Molecular Crystals and Liquid Crystals Science and Technology. Section A. Molecular Crystals and Liquid Crystals

Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/gmcl19

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Version of record first published: 24 Sep 2006

To cite this article: Edgar Medina & Jean Robillard (1997): Safetan, A Sun Exposure Indicator Based on Photochromism, Molecular Crystals and Liquid Crystals Science and Technology. Section A. Molecular Crystals and Liquid Crystals, 298:1, 265-270

To link to this article: http://dx.doi.org/10.1080/10587259708036170

Mol. Cryst. Liq. Cryst., 1997, Vol. 298, pp. 265–270
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SAFETAN, A SUN EXPOSURE INDICATOR BASED ON PHOTOCHROMISM

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ABSTRACT

A simple device for warning of overexposure to ultraviolet radiation is described. The device uses the amplified photochromic reaction of a photochromic material irradiated by the sunlight reflected from the skin. The change of color is compared to the permanent color of a dye with an optical density corresponding to a maximum safe exposure of the skin.

I. INTRODUCTION

Overexposure to UV radiation can result in damage to the skin varying in severity from a slight reddening and accompanying soreness to severe burning. Further, this overexposure has been linked to the development of skin cancer.

The present paper relates to the development of a simple, low cost warning device in the form of a Band Aid or inserted in a plastic bracelet in contact with the skin. The principle is based on the variation of the reflection of the ultraviolet light from the exposed skin. It has been found that correlation exists between that reflection and the total dose acceptable by the sunbather [1]. For example white skinned people (Albino, Irish or Scottish individuals) will tolerate a much smaller dose than black people.

The reflected light initiates a photochromic reaction which is amplified and causes a change in color proportionally to the dose received; the total dose acceptable is assessed by comparison with a permanent dye colored area adjacent to the sensing area. Current products on the market do not satisfy the requirement of a device personalized to an individual's skin, as they only measure UV intensity and rely on a user to subjectively determine his own skin type.

II. DERMATOLOGICAL IMPACT.

To assess the danger of overexposure to UV rays , the intensity of the sun radiation must be measured in the spectral region of 290 to 320 nanometers. Skin exposed to sunrays containing radiation in this region of the spectrum can cause the release of free radicals in the dermis or epidermis which results in erythema and melanogenesis. Erythema is a burning or at least irritation of the area whereas melanogenesis is responsible for the tanning or browning (Suntan).

The spectral range of ultraviolet light which mostly interferes with the skin is divided in two region : UV A (320 to 390 nanometers) and UV B (290 to 320 nanometers). UV B are by far the most dangerous but UV A can also cause damage with sufficient exposure. The reaction of the skin is also dependent to a certain extent of the ratio of UV A to UV B during the exposure. In the UV B region the wavelength of 297 nanometers is the most active. The reaction of the skin to sun exposure is characterized by a factor E which is a function of the wavelength and measure the potential damage caused in the skin. The variation of E as a function of the wavelength is called "Action Spectrum" and is represented in Fig. 1.

Tanning results from the creation of a subproduct of certain cells called melanocytes. The product melanin has a strong absorption in the UV (Which explains the protective effect of tanning) and the visible (which is characteristic of the brown color of the tan). Melanin is synthetized in the skin by enzymatic oxidation of the amino acid tyrosine. The final product is a polymer of which tyrosine is the monomer. The amino acid and the enzyme are both present in the chemical sructure of the skin. The reaction forming the melanin is activated by absorption of UV B , also it appears that UV A plays a certain role [2].

The average energy threshold of erythema for the most active regions of the spectrum (UV B) is 12,000 mW. $sec.cm^{-2}$ [3].

In a long range, erythema might be of secondary importance compared to solar carcinogenesis which is not immediately detectable and requires much larger doses of exposure. It also involves UV A to a greater extent as well as other regions of the spectrum which have little or no influence on the development of erythema [4].

III. AMPLIFICATION IN PHOTOCHROMISM.

1. Fixation of the open form of spiropyran

When a spiropyran molecule is adsorbed on a semiconductor substrate, chemisorption will occur. The molecule will then be adsorbed with one of its planes parallel to the surface of the substrate and the other one perpendicular to it. Upon irradiation with UV, the right part of the molecule will rotate to become coplanar with the left part and new bondings will be established between that part and the substrate. The now existing bonds between both sides of the molecule and the substrate will prevent the closing of the heterocycle back to the spiropyran structure and therefore increase the stability of the open form. The degree of stability depends on the nature of the adsorption bonds and the structure of the semiconductor substrate [5].

2. Amplification of the photochromic process

It has been shown that the ring opening of the spiropyran structures adsorbed on semiconductors can be initiated by charge transfer from the semiconductor acting as a donor to the closed form of the spiropyran [6]. The semiconductor can be inorganic such as ZnO, TiO_2, SnO_2 or PbO [5][7] or organic like Polypyrrole, Polyacetylene [8] or Polythiophene [6]. It is believed that the amplification could be related to the added contribution of the photoelectrons released from the semiconductor to the direct photoisomerization (Fig. 2).

The increased efficiency of the photochromism of spiropyrans adsorbed on semiconductors depends on the semiconductor, the correlation between the optical absorption spectra of both the semiconductor and the adsorbed dye as well as their individual band structures. Preliminary results are shown for ZnO, SnO_2, TiO_2 and Thiophene (Fig. 3).

IV. THE SAFETAN CONCEPT.

Due to the correlation existing between the amount of UV reflected by the skin and the total dose acceptable , it is possible for a passive device to determine the dosage of UV absorbed by a person's particular skin characteristic by measuring the reflected UV light [9]. Figure 4 shows the reflection of UV from different skin types.

The device comprises a laminar arrangement of a photochromic material and a reference material. This allows visual assessment of skin exposure to UV radiation based on UV reflected by a direct comparison of color densities of the photochromic and reference materials; i.e. the maximum allowable exposure to UV for a person's specific skin characteristics occurs when the color densities match (Fig. 5).

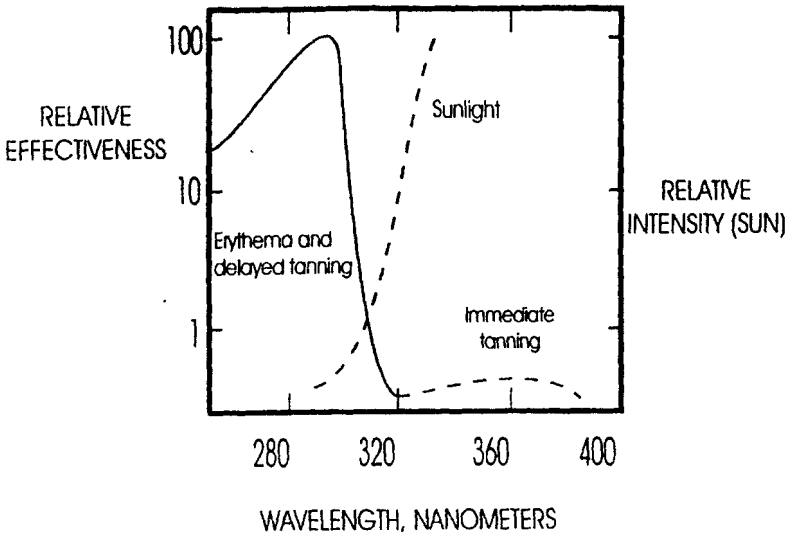

Fig. 1

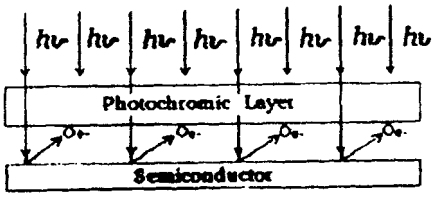

Fig. 2

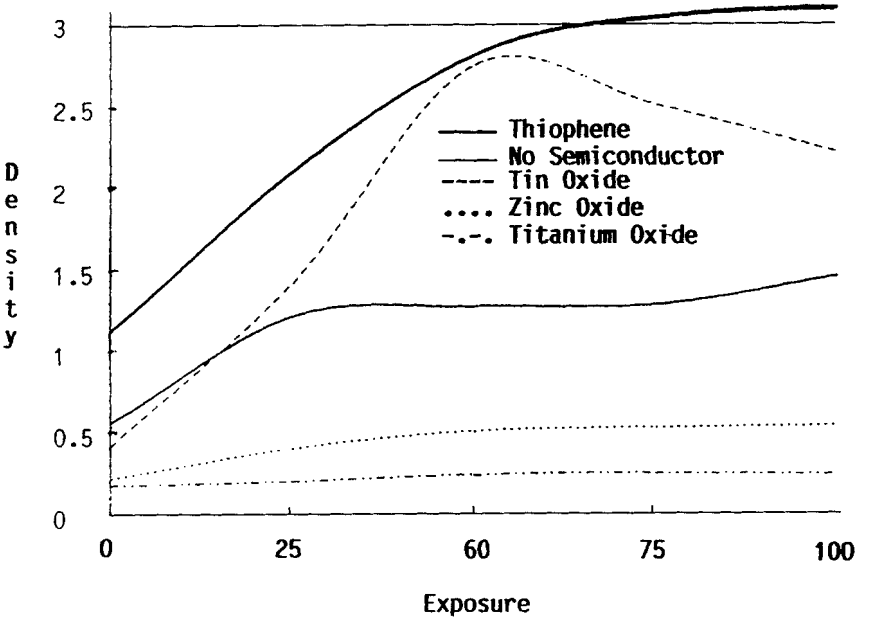

Fig. 3

The reference material is positioned adjacent to the photochromic material. The reference is a dye that closely matches the color of the photochromic material after exposure to a predetermined quantity of UV radiation corresponding to the maximum exposure tolerable by the person's particular skin type. The photochromic material is coated on the lower part of a transparent to visible, but UV absorbent, mesh material. This is exposed to sunlight in such way that UV radiation reaching the photochromic material is reflected from the skin (Fig. 5).

Because of the presence of the mesh structure, the photochromic material is not directly exposed to the ultraviolet of the sunlight. UV radiation penetrate through the open areas of the mesh structure, is reflected by the skin and absorbed by the photochromic layer. The color generation in the layer is observed through the solid parts of the transparent (to visible) mesh structure. Color development in the photochromic layer is due solely to UV radiation reflected from the surface of the skin. The amount reflected is generally not sufficent to produce a usable optical density, for this reason it is necessary to make use of a special photochromic compound involving amplification as described previously.

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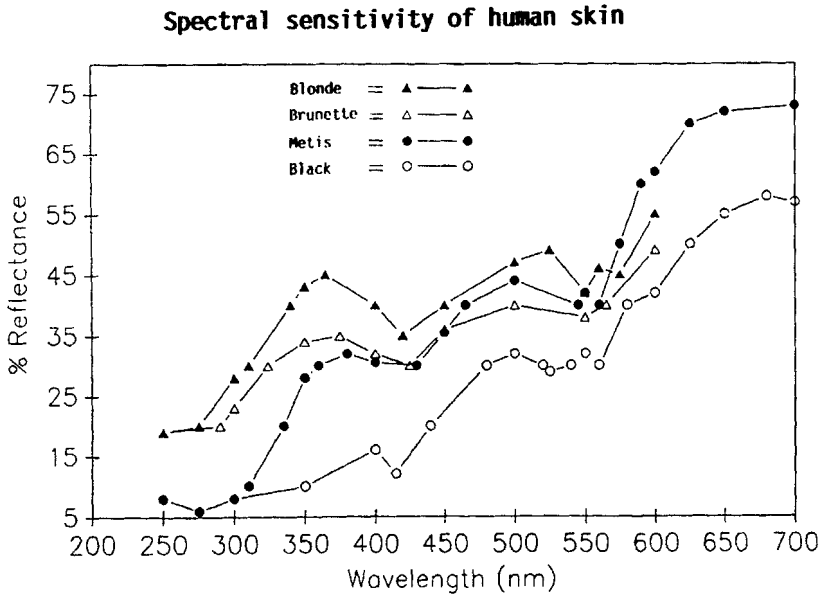

Fig. 4

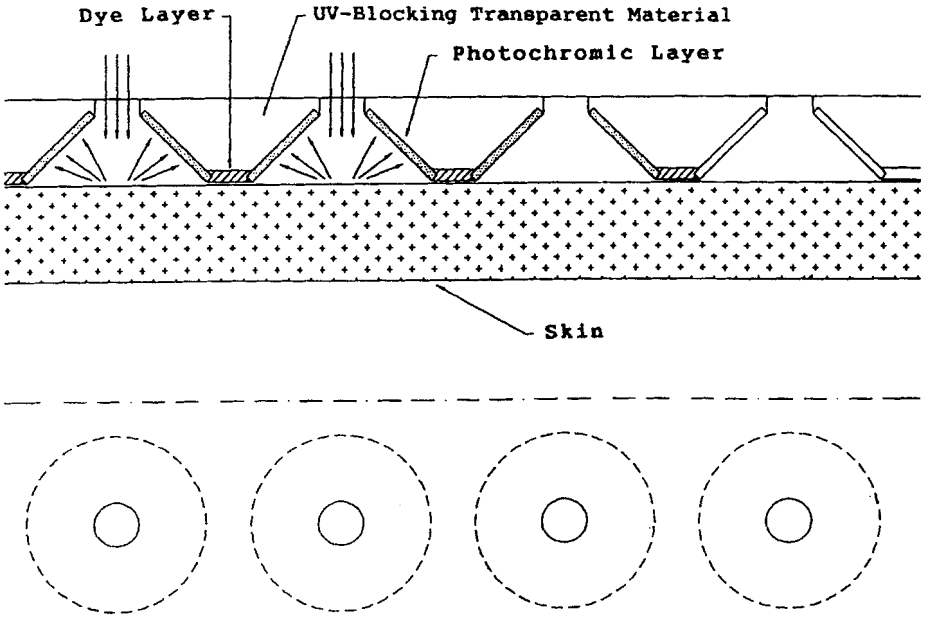

Fig. 5