ROENTGEN IMAGE RECORDING ON SILLENITE-TYPE ELECTROOPTICAL CRYSTALS BY ELECTROPHOTOGRAPHIC METHOD

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Abstract

To record Roentgen image on sillenite-type crystals while charging in a corona discharge field, a device has been performed. The resolution not less than 10 pairs of lines per mm, the sensitivity of 25 reciprocal Roentgens, the contrast coefficient not less than 2 at the exposure length of 0.6 s were obtained using $Bi_{12}GeO_{20}$ crystal. The device survives more than 10^4 of writing-erase cycles. From the sensitivity point of view, the considered registration is just as good as X-Ray films used for radiography and dosimetry.

1. Introduction

Currently the interest in X-ray technique does not relax owing to its more expanding use in practice. A brief survey of X-ray registration directions allows us to mark out the following main methods [1]:

- photography – utilizing X-ray sensitive photographic materials, necessary for further chemical processing;
- electrostatic photography – based on charging of X-ray sensitive layers in a corona discharge field followed by liquid or powdered visualization of an X-ray scene;
- Lumiprinting – converting the X-ray radiation to visible light with the wavelength caused by a luminescent material;
- Television method – using vidicons sensitive to X-rays;
- Methods based on the employment of semiconductor layers sensitive to X-rays.

Investigations done earlier have shown that by analogy with xeroradiography Roentgen image recording by the sillenite-type crystals ($Bi_{12}SiO_{20}$, $Bi_{12}GeO_{20}$) while charging their surfaces in the field of a corona discharge may be realized [2, 3]. This circumstance allows us to simplify the Roentgen image recording procedure and improve the responsiveness of the recording process in comparison with the conventional electrographic method. Physical principle of the developed method is based on the fact that sillenite-type crystals possess both the Roentgen sensitivity and electrooptic properties at the same time.

2. X-ray recording

X-ray image recording process is carried out by means of a small-sized unit the scheme of which presented in Fig. 1 illustrates well this process in automatic regime. The process itself can be divided into four consequent stages: charging of crystal surfaces in the corona discharge field; the Roentgen exposure of the crystal; readout of the formed image; erasure of the image prior to a following registration cycle. High-voltage bloc 19 controlled by the voltage ramp generator 18 feeds corona-forming filaments located in the charging device 4 which gives rise to working element 5 charging. An appearing field of a corona discharge

gives rise of a potential at the crystal surfaces according to a near –linear low. In the process of charging, the crystal is illuminated by the plain-polarized light with the wavelength λ = 700÷750 nm which is inactive for the crystal. This probe parallel beam is formed by the light source 21 (projector lamp КГМ), system of filters 22, lens 23, and polarizer 24 and it is directed on the sample by the stationary 1 and movable 3 mirrors.While charging the crystal, bloc 20 and the program-simulated unit 16 control a rotation gear 7 which sets up the movable mirror 6 horizontally so that the probe beam passes through the analyzer 8. A part of the light beam is diverted by the semitransparent mirror 9 on the photodiode 13 forming feedback.

Figure 1: The scheme of the small-sized device for Roentgen image recording.

During the charge accumulation process, the rising potential modifies the crystal refraction index that, in turn, changes the polarization characteristics of the whole optical system making it "blooming" on the output of the crossed analyzer 8. In accordance with Pockels' law

$$I = I_0 \sin^2 \frac{\pi}{2} \frac{U}{U_{\lambda/2}},$$

where I is the light intensity passed through the system "polarizer – crystal - analyzer" at the voltage difference U on the crystal; I_0 is the maximal intensity of light passing through the system under analyzer oriented parallel to polarizer in the no-voltage condition; $U_{\lambda/2}$ is the half-wave voltage of the crystal.

When the intensity I reaches a magnitude close to its maximal one, the photodiode signal entering the derivator 14 and, hereinafter, comparator 15 disconnects the charging. A potential close to the half-wave voltage $U_{\lambda/2}$ arises between the crystal surfaces. High values of the specific resistance ($\rho \sim 10^{14}$ Ω cm) and permittivity ($\varepsilon \sim 40$) provide sufficiently long time (more than 10 minutes) of the surface potential relaxation, i.e. being in the darkness the charged crystal is ready for the exposure quite a long time. When charging is carried out, the executive unit 20 turns the mirror 3 by means of the rotation gear 2 into the horizontal position overlaying the probe beam and opening the crystal for the exposure of X-ray radiation passed beforehand through the object "0" under investigation. At the same time, the command switching on the X-ray radiation power supply is given. X-ray quanta passing through the object fall onto the crystal generating non-equilibrium charge carriers in it, which are drifted to the crystal surfaces with the opposite sign of charge with a successive recombination. As a result, the charge relief is formed with corresponding distribution of the refractive index being stipulated by the electrooptic effect.

After the exposure ending, the X-ray radiation source supply turns off and the mirror 3 is rotated into its initial inclined position so that it might direct the beam of the inactive reading-out light on the crystal. Passing through the crystal and analyzer 8 crossed with polarizer 24 this beam contains information regarding the refractive index distribution, i.e. the Roentgen imagery data. The irradiated areas are reproduced as a dark background, but radiation-free ones remain light-colored. The beam passed through the analyzer is focused by the objective 10 at the recording instrument 11. As a recorder, digital video camera, camera with TV-monitor, or photo camera connected to computer may be used. Being observed and recorded, the actual image is erased by intensive, active for the crystal blue-green light from the source 21 after the command rotating the mirror 6 in inclined position.

3. Results and discussion.

Fig. 2 shows the Roentgen image photographs for some objects registered by means of the method worked out.

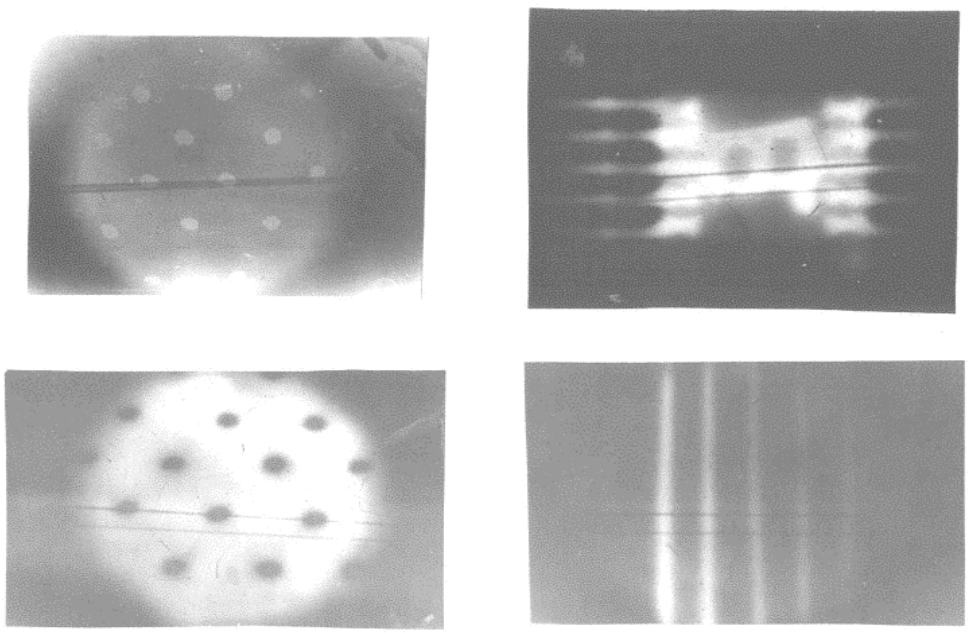


Figure 2: Samples of the obtained Roentgen images.

The negative (upper) and positive X-ray patterns of 3 mm – metal plates with holes of 1 mm across diameters are at the left. Dark dots in the positive photograph (below) comply with the holes through which Roentgen radiation falls onto the crystal.

The right-hand lower photograph offers X-ray pattern for a test-object, which consists of a system of the copper wires with different diameters (0.1, 0.15, 0.2, 0.33, and 0.44 mm). The places, where the wire model shields the X-ray radiation, keep the field created on the crystal and are recorded as light bands in the photograph. The given test allows us to estimate the value of the resolution capability of recording medium. As an illustration, the X-ray pattern of the seven-segmented opaque to visible light indicator is presented in the right-hand upper photograph.

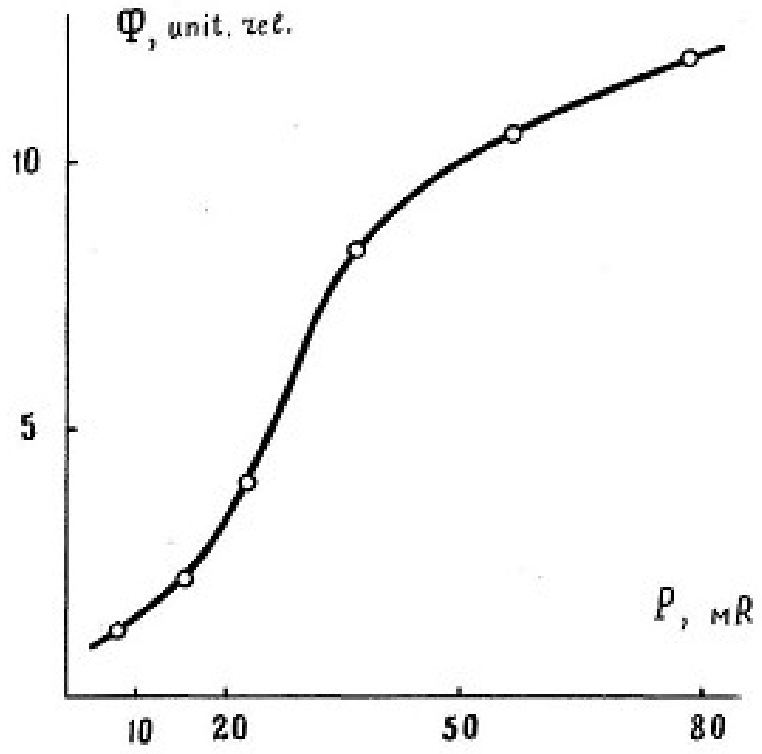


Figure 3. Probing light contrast versus the Roentgen radiation energy.

The main parameters specifying recording material properties are: Roentgen sensitivity, contrast ratio, photographic latitude, and resolution capability. Contrast of the line-process bloc image recorded on the crystal as a function of the X-ray radiation intensity is presented in Fig. 3. As the contrast value there was used $\Phi = I_{rf} / I_{ir}$, i.e. the ratio of intensities of the readout light passed through the crystal in a radiation-free position to irradiated one. It is possible to estimate the sensitivity by the formula $S = 1/(P_{exp.} C)$, i.e. the reciprocal to the product of the X-ray intensity and the exposure time C. The radiation power was measured by means of the calibrated standard instrument DRG 3-03. If we carry out the calculation of sensitivity proceeding from the plot $\Phi = f(lgP)$ at the value of Φ estimated for 0.85 of maximal Φ = 12.data, the sensitivity is equal to $S_{0.85}$= 25 PR^{-1}.

The contrast ratio is determined by the angle of the characteristic curve straight-line portion slope,

$$\gamma = tg\alpha = \frac{\Phi_2 - \Phi_1}{\lg P_2 - \lg P_1}.$$

This coefficient characterizes the recording material capability to reproduce different brightness (intensities) of the object under investigation. Photographic latitude $L = \lg (P_2 - P_1)$ defines a range of the object intensities reproduced in the image with the same contrast ratio. Metering conducted allows us to conclude that X-ray image recording method proposed here on the base of X-rays sensitive sillenite-type electrooptic crystals ensures the following parameters:

the sensitivity to X-rays, $S_{0.85} = 25\ R^{-1}$;

the contrast ratio, $\gamma \to 2$;

the photographic latitude, $L = 0.6$;

the resolution capability, $N \sim 10$ мм$^{-1}$;

the recording cycling -no less 10^4.

By the sensitivity, the developed method is just as good as photographic one using X-ray films employed for defectoscopy and radiation monitoring. The developed method can be successfully used in such fields of application as welded part checking (defectoscopy), express radiation monitoring, the definition of Roentgen particle tracks and their wave propagation (crystallography).

References

[1] A.M. Gurvich, *Fizicheskie osnovy radiatsionnogo kontrolia I diagnostiki, Energoatomizdat, Moskova, 1989.*

[2] V. Gladilin, I. Dementiev, E. Maximov, L. Tarakanova, and K. Sherban. "X-Radiation recording by sillenite – type electrooptic crystals while charging surface in corona discharge field", Optoelectronica, 3, nr. 3, pp. 71-73, 1995.

[3] Ig. Dementiev, E. Maximov, "*Instalație pentru roentgenografie"*. Brevet de invenție MD 928, G2, 28.02.1998.