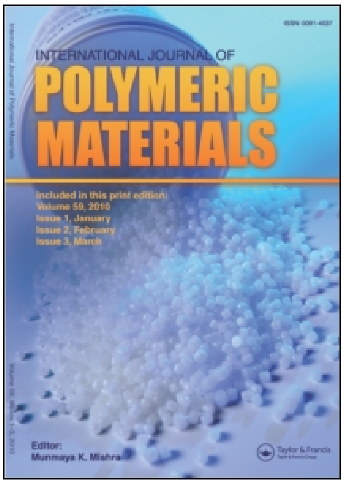

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# He-Ne Laser Protection Barrier by Means of Poly(tetrafluoroethylene-perfluorovinyl ether) Grafted by Acrylic Acid and Complexed with Cu(II)

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# He-Ne Laser Protection Barrier by Means of Poly(tetrafluoroethylene-perfluorovinyl ether) Grafted by Acrylic Acid and Complexed with Cu(II)

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*Appropriate eye and skin protection is a prerequisite for the safe operation of He-Ne laser in industrial and laboratory environments. This article reports on the measurement of the optical parameters of Poly(tetrafluoroethylene-perfluorovinyl ether) grafted by acrylic acid and complexed with Cu(II) when exposed to He-Ne laser beam of wavelength of 632.8 nm and power 12.5 mW. Transmittance, reflectance, and refractive index spectra are presented. The study showed that the material has a protective level 4. Environmental conditions like thermal and fading processes were tested. This suggested that the material preserves its protective features as a protective eye and skin barrier of protective level L4. This was applied for an occupational working time up to 8 h, temperature up to 50°C, and for a time of 74 days after laser irradiation.*

**Keywords:** Cu complex polymerfilm, He-Ne laser, optical parameters

## INTRODUCTION

Alexandrite solid state lasers with a wavelength of about 755 nm are frequently used in the field of medicine [1]. For removing tattoos, the Q-switched versions with impulse widths of several ten nanoseconds are an ideal instrument to keep the thermal stress of the patient's skin small.

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He-Ne laser is one of the most commonly used visible light lasers, giving off a red laser beam with a wavelength of 632.8 nm. It has been used extensively for medical treatment, holography, laser light displays, and more [2–5]. Its low cost and long lifetime make it extremely desirable for use.

## EXPERIMENTAL

Optical absorption of the samples is measured using Shimadzu UV 160 A spectrophotometer in the spectral range from 180 nm to 1100 nm. Helium neon (He-Ne) laser source type 05-LHP-001 of maximum power 12.5 mW at wavelength 632.8 nm is used. A broadband power/energy meter type 13 PEM 001 is used to detect the laser source power.

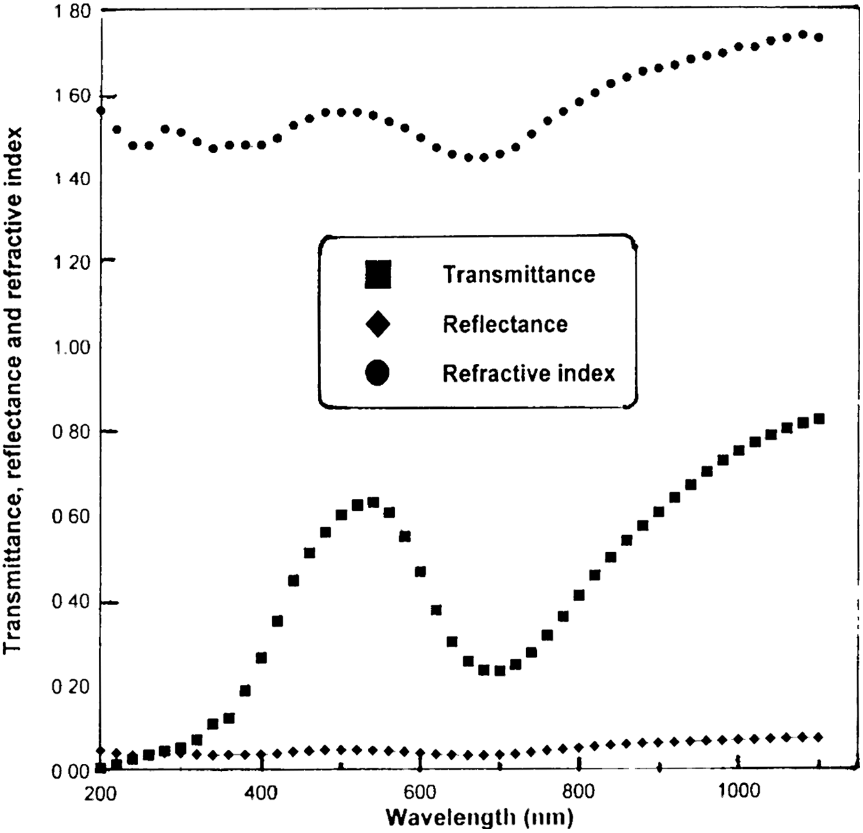

**FIGURE 1** Transmittance, reflectance, and refractive index spectra of unirradiated samples.

Poly(tetrafluoroethylene-perfluorovinyl ether) grafted by acrylic acid and complexed with Cu(II) is prepared according to References [6–7].

## Prolonged Exposure for He-Ne Laser

The present investigations have been undertaken to study the infuence of laser radiation doses on the UV-VIS-NIR light transmission through the samples. The problem is of importance because overexposure to laser radiation leads to some injury for the exposed parts, especially the eye and skin.

Light, as it penetrates a solid, interacts with it exchanging energy in the course of this interaction. The fraction of light energy reflecting off the boundary of the body is determined by the reflection factor or the reflectivity R. Light that has penetrated a solid is absorbed by it in compliance with the Bouguer-Lambert law [8]:

$$\text{Transmittance} = (1 - \mathrm{R})e^{-\alpha x} \qquad (1)$$

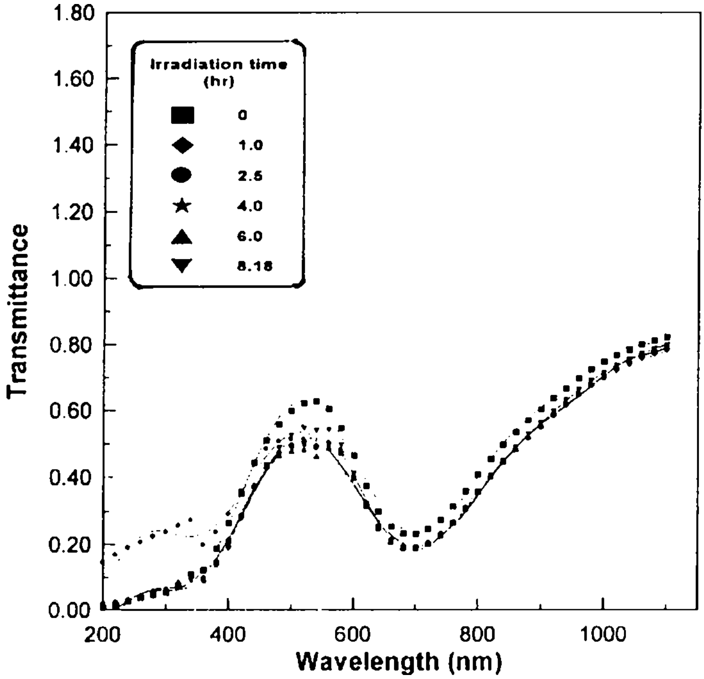

**FIGURE 2** Effect of laser irradiation on transmittance spectra.

$$R = \frac{(n-1)^2 + k^2}{(n+1)^2 + k^2} \tag{2}$$

where R, n, and k are the reflection coefficient, the refractive index, and the extinction coefficient, respectively.

Transmittance, reflectance, and refractive index spectra, for unirradiated sample, change are shown in Figure 1. Transmittance, reflectance, and refractive index spectra show minmum value at 700 nm [1,6–7]. From this it is clear that absorption became maximum. In Figure 2, transmittance spectrum of samples unirradiated and irradiated with He-Ne laser for different times are plotted. The spectra were identical to each other. The increase of the irradiation time reflects the increase of photons evolved from the source. This means that a chromophore (at 700 nm) was responsible for the transmission. The position of these prime transmittances and the whole spectrum does not change on irradiation with laser. This gives an indication about the electronic transition estability of the samples on their irradiation with maximum power source. Figure 3 indicates a certain

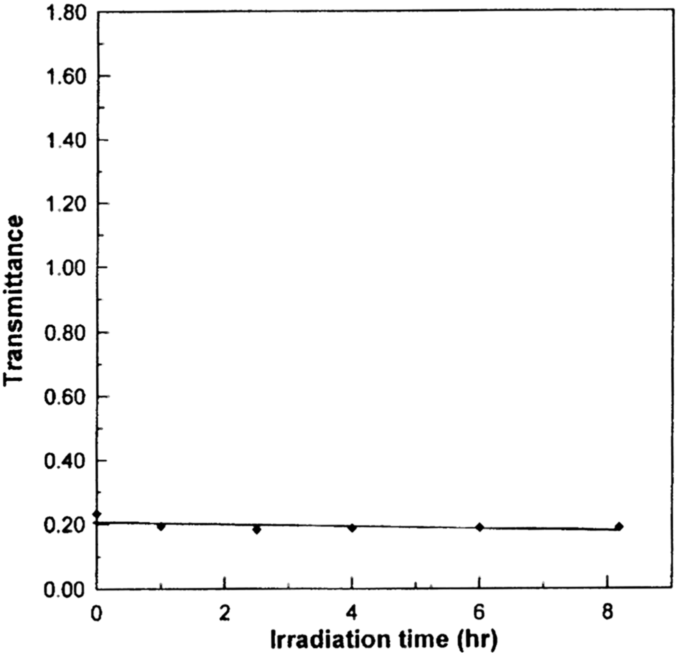

**FIGURE 3** Relationship between transmittance and different irradiation times.

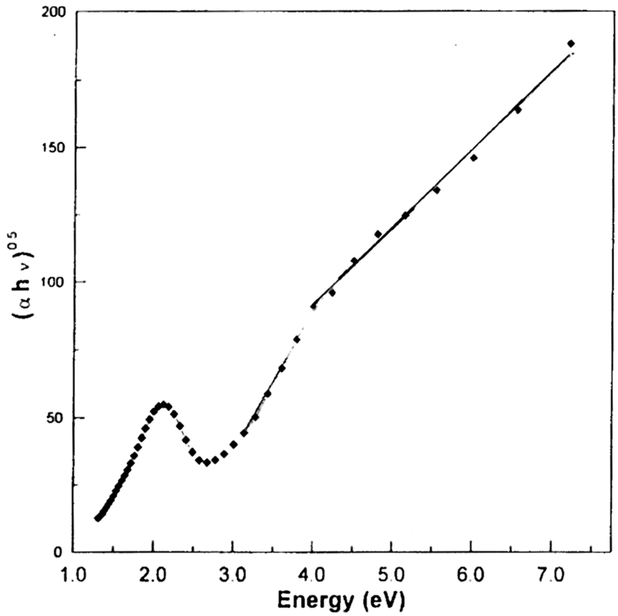

**FIGURE 4** Relationship between $(\alpha\ h\nu)^{0.5}$ and the light beam energy.

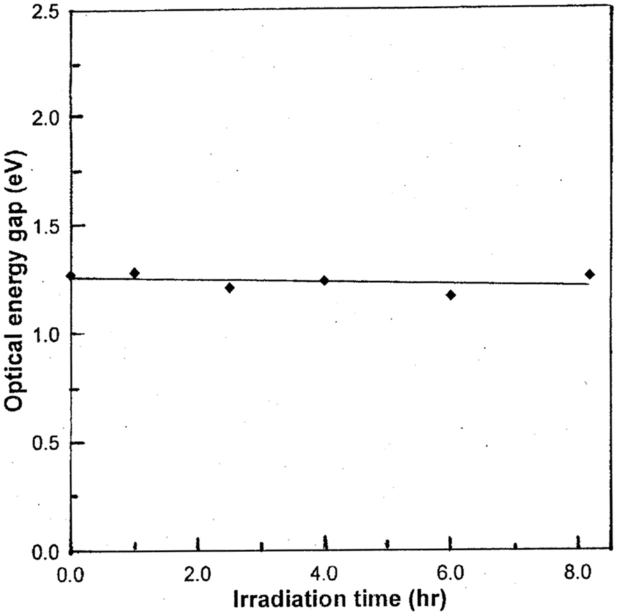

**FIGURE 5** The optical energy gap change with irradiation time.

degree of stability of transmittance at 700 nm. The minimum transmitance and the stability of samples at 700 nm encouraged the authors to test the ability of these samples to attenuate He-Ne laser source later.

Tauc et al. [9] introduced an equation for the absorption coefficient $\alpha(v)$ as a function of photon energy in amorphous materials:

$$\alpha(v) = \beta\ (hv - E_{opt})^{m}\ hv \qquad (3)$$

where $\alpha(v)$ is the absorption coefficient at frequency v, $\beta$ is constant, $E_{opt}$ is the optical energy gap of the material, and hv is the photon energy. The exponent m may take the value 2 for an indirect allowed transition, 1/2 for a direct allowed transition, 3/2 for a direct forbidden transition, and 3 for indirect forbidden transition. The correlation between $(\alpha\ (v) \times hv)^2$ and the photon energy is the suitable relationship for determining the optical energy gap for unirradiated and irradiated sample. This means that the present samples have the direct allowed transition.

The relations among the optical energy and $\alpha$ hv to different powers m prove the allowed indirect transition character of the samples as in Figure 4. The change of the optical energy gap with laser irradiation

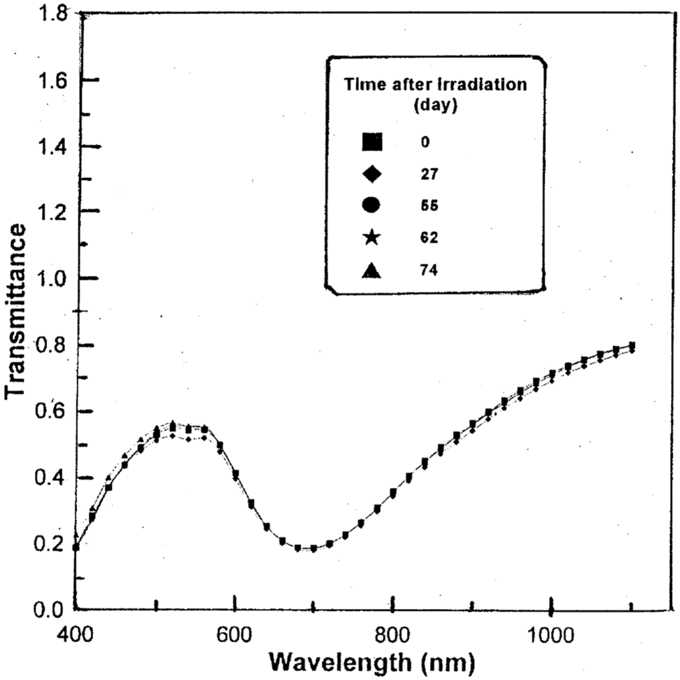

**FIGURE 6** Transmittance spectra of samples at different times after irradiation.

time is plotted in Figure 5. A certain degree of stability is satisfied over the inspected irradiation time.

The aforementioned study illustrates the low effect of exposing the samples to He-Ne laser beam of power 12.5 mW for times up to 8.18 h. Because some experiments and applications need to use a He-Ne laser, it is necessary to avoid the exposure of eye and skin of the workers. To meet these requirements, eye protector materials or curtain or performing the experiment inside a protected facility are used. The authors are going now to test the inspected samples for these purposes.

## Fading Effect

Regarding the environmental effects, sample transmittance may be changed when measuring it after irradiation for different times. This effect is called fading effect. Over 74 days, the transmittance spectra of the samples are obtained in Figure 6. The general features of the spectra were similar. This was verified by tracing the change of He-Ne laser transmittance of the samples over 74 days in Figure 7. The

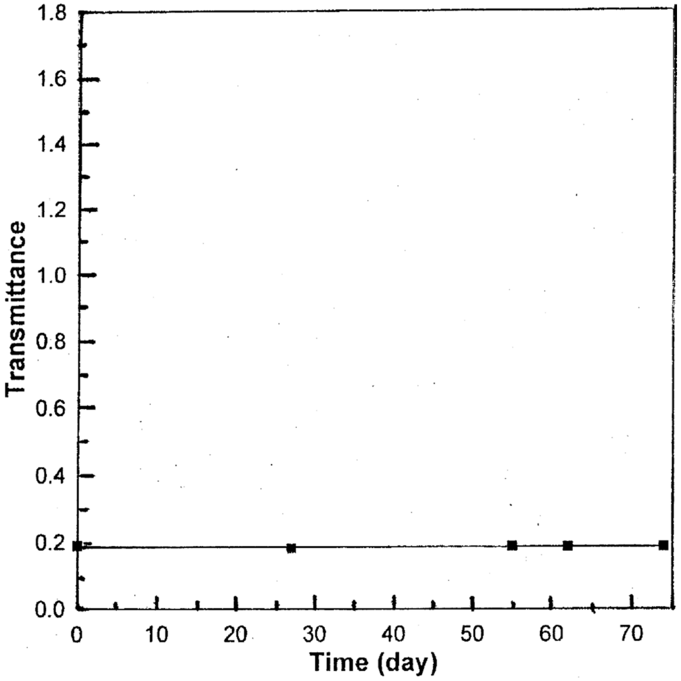

**FIGURE 7** Fading effect of irradiated samples at 700 nm.

graph shows a 3.87% (at 700 nm) change in transmittance over the aforementioned time.

## Thermal Effect

Measurement of the He-Ne laser beam transmittance through the sample was done and the optical density was subjected to Beer's Law:

$$I = I_0 e^{-\alpha x}$$

where $\alpha$ is the absorption coefficient and x is the sample thickness.

Temperature effect on the irradiated samples is one of the environmental condition needed to study.

### *Isothermal Treatment*

Isothermal treatment is recorded in Figure 8 where the samples were kept at 50°C. The figure illustrates the time stability of the sample to He-Ne laser exposure up to 8.5 h. An increase of the transmittance is only 3.74%.

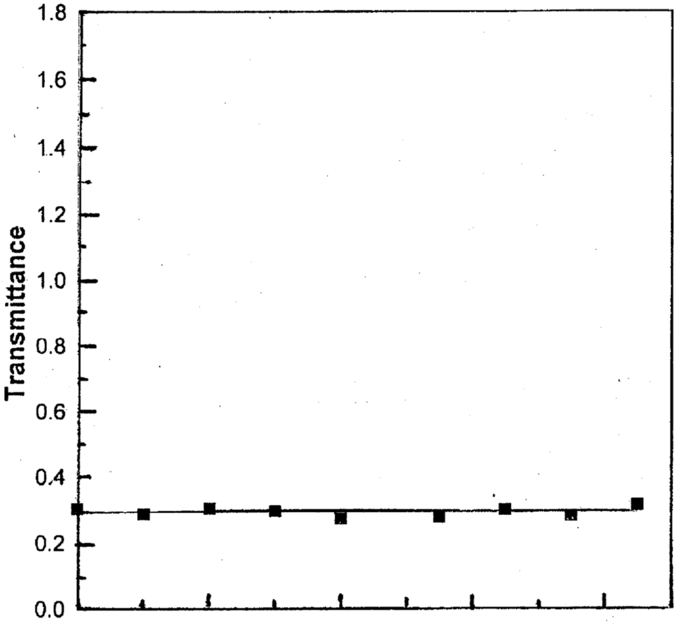

**FIGURE 8** Effect of heating time at 50°C on He-Ne laser beam transmittance.

## *Isochronal Treatment*

Samples were kept for one hour at different temperatures up to 95°C. Measurement of sample transmittance for He-Ne laser beam of power 12.5 mW was performed. The data obtained are plotted in Figure 9. Transmittance of sample showed a temperature stability when heating it up to 50°C.

## Effect of Thickness

Plotting the change of transmittance with sample thickness (Figure 10) showed an exponential decrease up to 0.0025 for 7 mm sample thickness while the optical density increased to a value of 3.61.

The attenuation of laser beam is deduced from the relationship:

$$\mathrm{Ln}\ (I_0/I) = \alpha\ x$$

The variation of the Ln $(I_0/I)$ with the sample thickness led to a straight line, its slope equal to the attenuation coefficient 9.3 $\mathrm{cm}^{-1}$.

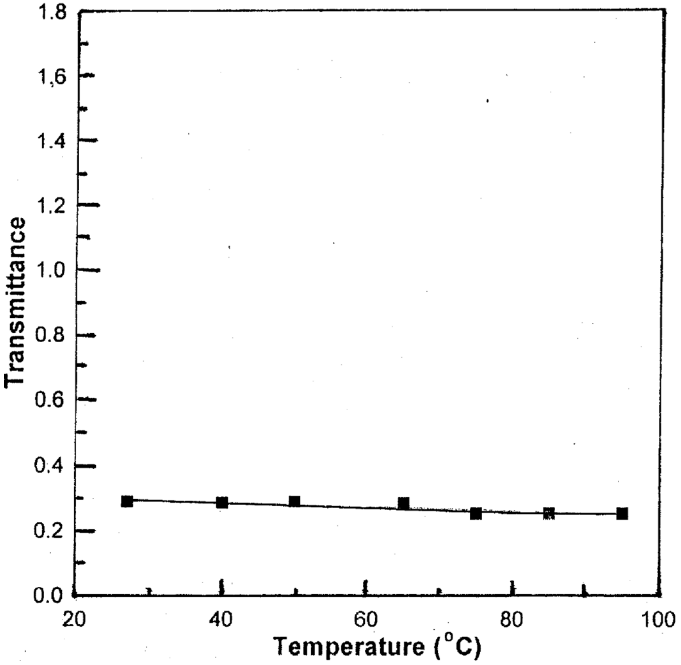

**FIGURE 9** Effect of heating the sample for 1 h on He-Ne laser beam transmittance.

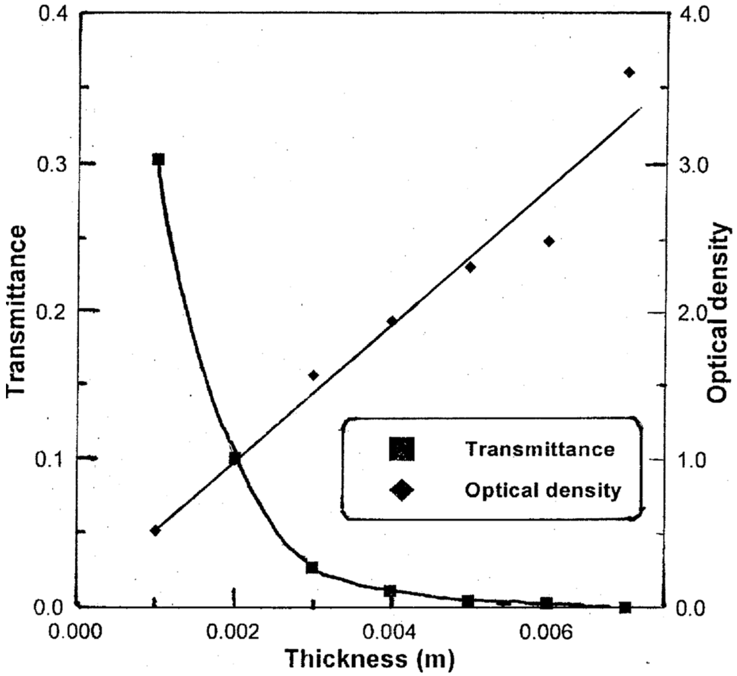

**FIGURE 10** Effect of sample thickness on He-Ne laser beam transmittance and optical density.

## CONCLUSION

In the past few years, polymers (plastics) have stirred excitement with the prospect of inexpensive flexible products, out the laser barriers market seemed closed to the use of polymers.

Depending on the presence of copper, the region of high absorption at 700 nm lies in the range from 600 nm to 700 nm where He-Ne laser wavelength lies. To barriers showing induced transmittance, only a small or moderate protection level would be assigned. If the barrier is then chosen correctly for the specific laser, no injury will be suffered even if the direct laser beam falls on the applicant's eye protector. Good tests of barriers will yield one of a protective level that combines spectral transmittance and resistance to laser radiation.

Poly(tetrafluoroethylene-perfluorovinyl ether) grafted by acrylic acid and complexed with 50% Cu(II) sample of 7 mm thickness, exhibits high absorption coefficient. Optical parameters, thermal treatments, and fading studies proved the stability of the samples. The used He-Ne laser is assigned to class 3b. The inspected sample had a protective level of L4, which implied use up to 12.5 mW for He-Ne laser in a working day of 8 h and temperature up to 50°C.

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