ORIGINAL PAPER

STUDY OF THE OPTICAL PROPERTIES OF POLAR BEAR HAIR IN THE INFRARED RANGE AND THEIR MICROSCOPIC STRUCTURES FOR PASSIVE CONTROL OF TEMPERATURE

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Abstract. *If you are looking for the biggest land mammals, you will find them in northern Alaska, northern coast of Russia, Canada, Greenland and Norway. Polar bear (Ursus maritimus) is immediately recognizable by the white fur; it can survive in such latitudes. In recent decades, scientists make an assumption that this bear's fur keep it warm because each hair carries the sunlight to reach finally the pelt. To clarify this phenomenon, we were led to study the optical properties of polar bear hair in infrared and its microscopic structure. The optical responses are measured using the Fourier Transform Infrared (FTIR), when the microscopic structures are viewed by Scanning Electron Microscope (SEM). The microscopic pictures of polar bear hair have shown internal structures that can explain the spectra of absorption. This later showed that the hair absorb a large proportion of infrared radiations. The interpretation of the results allowed us a better understanding of the optical mechanism advanced early in the polar bear and its adaptation to its environment.*

Keywords: *FTIR, Optical properties, Photonic structures, Polar bear hair, Temperature.*

1. INTRODUCTION

Biophotonic, defined as the use of visible rays, ultraviolet rays, infrared rays or X-rays for analysis or modification of biological objects, is without doubt one of the most promising applications of science and technology of light. The first biophotonic bases were launched by Yablonovitch [1, 2] in 1987 when describing the structure of a photonic crystal with the Band Gap, Photonic Band Gap (PBG), a photon can pass valence band to the conduction band in the same way that an electron in a semiconductor crystal. PBG in the most basic case, present a composite of two materials with two indices of refraction n_1 and n_2 [3], global index of the crystal is a periodic function in space. The periodicity of these structures should be comparable with the range of wavelengths to which our crystal will be exposed. Note that

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theoretically the wavelengths of the band gap are completely reflected by a perfect photonic crystal. The ability to produce photonic crystals, complex and costly procedure, may open the field to wide applications including: optical computing [4], through tunable photonic circuits [5], increase the efficiency of laser [6,7], optical fiber communication [8], less harmful pigments [9], arriving to Photonics paper [10].

Other applications are still very promising in the living world, we can learn from these models indeed exist in nature to design cheap photonic structures, working with high efficiency. The more concrete example is the case of Lepidoptera, commonly called butterflies, which are stained in most cases blue and green [11] of structural origin, though sometimes you can find colors like yellow or red, which are generally pigment color [12]. In addition to their beauty, these colors have several functions such as sexual communication [13-15], camouflage [15], thermal regulation described by fading in the case of Daphnis Polyommatus [16]. Still in the animal world, one can cite other examples of photonic structures in birds [17], Coleoptera [18] and marine organisms [19].

Photonic structures are quite abundant in animal world, however, Edelweiss [20], Leontopodium alpinum (Asteraceae), is one of the few examples in plants, it lives in high altitudes above 3400m, stems and leaves are covered with white pad, which have for aim, to protect the plant from severe climatic conditions prevailing in this region particularly dry and windy. Edelweiss has a white filaments layer with more density in the bracts of the head than the rest of the plant, this layer's role is protection against the cold and dehydration but also harmful UV rays. This protection is done through the absorption and not the reflection with the layer above, and this, supply by dissipation diffraction effects.

Continuing on the same path, our work on the polar bear hair take place, because we believe that there’s a certain similarity between our study and the Edelweiss one, where the white hair of this Last absorbs the UV and then dissipate it by a mass effect, the polar bear hair works by the same way but this time it's the infrared which will be absorbed then stocked for later use.

2. RESULTS AND DISCUSSION

Polar bears’ fur consists of a dense, insulating undercoat topped by guard hairs of various lengths; the undercoat is dense and short. The coat is thick and stiff 12 to 15 centimeters and covers the entire body except the nose and pads, making their manipulation quite delicate. The fur is not actually white, it just looks that way, it have yellowish reflections which are due to the ultraviolet absorption according to many zoologists. Polar bears have black skin under which there is a layer of fat that can measure 11.5 centimeters thick. But it is their fur, not their fat that prevents bears from suffering nearly any heat loss. In fact, adult males quickly overheat when running, usually at temperatures above 10°C (50°F).

In following, we will present the optical responses of polar bear hair after measuring by the FTIR spectrometer, we should note that reflectance and transmittance properties are directly given by the device, whereas the absorbance is deduced from the relation:

$$A = 1 - T - R \qquad (1)$$

where A: Absorbance, T: Transmittance and R: Reflectance

2.1. OPTICAL SPECTRA IN THE INFRARED

Transmittance

Overall transmittance of the polar bear hair (Fig. 1) is weak and does not exceed 12% in the best cases; it also continues to decrease depending on the wavelength in the infrared range.

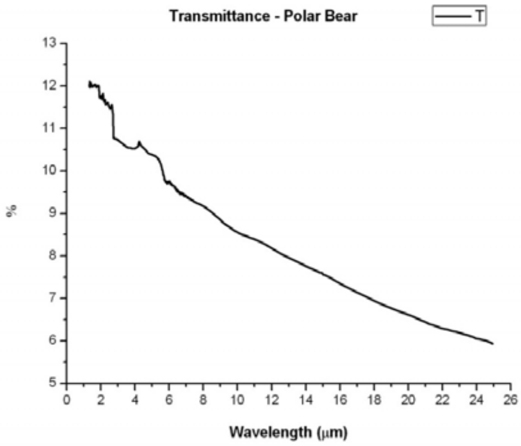

Fig. 1. Transmittance spectrum of the polar bear hair in infrared.

Reflectance

We note that in the near infrared (until 2.5μm), the polar bear hair has a significant reflectance (Fig. 2), but after this limit, it fall very quickly with a small jump around 5μm, but the general curve shows that polar bear hair reflected infrared but with very small proportions.

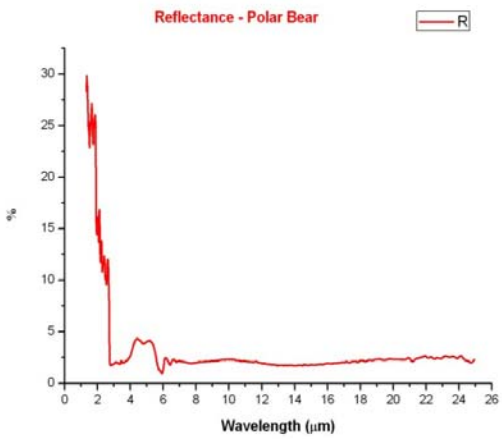

Fig. 2 Reflectance spectrum of the polar bear hair in infrared.

Absorbance

Unlike what happens with the reflectance and transmittance, the polar bear hair absorbs with different proportions but globally important in the whole infrared (Fig. 3). In the near infrared, absorbance increases to values that exceed 80%, and keep that in the mid-infrared but this time with almost constant way to exceed 90% at last.

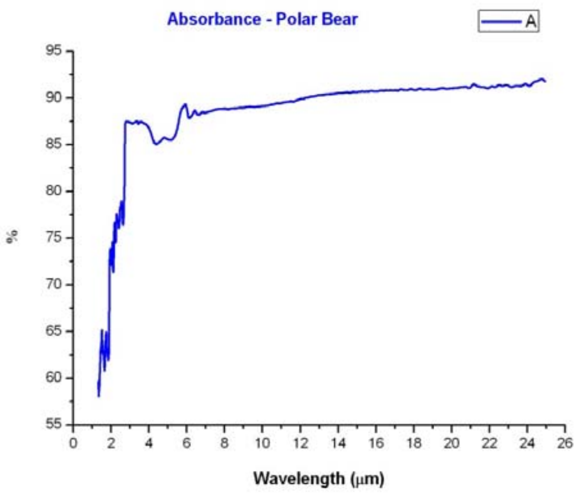

Fig. 3. Absorbance spectrum of the polar bear hair in infrared.

Finally we present the three spectra on the same graph (Fig. 4), and as noted before the major phenomenon is absorbance, it's above all the rest.

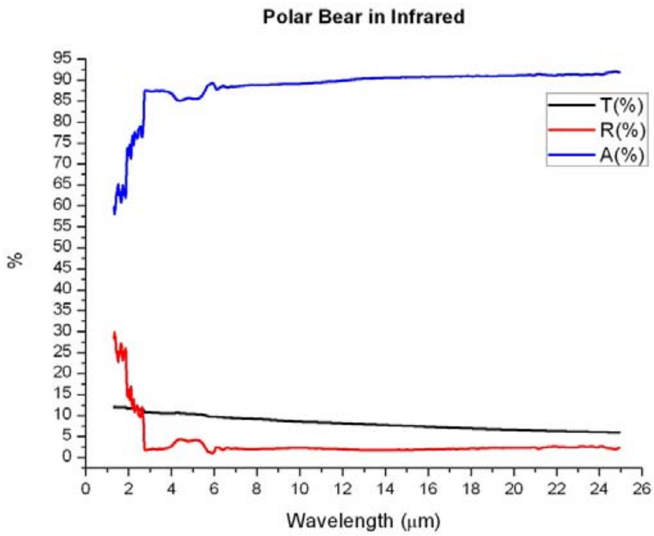

Fig. 4. Transmittance, Reflectance and Absorbance spectra of the polar bear hair in infrared.

Microscopic structures of hair

To probe the internal structure of polar bear hair, we were led to an analysis by Scanning Electron Microscope (SEM).The hair has been first sectioned to obtain a sort of cross-sectional of our sample.

The pictures obtained by SEM show us that the polar bear hair has an interesting structure, based on analysis of Figs. 5 and 6, the hair has an elliptical form, but not perfectly cylindrical.

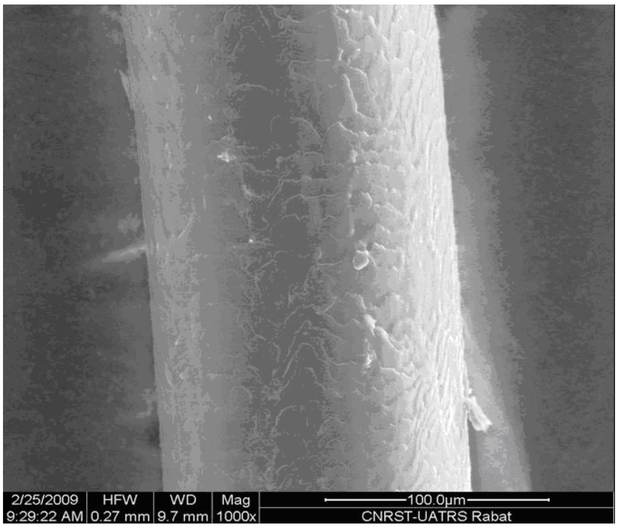

Fig. 5. General view of a polar bear hair.

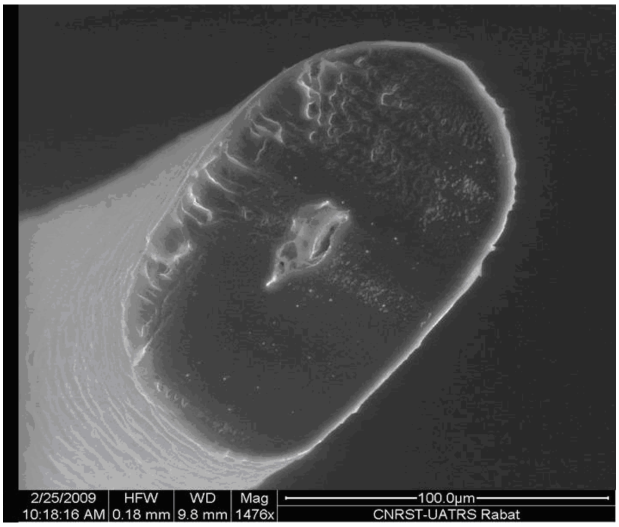

Fig. 6. Cross section of a polar bear hair.

Next step was calculating the hair diameter, which has from Fig. 6, minor and major axis, so we have to know their values.

After measurement we found: Major axis ≈ 149μm; Minor axis ≈ 92μm.

Figs. 7 and 8 shows sub-structures quite interesting, beginning with the first, the hair core is an entity quite different from the rest (point of view chemical composition), which contains a form of hole stretches along the hair. Fig. 8 shows a pattern found at the periphery of the hair and repeated in the entire circumference.

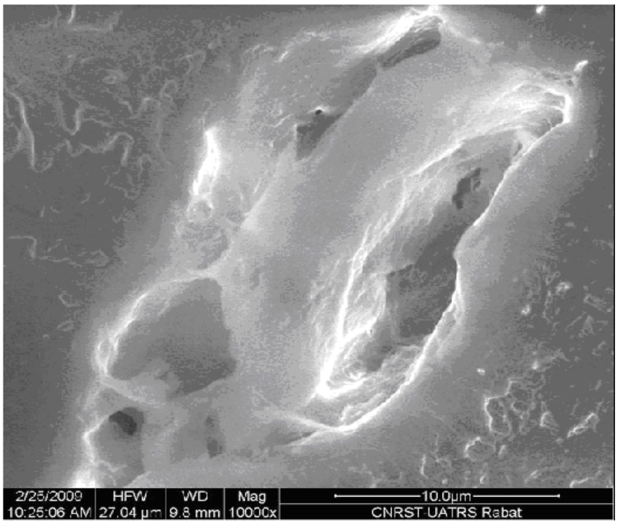

Fig. 7. The core of a polar bear hair.

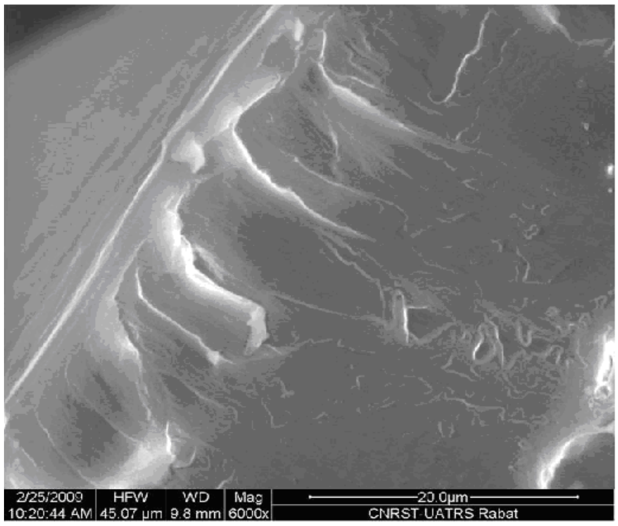

Fig. 8. The circumference of a polar bear.

What really interested us is the behavior of the polar bear in the infrared, reflectance and transmittance was indeed low, however the absorption was important and therefore the most obvious question was why? By analogy to the work that was performed on the edelweiss [20], we suspect the hair core responsible for absorption, so we try to find a relation between our SEM pictures and the absorption coefficient.

When analyzing the last spectrum, we note that the point where the intensity of the absorption coefficient (Fig. 9) drops significantly indeed coincides with the diameter of the hair core measured (35µm). Here comes the idea that all the wavelengths that are equal or less than the diameter of the hair core are absorbed, a phenomenon which is absent outside this limit.

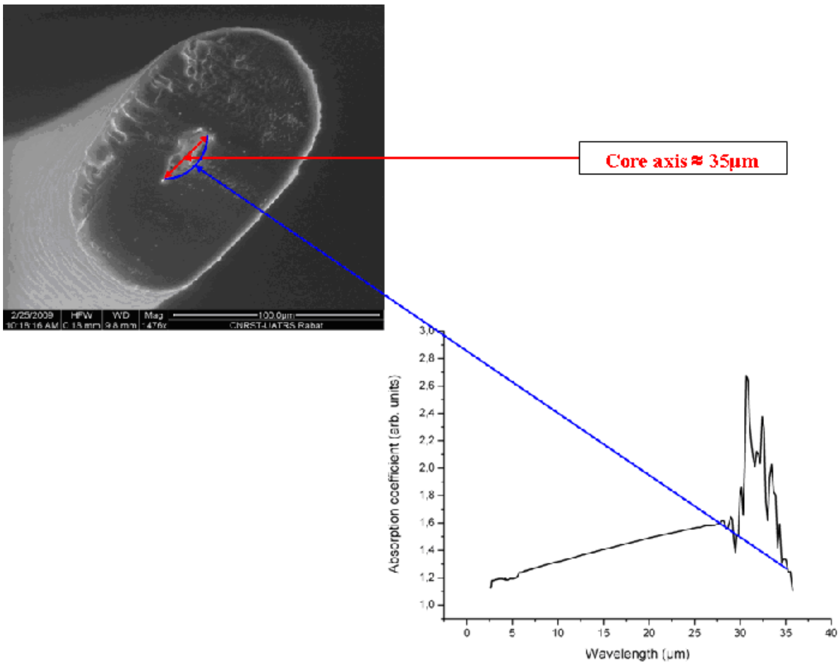

Fig. 9. Relation between infrared radiations absorption with the polar bear hair core.

3. CONCLUSIONS

The polar bear has always attracted a lot of questions by its resistance to the cold climate prevailing in the Antarctic; we initiated this study to unravel this mystery. Speaking of hot or cold, it involves the concept of infrared radiation known by its calorific power. Hairs from the polar bear fur were collected and after preparation, characterized by Fourier Transform Infrared (FTIR). Spectra obtained show that the absorbance clearly dominates the others, while the transmittance and reflectance are low. This step completed, hair was analyzed by Scanning Electron Microscope (SEM), pictures shows elliptical structures composed of a major and minor axis that we have calculated carefully. The diameter of the hair core is exactly the same as the wavelength at which the absorption coefficient drops significantly; direct consequence is the absorption of all wavelengths those are equal or less than 35µm.

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