Device for diffused reflectivity measurement of samples immersed in water

J.C. Arteaga Velázquez*, C. Vázquez López** and Arnulfo Zepeda***
Departamento de Física, CINVESTAV, Apartado Postal 14-740, 07000, México, Distrito Federal, México

In this work, we describe an automatized system involving the control of a stepping motor and data acquisition to determine carefully the diffuse reflectivity of any sample immersed in water. Also, we show the results of measurements of diffuse reflectivity of Tyvek for λ= 488 *nm*. Some of the advantages of this system allow us to save time and have a good angular resolution when comparing with the common manual systems.

Keywords:

1. Introduction

With the purpose of measuring the diffuse reflectivity of Tyvek [1] in air and water, we built an automatized system involving the control of a stepping motor and data acquisition to determine the diffuse reflectivity of Tyvek as a function of the reflection angle for several incidence angles of a laser beam[1].
In the other hand this experimental system can be used for measurements of reflectivity of other samples within different contexts [2].
Unlike the manual procedure our system includes a stepping motor to have a better angular resolution and save time.

2. Experimental set-up

The experimental design is shown in figures 1 and 2. Here the main measured parameters are the incidence angle q_i, the reflection angle q_r and the amount of reflected light I_t in that direction.
According to Fig. 1, the detector and the laser beam lie on an horizontal plane while the surface of the sample stands on the vertical plane.
In order to immerse the sample in water we used a cylindrical container whose inner surface was sprayed with black paint to avoid undesirable reflections. This container was provided with a glass window to allow the incidence of the laser beam on the sample.

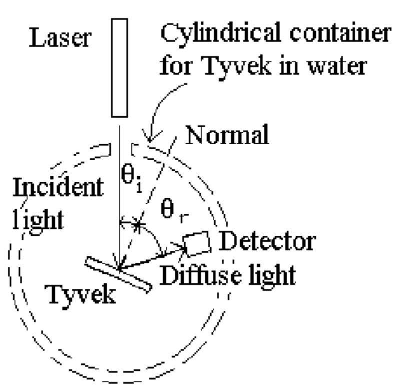

Figure 1. Experimental set-up

The parameters mentioned before are measured in the following way:
1) q_i: In this experimental design, the position of the incidence laser beam is fixed, so q_i must be controlled by rotating the sample about the vertical direction so, in order to do it, we built a goniometer (see Fig. 2) to hold and rotate the sample by using an aluminum joint, a metallic cylindrical core (made of brass) and pincers made of aluminum covered with black paint.
Two perforations, one horizontal and another one vertical, were made on the aluminum joint to fix it to the principal support and hold the metallic core respectively.
The length of the metallic core must be chosen according to the depth at which we want to immerse our sample in the container with water. In order to measure the rotation angle of the sample we attached a goniometer on the top of the metallic core. Here we took into account the coincidence of their central axes. In our case the rotation of the sample was made by hand, but in principle one may use another stepping motor besides the one used by us to measure θ_r (see bellow).
In the other hand, to hold the sample, we used the pincers. If we were dealing with a soft sample we could put it on a piece of glass and hold it with the pincers.
2) q_r: The rotation q_r of the detector around the sample was

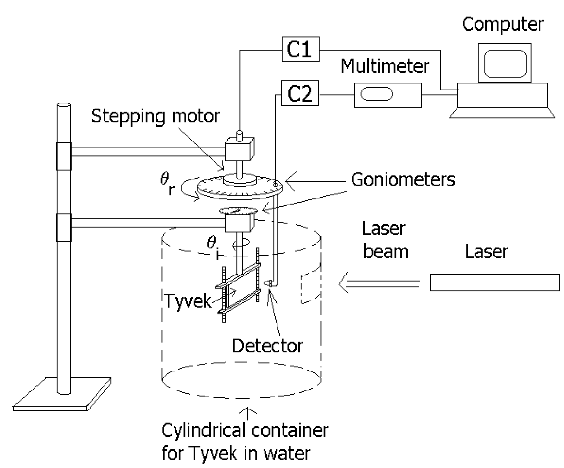

Figure 2. Device for diffuse reflectivity measurements of a sample immersed in water

*jarteaga@fis.cinvestav.mx
**cvazquez@fis.cinvestav.mx
***zepeda@fis.cinvestav.mx

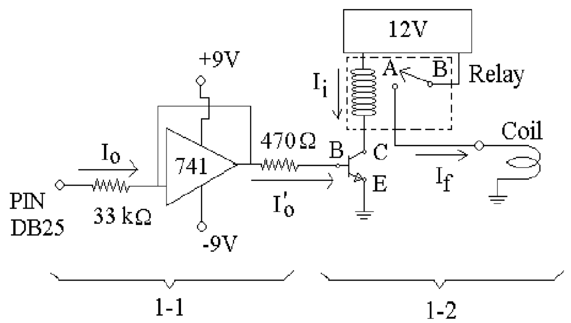

Figure 3. Circuit 2. It was used for the measurement of the intensity of the reflected light.

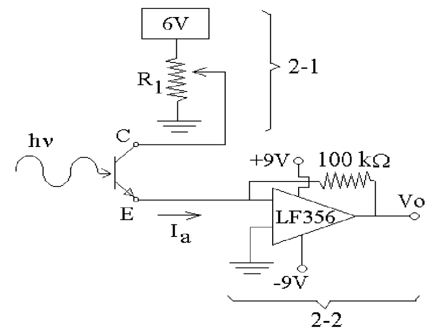

Figure 4. Circuit 2. It was used for the measurement of the intensity of the reflected light.

controlled by using a four-coil stepping motor Mitsubishi of 1.8°/*step* (like those used for old floppy drives of 360 kB). This model was chosen due to the simplicity of the driving circuit, which feeds each coil sequentially.

The coils of the stepping motor are fed by the data bus of the DB25 parallel port of a PC. The data bus is controlled by software, and consist of TTL level voltages. In this work, only four pins of the data bus were needed. The sequence of steps for the motor were obtained by sending the following binary numbers to the parallel port: *(1000), (0100), (0010), (0001).*

It was imperative to take into account that the current supplied by the parallel port is 5 mA, while the stepping motor requires 300 mA, so we had to assemble (for each data pin) the circuit shown in Fig. 3 to supply that current. It works in the following way: In order to protect the parallel port a unity gain follower is used (circuit 1-1). Thus, the available current of the data bus (I_o) increases by a factor 4 (I'_o). In this way the base of a TIP41 NPN transistor is able to be polarized, which determines the Emissor-Collector current (I_i) provided by the 12V CC power supply. This current energizes the corresponding coil of the stepping motor by means of a relay.

3) I_t: As a photodetector an NPN silicon phototransistor was used. This phototransistor was chosen because it is covered by a protective plastic case. An operational amplifier LF356 (with field effect transistors inputs) is used to amplify and convert the photocurrent to a proportional voltage. This voltage is measured by a KEITHLEY multimeter provided with a 232 serial communication port as a DCE, connected to the serial port of the PC, which has the role of a DTE (see Fig. 4).

Let us describe how the circuit 2 works:

The circuit 2-1 has a 6V CC power supply and a variable resistor R1 connected to the collector (C) of the phototransistor . When the light incides on the Base of the phototransistor, it permits a flux of current I_a (proportional to the intensity of the light). This current is applied to the inverse input of a current-to-voltage converter (circuit 2-2). The feedback resistance was chosen to be of 100 kΩ, which permits a gain conversion factor of 10^5 *Volts/Ampere*

In order to isolate the connections of the detector from the water we used a glass tube with the shape of an "L" with a length of 15 cm and diameter of 5mm, then the phototransistor was fixed to the shorter edge and we put the connections inside the tube and finally to avoid the presence of water inside the tube we sealed the joint between the tube and the detector by using silicon paste.

The other edge of the tube was fixed to a disk which was attached to the stepping motor (see Fig. 2) so, in this way, the rotation of the stepping motor was transmitted to the detector. To do this we took into account that the detector must be always pointing to the central axis of the stepping motor and that the position of the tube must be parallel to this axis.

In order to hold the stepping motor we use a metallic tube and an aluminum joint to fix it to the principal support.

Finally all the elements are assembled in such a manner that the vertical central axis of the system to control q_i and q_r must be aligned.

4) Acquisition data system: In Fig. 5 the flux diagram of the control system and data acquisition is shown.

Before taking the measurements we must check that:

a) The laser beam must fall on the center of the sample which must coincide with the central axis of the system.

b) The detector must be at the same distance (for different values of q_i *and* q_r*) from the incidence point of the laser beam on the sample.*

c) The detector and the laser must be at the same height.

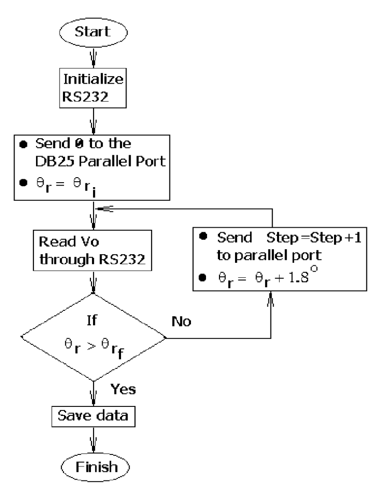

Figure 5. Flux diagram of the control system and data acquisition

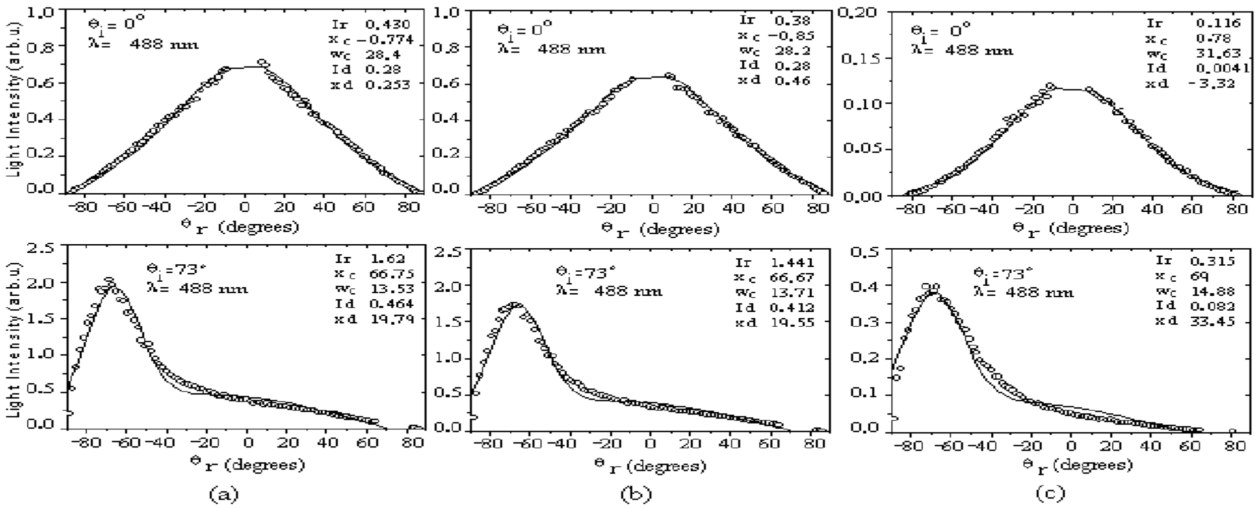

Figure 6. Diffuse reflectivity spectrum of Tyvek as a function of q_r for λ = 488 *nm*, and q_i = 0°, 73° for Tyvek: (a) in air, (b) inside the cylindrical container, and (c) in water. The circles represent the experimental data while the solid line the fit by using the relation

3. Results

The graphs for diffuse reflectivity of Tyvek in air and inside the cylindrical container with and without water are shown in Fig. 6 for q_i and q_r = 73°. These results were obtained from a typical sample of Tyvek. The behaviour has been checked to be reproducible. For the incidence light we use a laser beam with λ = 488 *nm* produced by an Argon laser with nominal power of 11 *mW*. In Fig. 5, units are arbitrary but the same scale is used for all the cases. The distance between the detector an the incidence point of the laser on the sample was 2.5 cm, while the distance of the Tyvek to the laser source was 35 cm.In order to fit the data (see Fig. 6), we proposed the following relation:

$$I_t(q_i q_r) = I_r e \frac{-(q_r + x_c)^2}{2w_c^2} + I_d \cos(q_r + x_d) \quad (1)$$

by similarity with the relations proposed by Hasenbalg et al [3], and Filevich et al [4], where it is assumed a cosine function (suggested by Lambert's law) to fit the diffuse light, and a gaussian term to fit the peak (which has a specular contribution). Here, x_c give us the position of the I_r component while x_d is a phase displacement of the cosine function.

The decrease of the diffuse reflectivity when the sample is immersed in water is mainly associated with the increase of the refractive index of the incidence medium, from 1 in air to 1.34 (for λ=488 *nm* in water [5]. The I_r and I_d parameters are identified as the specular and diffuse components, respectively. The changes observed when the incident angle increases correspond to the predominance of the specular component over the diffusive part.

4. Conclusions

By building a simple automatized system involving the control of a stepping motor and data acquisition, the diffuse reflectivity of Tyvek has been carefully obtained. The incorporation of the stepping motor and the use of a computer to control the process of measurement is a major improvement to get a better angular resolution and to save time. This can be seen from the graphs obtained for the diffuse reflectivity of Tyvek.**5.**

Acknowledgements

The authors thanks the technical assistance of B. Zendejas.

References

[1]. This material has be chosen to cover the inner surface of the Cherenkov detectors in the Pierre Auger project to detect ultra high energy cosmic rays. Tyvek is a registered trademark of DuPont Company. DuPont. http:// www.dupont.com,

[2]. M. Zvara et al., J. Magn. Magn. Mat. 12, 219 (1979). http://pygarg.ps.umist.ac.uk/ianson/paper_physics/Optical_ Properties.html

[3]. F. Hasenbalg and D. Ravignani, Tyvek Diffuse Reflectivity, GAP 97-035.

[4]. Filevich, P. Bauleo, H. Bianchi, J. Rodriguez Martino and G. Torlasco, Spectral-directional reflectivity of Tyvek immersed in water , GAP 97-065.

[5]. D.J. Segelstein, The Complex Refractive Index of Water, M.S. Thesis, Department of Physics, University of Missouri-Kansas City, 1981.