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NDT&E International 38 (2005) 59–68

NDT&E international

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Optoelectronic nondestructive testing techniques of cocoon properties and applications

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Received 3 June 2004; accepted 27 June 2004

Available online 6 August 2004

Abstract

In this paper, cocoon properties are examined, spectral characteristics and mathematical expressions that define cocoon shell's absorption and reflection of light in various wavelengths are obtained and given in graphical form. Finally, optoelectronic methods and systems that determine cocoon properties are designed and explained.

Keywords: Cocoon properties; Spectrum; Passing of light; Reflection; Propagation; Nondestructive testing; Optoelectronic sensors

1. Introduction

Cocoon production has been made since ancient times. It has an important part in Turkish economy like in various countries.

Cocoon properties (perfect cocoon, internally and externally stained cocoon, faulty cocoon, cocoon having holes, crushed cocoon, mouldy cocoon, cocoon shape, etc.) determine the quality of the cocoon [2,15]. Cocoons must be classified before unraveling process. Sensors that are sensitive to cocoon properties are required for classification [10–13,35]. Optoelectronic systems can be used as sensors [3,29,30].

Theoretical knowledge is required for designing optoelectronic systems sensitive to cocoon properties. In this study, research about cocoon's reflection and passing of light has been made and optoelectronic methods detecting cocoon properties has been described.

2. Cocoon properties and determination of these properties

Important properties considered in cocoon classification according to the related Turkish Standards (TS 5916 'Silkworm Cocoon' 1988) can be described as follows [1].

Perfect (good quality) cocoon is suitable for good quality silk pulling because of its shape, color and other properties.

Faulty cocoon is not suitable for regular silk pulling.

Double cocoons, internally stained cocoons, externally stained cocoons, cocoons having holes, cocoons with thin shells, shapeless cocoons and mouldy cocoons can be given as examples for faulty cocoons.

According to its race, cocoon shape can be (a) articulated, (b) Oval, (c) circular and (d) spherical. Various cocoon shapes are shown in Fig. 1.

Pulling ability of cocoon (relative rate of cocoons that can be pulled without breaking the cocoons exposed to pulling process) is determined by cocoon properties [8]. If faulty cocoons meet good cocoons during the pulling process, quality of the silk will be affected. Therefore, cocoons are classified before pulling and faulty cocoons are separated. Good cocoons are also classified according to their body thickness and shapes [9]. Currently, this is done manually causing subjective errors. Moreover, manual grouping method has a very low efficiency. Optoelectronic methods have been developed for increasing the efficiency of grouping and decreasing the amount of subjective errors.

3. Spectrum characteristics of cocoon

Cocoon body has a natural structure and generally protects the silkworm from hot and cold weather.

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doi:10.1016/j.ndteint.2004.06.003

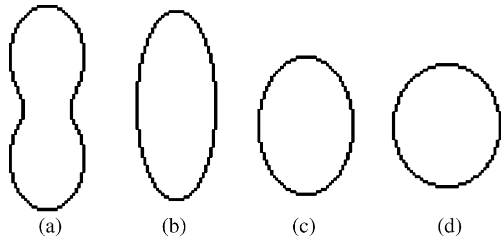

Fig. 1. Cocoon shapes.

Moreover, it welcomes useful light for the silkworm while it filters harmful ones [4]. That is, cocoon body reflects light in specific wavelength ranges and absorbs light in different wavelength ranges [5].

Spectrum characteristics of the cocoon body are shown in Figs. 2 and 3. As shown in Fig. 2, much more light passes through the cocoon shell in the wavelength range of 0.4–1.2 μm.

After 1.2 μm, a significant decrease takes place in the amount of light that passes through the cocoon shell. Reflection coefficient of the cocoon body depends also on the wavelength. As shown in Fig. 3, there is a high reflection coefficient in wavelengths between 0.4 and 2 μm.

Reflection coefficient decreases as the wavelength increases [6]. Considering the spectrum characteristics, light emitters in required wavelengths can be selected to determine cocoon properties with optoelectronic methods.

4. Passing of light through cocoon shell

Passing through a medium, some percent of light is absorbed by the medium and some percent is propagated [6,7]. Light intensity absorbed by the cocoon shell when light with an intensity of F falls on a small region of dx on the cocoon shell can be expressed as

$$dF_\alpha = -\alpha F\,dx \tag{1}$$

where α is the absorption coefficient. The '$-$' sign in (1) is an expression of a decrease in the light intensity.

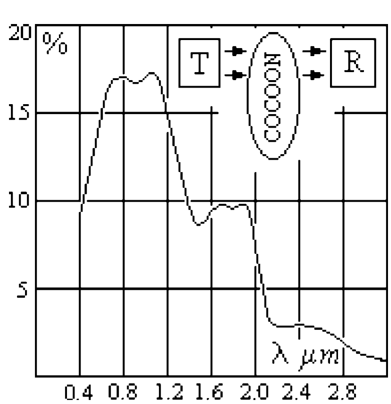

Fig. 2. Spectrum characteristics of light passing through cocoon body.

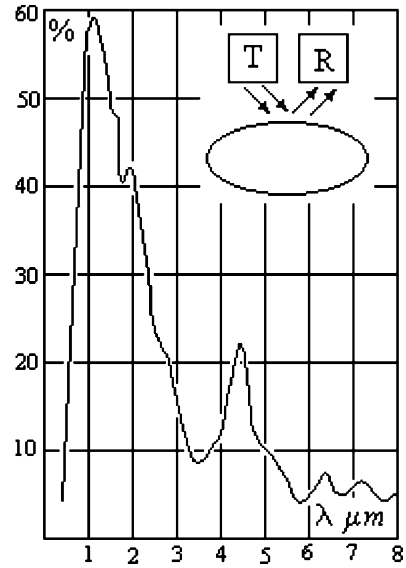

Fig. 3. Spectrum characteristics of light reflection from cocoon body.

Absorption coefficient is determined by the cocoon shell properties and wavelength of the light.

In a similar way, propagation of light in the cocoon shell can be determined by

$$dF_\beta = -\beta \cdot F dx \tag{2}$$

where β is the propagation coefficient.

The decrease in the light intensity while the light is traversing a distance dx can be written as

$$dF = -(\alpha + \beta)dx\,F = -c\,dx\,F \tag{3}$$

where $c=(d+\beta)$ is a coefficient expressing the decrease of light. Taking the integral of (3) from $x=0$ to $x=L$ one can get

$$\ln F = -cL + C \tag{4}$$

where C is an integral constant and it depends on initial conditions. Assuming $C=0$ and $F=F_0$ one can obtain

$$F = F_0\,e^{-cL} \tag{5}$$

where $F_0$is the light intensity that falls on the cocoon shell, L is the distance traversed in the cocoon shell. (5) shows that the amount of light passing through the cocoon shell is an exponential function and expresses Burger equation. In Burger equation, taking $\tau = e^{-c}$[31–34]

$$F = F_0\tau^L \tag{6}$$

can be written, where $\tau = e^{-c}$ is the light passing coefficient of the cocoon shell. To express the propagation of light in the cocoon shell, let us consider the formation of a small cylinder whose base area is S and height is dx in passing region of the light [14]. Since it is too small, assuming this cylinder as a spot light source, intensity will be

$$dI_\alpha = \frac{1}{4\pi}f(\alpha)F\,dx = \frac{1}{4\pi}f(\alpha)E_N S\,dx \tag{7}$$