as shown by sample 6, the ability to evenly spread the sunscreen has a significant effect on its protection benefits.

This same experimental setup also could be used to measure SPF factors of fabrics and other materials in a manner that is both reproducible and robust, once again demonstrating the ability of modular spectroscopy systems to measure a wide range of samples for problems relevant to health and safety.