INFRARED DETECTORS FOR SAFETY-CONTROL OF POSTOFFICE MESSAGES

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(Received 31 March 2009)

Abstract

A method for simultaneous processing and control of potentially dangerous objects like viruses or explosives is proposed. The method is based on the prophylaxis of irradiation and post irradiation IR-control.

1. Introduction

One of the reasons of the modern world vulnerability is high organization and mass character of its industrial, commodity, and transport lines. Unfortunately, one of the most unsafe items is mail because of the following reasons: high speed of delivery, integration into the WorldNet, the sender's actual anonymity, and identification of the addressee. The disadvantage of the use of this channel for mailing items of provocative character is their restricted carrying capacity; therefore, the subject of dangerous enclosures can be, as it is already known, bacteria and viruses culture or plastic explosive used even before the peak of terrorist activity.

While searching for ways to reveal and neutralize possible dangerous enclosures in mail items, our team of authors has turned to existing civil and special experience, in particular, to construction of sterilization sections for disposable medical production and to detection and identification of objects by indirect temperature-contrasting imagining [1, 2]. In our opinion, these two methods can successfully supplement each other, especially while using advanced developments in nanotechnologies.

For preventive bactericidal treatment of mail items, it is expedient to use the method of radiative sterilization, which is widely applied all over the world for processing of medical production. The absorbed dose value of 15-25 kGr can kill the vital activity of pathogenic microorganisms. Estimated cost of such treatment can be obtained from the calculation that for processing of 15 kg of envelopes it is necessary to apply an electric power of 1 kW·h.

In addition to the preventive treatment, there is a problem of revealing of envelopes with suspicious enclosures. Here we should return to values of the sterilizing absorbed doses of ionizing radiation. It is known that when radiation passes through a substance, a part of the absorbed energy is spent for increasing temperature of the irradiated object. Thus, the absorbing ability of the object depends on its density and geometrical sizes, in particular, thickness of absorbing layer.

2. Decontamination and control of postoffice messages

The processing of mail is supposed to be made, as well as in the case of medical production, by the conveyor method (Fig. 1). Taking into account that we initially know homogeneity of the processed mass flow, objects that are in the area of irradiation will absorb the radiation field with equal intensity and, according to this, their temperature will increase by a given value. If a post envelope has an unauthorized enclosure (for example, plastic explosive), the radiation field will be absorbed more intensively, and the temperature at the output of the irradiation zone will differ from the background temperature. Radiation induces heating of polymer materials determined by the formula

$$\Delta T = \frac{D \pm E}{c}, \tag{1}$$

where D is the absorbed dose, kGr, c is the heat capacity, kJ/(kgK), E is the energy adsorbed as a result of chemical reactions.

There appears the problem of revealing objects with increased temperature and fixing of more intense absorption of radiation field appears.

One more indication of the presence of an unauthorized enclosure can be a change in the radiation field after passing through the irradiated object. To control radiation field, it is proposed to use a screen made of a thin foil. A change in the radiation flow will also cause a change in its surface temperature.

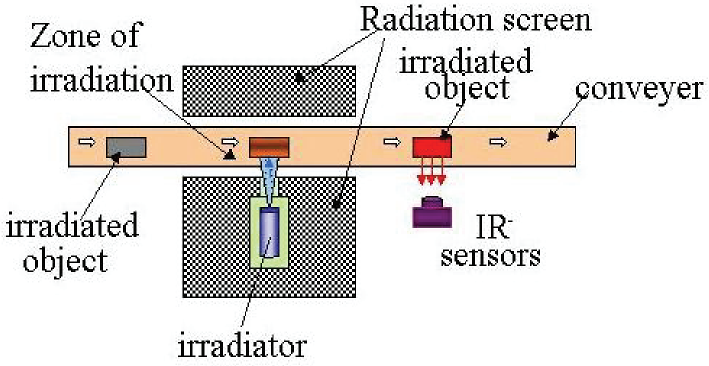

Fig. 1. Equipment for the post-office processing and control.

The measuring of a screen temperature and irradiated objects is offered to be made with the help of an Infrared radiometer (Fig. 2).

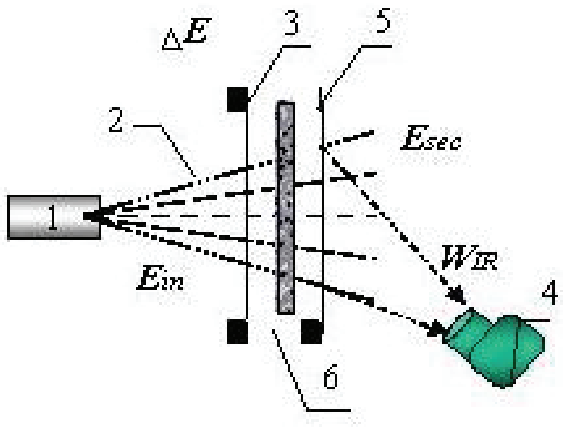

Fig. 2. Method of thermal imaging control/measuring: *1* is the source of accelerated electron beam; *2* is the accelerated electron beam; *3* is the sounding screen for determination of irradiation doses (is installed in the frontal plane of the object irradiation zone); *4* is the thermal imaging device [3]; *5* is the sounding screen for determination of absorbed doses; *6* is the irradiated object; $\mathbf{E_{in}}$ is the energy of initial electrons; $\mathbf{\Delta E}$ is the energy of electrons absorbed by the screen; $\mathbf{E_{sec}}$ is the energy of screen-transmitted electrons; $\mathbf{W_{IR}}$ is the energy of infrared radiation.

The temperature T_s of the ΔS element of the irradiated screen surface can be determined if we assume that the main losses are radiation losses in the infrared band of the radiation spectrum. The value is defined by the Stefan-Boltzmann law. Under steady conditions, the energy of the accelerated electron beam absorbed by the S element is equal to energy of infrared radiation increase W_{IR} with respect to the energy of the element radiation at the environment temperature, i.e., at $T_s = T_{en}$

$$\Delta E = W_{IR} = \varepsilon\sigma\left(T_s^4 - T_{en}^4\right)\Delta S. \qquad (2)$$

Temperature T_s of the ΔS element of the irradiated screen surface is defined from the expression

$$T_s = \left(\Delta E / \varepsilon\sigma\Delta S_{ir} + T_{en}^4\right)^{1/4}, \qquad (3)$$

where T_{en} is the environment temperature, (K); $\Delta S_{ir} = \Delta S/2$; ε is the coefficient of screen surface irradiation; σ is the Stefan-Boltzmann constant (5.67$\cdot$ 10^{-8} W/m^2 K^4).

The transient time τ_{tr} of T_{en} settling is determined as

$$\tau_{tr} = \left(T_s - T_{en}\right)/\Delta T_v, \qquad (4)$$

where $\Delta T_v = \Delta E / C_p \Delta m$ is the rate of the ΔS element temperature increase (K/s); C_p is the heat capacity of screen substance (material) (J/kg K); Δm is the ΔS element mass (kg).

It is possible to estimate the spatial (linear) resolution δ_{sp} of the method from calculation of temperature gradient ∇T, which appears due to temperature difference between the ΔS element and contiguous-to-it screen surface, and values of temperature sensitivity T_w and linear resolution of the thermal imaging device δ_{sp}

$$\nabla T = {}^{q}\!/_{\lambda} = \Delta E / \lambda l_p d, \qquad (5)$$

where $q = \Delta E / \Delta S_p$; λ is the screen substance heat conductivity (W/m K); q is the heat flow density, (W/m$^{2)}$; ∇T is the temperature gradient along the screen surface (K/m); $\Delta S_p = l_p d$, ΔS_p is the ΔS element profile area along its perimeter (m^2); l_p is the ΔS element perimeter.

For ΔS, that is a square of side l, under the condition $\nabla T l = T_w$ and $l > \delta_{sp}$,

$$\delta_{sp} = T_w / \nabla T. \qquad (6)$$

The value (density) of radiation energy E_{in} that effect on the ΔS element is determined by the measurement of the element temperature T_s

$$E_{in} = T_s / f\left(\Delta S, \Delta E, p_1, p_2\right), \qquad (7)$$

where $f\left(\Delta S, \Delta E, p_1, p_{2,...}\right)$ is the function (coefficient) of the ΔS element radiation temperature conversion to the energy characteristics of the electron beam influencing ΔS; $p_1, p_2, \ldots$ are the functional parameters of the sounding screen pointing out on its thermophysical, radiation, and constructional characteristics.

3. Estimation of the method sensitivity

Dependence of ΔS screen element temperature increase on absorbed energy ΔE and screen irradiation coefficient ε, which is calculated by formula (2), is shown in Fig. 3.

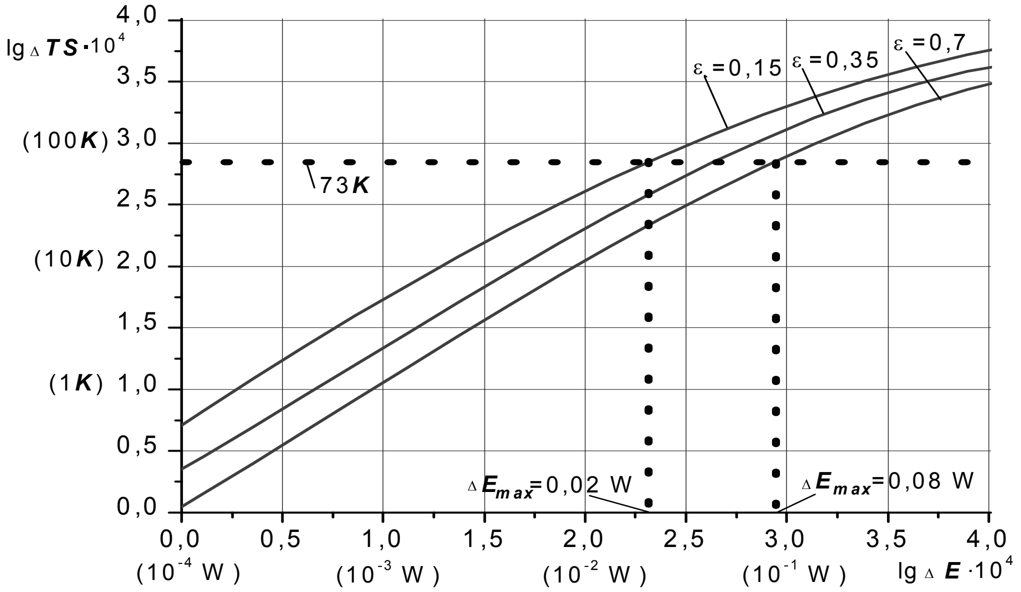

Fig. 3. Dependence of the ΔS screen element temperature increase [K] on absorbed energy ΔE [W/cm^2] (at $T_{en} = 300\ K$). $\Delta E_{\max} < (2\cdot10^{-2} \div 8\cdot10^{-2})$ [W/cm^2] is the area of maximum values of the absorbed energy (depends on ε value of the screen) at which the screen element temperature achieves 373 K (~100°C).

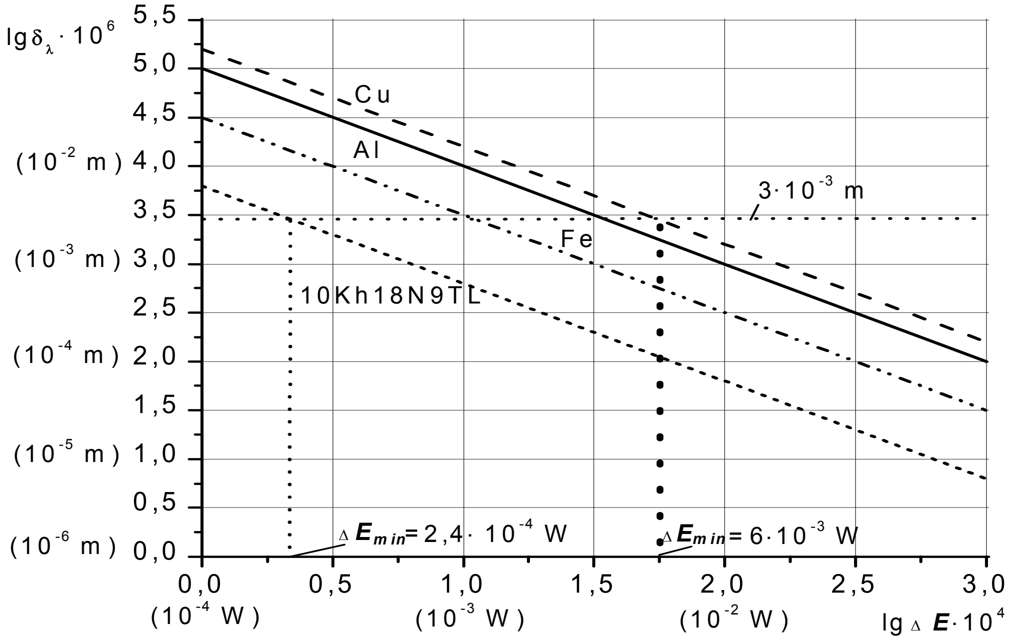

Fig. 4. Dependence of spatial (linear) resolution δ_{sp} of the method on sounding screen substance (Cu; Al; Fe; alloy 10Kh18N9TL). $T_{en} = 300\ K$; screen thickness d = 10^{-5}m; $\Delta E_{\min} > (2.4\cdot10^{-4} \div 6\cdot10^{-3})$ Watt/cm^2 – the lower threshold of the absorbed energy value $\Delta E_{\min}$ at which $\delta_{sp} < 3\cdot10^{-3}$m.

Figure 4 presents the calculation data on δ_{sp} of the sounding screen made of foil with a thickness of 10 microns for various metals (Fe; Al; Cu; corrosion-proof steel 10Kh18N9TL10-4. One can see from the diagrams that, for example, for maintenance of

$\delta_{sp} \leq 3$ mm, the lower threshold of absorbed energy $\Delta E_{\min}$ should be not less than $(2.4 \cdot 10^{-4} \div 6 \cdot 10^{-3})$ W/cm^2 for the specified materials. Usage of thinner foils and alloys of iron, aluminum, copper, and aluminized polymeric (lavsan) film with small values of thermal conductivity λ allows increasing the resolving ability δ_{sp} up to 100 microns. The relative error ξ_E of the measurement of electron energy E_{in} can be estimated by the selection of optimum range of screen temperature values T_{en}, within the limits of which the minimum value of the relative error of temperature measurement ξ_T is obtained. For values $T_{en} = (310 \div 350)K$, $T_{en} = 300\,K$, and $T_w = 0.1\,K$, at the absorbed energy $\Delta E = 5 \cdot 10^{-3}$ W/cm^2, the temperature measurement error ξ_T is $(0.2 \div 1)$%, which is in agreement with the absorbed energy measurement with an accuracy of $(10^{-5} \div 5 \cdot 10^{-5})$ W/cm^2. At maintenance of stability of absorption coefficients (electrons) and radiation (infrared radiation) of the sounding screen, the relative error ξ_E of the measurement of electron energy E_{in} can be estimated by the selection of optimum range of screen temperature values T_{en}, within the limits of which the minimum relative error of temperature measurement ξ_T is obtained. Under the above-mentioned conditions, the relative error ξ_E of the measurement of electron energy E_{in} can amount to ~0.5%.

4. Conclusions

A method for simultaneous processing and control of potentially dangerous objects like viruses or explosives is proposed. The method is based on the prophylaxis of irradiation and post irradiation IR-control.

Acknowledgments

This work was supported by the National Academy of Sciences of Ukraine and the Academy of Sciences of Moldova (under the State Program 1.3.5. Nanotehnologii, materiale noi multifunctionale si microsisteme electronice), and by the RFBR-Moldova grant 08.820.05.28RF “Investigation of nanostructures superconductor/ferromagnet – base element of superconducting spintronics”.

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