UV-protection by fabrics has been a topic for discussion for at least a decade but it remains a complex subject and, even now, there are not many people, even in the textile industry, who fully understand the details. Without going into all the scientific and application details of the original presentation, this article shows how recent developments at Ciba continue to advance the concept.

The application of ultraviolet absorbers for sun protective fabrics

While clothes provide good sun protection, not all apparel is sufficiently protective against UV radiation. UV-protective clothing is yet to make the big breakthrough into the general market and the lengthy debate about standards and labels is considered one of the main reasons for this. At present there is an Australian Standard, a British Standard and the EU and the USA are likely to come up with their versions; even private organisations propose their own labels. And there is no independent body that checks their quality.

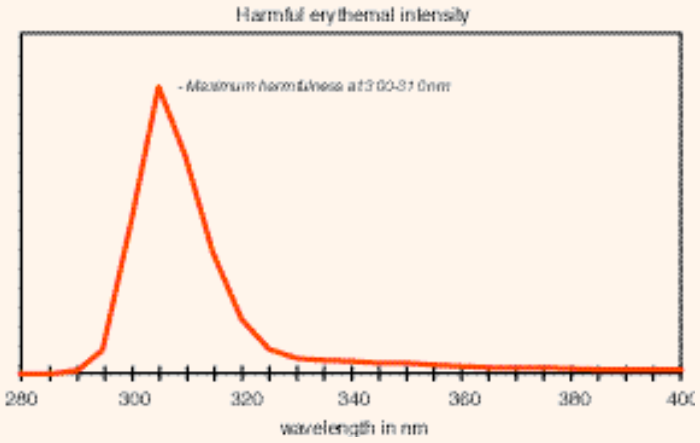
The ultraviolet protection factor (UPF) of a textile fabric is determined first by the chemical structure of its constituent fibres and the substances it contains or carries and, second, by its structural characteristics, such as porosity/pores per unit area, thickness, dimensional stability and its elastic properties. In its development laboratories, Ciba has developed its Tinofast CEL, a reactive UV absorber which can markedly and permanently improve the UPF of cotton, viscose, lyocell, polyamide and their various blends, especially if these are dyed or printed in pale shades, and provided they are close textured with low porosity. Its newly developed PES version boosts the UPF of aromatic fibres such as polyester.

The erythemal effect

The solar radiation which reaches the earth's surface consists of infrared, visible light from red to violet, and ultraviolet radiation (UVR). UVR is usually divided into UV-A, UV-B and UV-C. The latter and radiation of shorter wavelength is filtered off in the upper atmosphere. UV-A and B have different beneficial and detrimental effects on the human skin: the shorter the wavelength the more harmful the effect. The skin reddening effect, so frequently seen on holiday-makers newly arrived on the beaches of summer resorts around the world, is known as the erythemal effect. Combining the UV-spectrum with the relative spectral effect of UVR gives the erythemal effectiveness which is a measure for the harmfulness of UVR. In order to be effective, UV protective fabrics have to ensure absorption in the UV-B and UV-A region with a maximum at about 300-310nm in the wavelength band where the erythemal effectiveness is at its highest.

The transmittance spectra of a textile sample can be measured with UV/VIS spectrophotometers, the radiation consisting of two components - direct UVR passing unchanged through the interstices or pores of the fabric and

Figure 1: Erythemal effectiveness as a measure of harmfulness of UVR



scattered UVR which interacted with the fabric.

The transmittance spectrum always reflects the behaviour of a particular fabric sample with given porosity but it is clear from Figure 2 that wool and polyester substrates have an inherent UV absorption. In contrast, cotton and polyamide allow UVR to pass through and afford scarcely any protection.

The UPF of a fabric is a quantitative measure of how effectively a textile can protect human skin against UVR. The optical porosity is an important limiting factor to the potential of a fabric to protect from UVR and it is only the transmittance through the fibres which can be blocked, for example by the application of a UV absorber to the fibre. To ensure that a fabric provides adequate protection against UVR, the textile fabric must guarantee an optical porosity of not higher than 1.5-2.0% - the amount of UVR passing straight through the interstices in the fabric. This would indicate too that fabrics designed to stretch should never open more than 1.5-2.0% in use and the UPF must be measured in the desired state of stretch.

For fabrics made from cellulosic fibres (and their blends with polyester) or polyamide, the use of UV absorbers is imperative in order to achieve the required UV-protection levels, especially important with pale to medium shades.

How to make fabrics UV-protective

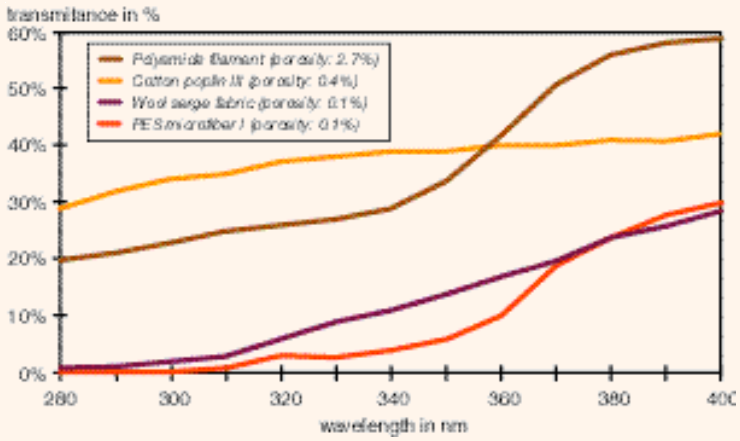
The fabric construction limits the maximum possible UV protection. The best choices of UV protective fabrics are dense knits and weaves with an optical porosity below 1.5-2.0%. The fibre has a characteristic transmittance behaviour. However, polyester and wool which have good inherent UV-absorption are not necessarily the right fibres for light summer garments, and about 90% of garments worn in summer are estimated to be made of cellulosic fibres. This means that a special treatment is required to make them UV-protective. Fibre additives are often an integral part of synthetic fibres. For example, polyester always contains TiO_2 as a delustrant. In 1996, AKZO promoted a viscose fibre (Enka-Sun) to which TiO_2 is added as a UV-absorber during the spinning process. TiO_2 is also added to some polyamide microfibre and swimwear qualities.

Dyes, especially dark shades, often provide fairly good protection to UVR. However, pale to medium shades of the same dyes only show a slight to medium increase of UVP and for such shades the application of a UV absorber is essential. Fluorescent whitening agents absorb UVR and transform it into visible light; white fabrics treated with such an agent show moderate UVR protection. Extra UVP can be provided by the application of UV absorbers but these may impair the whiteness of the brightened fabrics.

Special fluorescent UV absorbers for laundering have been developed recently by Ciba, products which are added during the laundering process and increase or restore the UV protection level at each washing cycle. (An unpredictable factor is shrinking and pilling during laundering which increases the UVP factor.)

The application of specially designed UV absorbers is probably the strongest lever to improve UV-protection.

Figure 2: Transmittance in % of textile fabrics made from various fibres

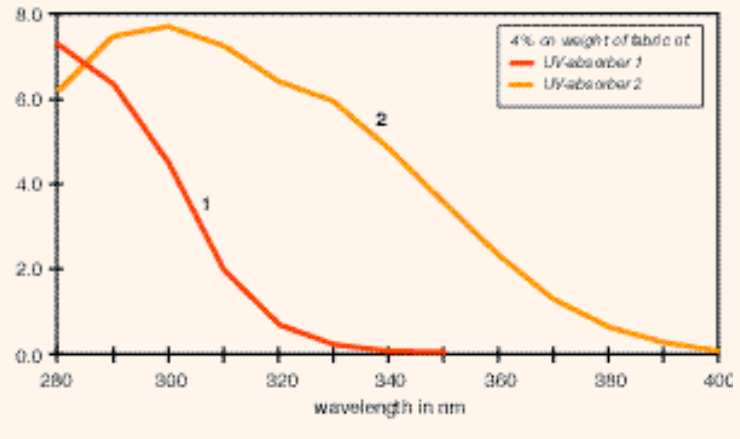


Cotton is still the key

UV absorbers have been on the market for over 20 years for a variety of products to guard against UV-induced degradation. Their use on textiles has been mainly to improve the lightfastness of automotive polyester fabrics and to improve the stability of polyamide fibres against degradation. No UV absorber existed for application on cotton.

When the UV-protection issue came up in the early 1990s, Ciba started developing special UV absorbers for cellulosic fibres. Optimally this UV absorber should absorb in a region of UVR where the erythemal effectiveness is at its highest. It should be durable to repeated washing, not a skin irritant, stable to UV-light, compatible with textile application procedures, and absorption in the wet state should not decrease. (It is interesting to note that among the profusion of standards and labels, the Australian/New Zealand standard excludes wet, used, washed and stretched fabrics from classification which raises questions about the durability of UV-protection

Figure 3: Absorption curve of cotton poplin III



during use. Because the Skin Cancer Foundations and others warn that "the UV-protection of a garment in the wet state is lower than in the dry", Ciba included an investigation of these factors in its research.)

Figure 3 illustrates the progress which has been made for the clothing sector. Both absorbers tested are commercially available for application on cellulose. UV-absorber1 is a chloro-sulfo-phenyl-triazine originally sold for space dyeing of carpet. This is more of a UV absorbing substance than a real UV absorber by design. UV-absorber 2 is a bi-reactive oxalic acid di-anilide derivative from Ciba, known as Tinofast CEL, that was especially developed for UV-protection on cotton. While UV-absorber1 absorbs mostly in the UV-C and UV-B range (less than 280nm to 320nm), UV-absorber 2 absorbs in both ranges, UV-A and UV-B. Additionally, its maximum absorption is at the level of maximum erythemal effectiveness (see Figure 1). The amounts of UV absorber are as formulated on fabric weight. Figure 4 shows the transmittance of a typical cotton shirting quality fabric, untreated and treated with UV-absorber 2 (the wavelength spectrum has been extended to 440nm).

In summary, the right UV absorber properly applied minimises the risk of losing the UV-protection of a garment during use: the UV absorber used on cellulose should be fibre-reactive. The absorber has to absorb both UV-B and UV-A in order to ensure the highest possible ultraviolet protection factor. The application of a UV absorber will influence the degree of white but full whiteness on cotton is possible with an appropriate bleaching process and an ingenious combination of fluorescent whitening agent and UV absorber. The protection factor of polyamide and polyester fabrics can be markedly increased by the application of an appropriate UV absorber. However, the aromatic polyester fibre has good intrinsic UV absorption - which makes the application of UV absorber unnecessary in most cases.

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Figure 4: Transmittance in % of cotton poplin III with a porosity of 0.4%

