

TWO INNOVATIONS FOR PERSONAL PROTECTION FROM IONIZING RADIATION

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Received on September 4, 2024

Presented by Ch. Roumenin, Member of BAS, on September 17, 2024

Abstract

This paper elaborates on two innovations for personal protection from ionizing radiation and their use as personal dosimeters. Besides the radiation dose, the presented herein devices determine the direction towards the ionizing radiation source. The article discusses the construction, method of operation and advantages of the two inventions the first of which is a pen embodying an ionizing radiation sensor capable of determining the direction in space towards the radiation source. The second invention is a wristwatch having the same capabilities. Both devices also show spectral energy density graph of the ionizing radiation source and determine the type of the radiation source based on this data.

Both innovations are subject of patent protection.

Key words: ionizing radiation protection, ionizing radiation dosimeter

Introduction. Ionizing radiation may pose significant danger for health by causing microscopic damage to life tissue. The irradiation may occur by plan or by accident. The threat from radiological terrorism is particularly alarming.

This article was developed within the National scientific programme (NSP) “Security and Defence”, task 1.2.10, according to Agreement No. D01-74/19.05.2022 between the Ministry of Education and Science and the Bulgarian Defence Institute “Prof. T. Lazarov” for fulfilment of NSP “Security and Defence” accepted with decree of the Council of Ministers No. 731 from 21.10.2021.

<https://doi.org/10.7546/CRABS.2024.11.08>

Probability of irradiation occurs during radioactive material/sources utilization, production, processing, remoulding, manipulation, burying, storage, transport, import and export of radioactive material. Further risk is caused by the manufacture and utilization of electrical equipment generating ionizing radiation or employing components being subject to voltages exceeding 5 kV.

Of all human organs and tissues the bone marrow, gastrointestinal tract, gonads (reproductive glands), and lymph tissue are most sensitive to ionizing radiation. Radiation-induced malignant tumours are leukaemia (malignant blood disorders) and solid tumours. The major critical systems undergoing analysis for diagnosis and treatment of individuals suffering from radiation incidents are: nervous and central nervous and circulatory system; cardiovascular system; haematopoietic and immune system; eyes; respiratory system; excretory system; skin; endocrine system; skeletal and muscular systems; reproductive tissue and prenatal human development [1–4].

After decades of medical research with atomic bomb survivors in Hiroshima and Nagasaki in Japan in 1945, and also with individuals having professional exposure to ionizing radiation, a number of studies focus on carcinogenic and genetic risk. The implication of the observed biological effect is proportional to the radiation dose magnitude over the accepted risk free thresholds. Latent period is the shortest with leukaemia diseases – 2–3 years, for thyroid tumours – 4–5 years, and over 10 years for the rest solid tumours [2–4].

Radiation protection is a complex of activities for restricting personnel irradiation and that of the population to the lowest possible levels.

Most countries utilizing technological sources of ionizing radiation observe radiation protection legislation. In the Republic of Bulgaria there is an established legal threshold of effective dose for every professionally irradiated individual – that of 20 mSv for a period of one year. Generally, radiation risk with children is higher in comparison with the elderly. Special attention is paid to pregnant women with the purpose of restriction and termination of occupational exposure to ionizing radiation due to serious risks of growth impairment, embryonic, foetal or neonatal death, or innate malformations in the course development of the prenatal foetus [4].

The current article presents two innovative developments for personal ionizing radiation protection, namely employing them as personal dosimeters. Besides the doses, the two presented devices detect the direction of the incoming radiation and thus they are used to localize the radiation source. Both protection devices are intended for people potentially exposed to the effect of ionizing radiation such as workers at atomic power plants, cosmonauts and astronauts, military personnel, physicians, scientists, researchers, etc. The devices are employed as personal dosimeters and instruments identifying the ionizing radiation source type and location.

The application of the innovative devices is in: disaster management; acci-

dents and incidents at infrastructure facilities related to radiation materials and apparatuses; radiation material-smuggling countermeasures; radioactive ore natural deposits exploration; anti-terrorist activities employing dirty bomb; personnel working in space; in facilities imposing risk of radioactive irradiation; medicine; nuclear physics and high energy physics; etc.

Both developments are subject to patent protection [5, 6].

Pen embodying ionizing radiation sensor capable of detecting the direction towards the radioactive source. There are a few existing portable devices comprising pocket-sized dosimeters for ionizing radiation having the shape and dimensions of a standard pen [7]. None of the latter relies on two ionizing radiation sensors based on different technologies, namely a semiconductor diode and a scintillator [8]. All known devices rely on a single sensor, either a semiconductor diode or a scintillator. The diode based apparatuses exhibit low sensitivity to gamma rays with high energies. It follows that the time to register radioactive sources emitting high energy gamma photons is long and the distance at which the instrument signals the user of danger is too short to ensure high safety for their health. On the other hand, the scintillator based devices lack sensitivity to low energy gamma photon and x-rays endangering the user in a similar manner but this time not alarming early upon threats of low energy gamma photons and x-rays. Yet another drawback of the existing devices is their inability to detect the direction towards the radiation source. This shortcoming obstructs the user from evacuating in the correct direction away from the radiation source, or in cases of radiation source searching these devices make the process of discovery quite cumbersome and time consuming.

The pen embodying ionizing radiation sensor capable of detecting the direction towards the radioactive source invention overcomes the drawbacks of the existing technology described about by combining two different types of sensors – the semiconductor diode and the scintillator. By these means the invention broadens its sensitivity range towards both low energy gamma photon and x-rays, and high energy gamma photons. Further, by implementing more than one semiconductor diodes positioned around the scintillator, the apparatus is capable of detecting the direction the ionizing radiation is coming from. Another feature of the device is that it offers spectral analysis of the incoming ionizing radiation based on the data from both the scintillator and the diodes, thus presenting to the user spectral data for low to high gamma energies. Drawn from spectral information, the invention is able to identify the radiation source type or describe the isotopes comprising the radioactive material.

The pen consists of several components: a nib (1), control electronics unit (2), display (3), semiconductor diodes capable of sensing ionizing radiation (4), and a scintillator sensor of ionizing radiation (5).

The device functions in the following order: the ionizing radiation particles enter the semiconductor diodes (4) and the scintillator (5), where they induce

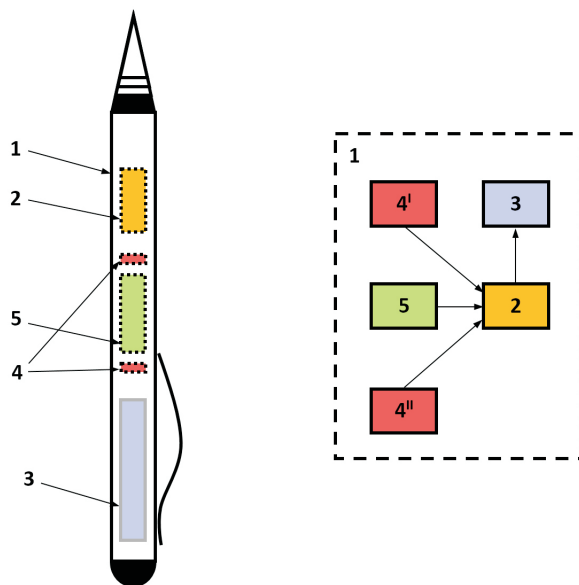


Fig. 1. Pen embodying ionizing radiation sensor capable of detecting the direction towards the radioactive source

electrical impulses. The latter are further measured by the control unit (2). The control unit processes this information and calculates the intensity of the incoming radiation and its dose. Furthermore, the control unit determines the ionizing radiation source type by generating spectrogram of the incident ionizing particle energies. By placing the semiconductor diodes (4) around the scintillator sensor (5), the latter shadows some of the semiconductor diodes in relation to the direction of the incoming radiation. This way the apparatus is capable of determining the direction towards the ionizing radiation source. The results of the calculations are presented on a display (3).

Wristwatch embodying an ionizing radiation sensor capable of detecting the direction towards the radioactive source. In recent years, it has been widely adopted that all devices worn on the wrist and showing the current astronomical time be called a wristwatch. A modern wristwatch may represent many additional measurements and information besides the current time – it is still called a wristwatch. We have come across wristwatches showing the magnetic field vector (electronic compass), the atmospheric pressure and air humidity, the temperature of the surrounding air and the body temperature, heartbeat, blood oxygen levels, etc.

There are also wristwatches designed to measure ionizing radiation [9]. Similarly to the previously described ionizing radiation monitors with the size and shape of a standard pen, these wristwatches do not embody both semiconductor diode sensors and scintillator sensors of ionizing radiation. Instead they resort to

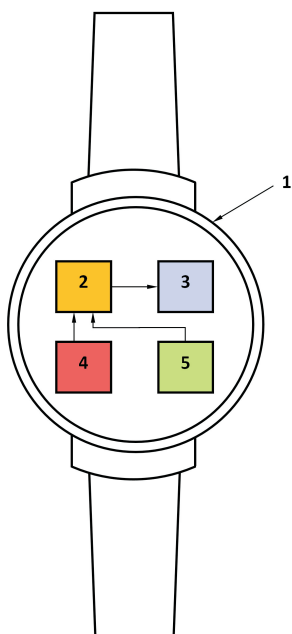


Fig. 2. Wristwatch embodying an ionizing radiation sensor capable of detecting the direction towards the radioactive source

a single sensor, in most cases a semiconductor diode. All drawbacks already described with the previous invention hold here as well, hence shall not be repeated.

The presented invention of a wristwatch embodying an ionizing radiation sensor capable of detecting the direction towards the radioactive source consists of enclosure (1), control electronic unit (2), display (3), semiconductor diode sensors of ionizing radiation ($4^I \dots 4^n$), and a scintillator sensor of ionizing radiation (5).

The device functions in the following way: ionizing radiation particles come across the ionizing radiation sensors in the apparatus. The semiconductor diodes and the scintillator transform the incident particle interactions into electrical impulses that are sent to the control electronic unit. The latter unit processes these signals and calculates the intensity of each channel of the energy spectrum. Through these means, the device is able to determine the radiation source type, its intensity and dose delivered to the user. The semiconductor diode sensors are placed around the scintillator sensor. The scintillator inevitably shields some of the semiconductor diodes from the incoming radiation. The shielded diodes register fewer impulses or impulses of lesser magnitude. Based on this information, the device determines the direction towards the radiation source. The results of all these calculations are shown in the display.

Conclusion. The herein described innovations offer significant benefits in comparison to existing apparatuses. Due to combined implementation of semiconductor diode sensors and scintillator sensors of ionizing radiation the innovative devices are capable of calculating the received dose, the intensity of the incoming radiation, the direction towards the source, its energy spectrum and its compo-

sition or type. Furthermore, the employment of two different sensors broadens the energy range of incoming gamma rays that the two devices are able to register without loss of sensitivity. The widened energy spectrum range improves the device capability of identifying the radiation source type and composition and shortens the time and exposure to ionizing radiation before an alarm is triggered.

REFERENCES

- [1] HAMADA N., Y. FUJIMICHI (2014) Classification of radiation effects for dose limitation purposes: history, current situation and future prospects, *J. Radiat. Res.*, **55**(4), 629–640.
- [2] LITTLE M. P. (2009) Cancer and non-cancer effects in Japanese atomic bomb survivors, *J. Radiol. Prot.*, **29**(2A), A43–59.
- [3] ZIELINSKI J. M., N. S. SHILNIKOVA, D. KREWSKI (2008) Canadian National Dose Registry of radiation workers: overview of research from 1951 through 2007, *Int. J. Occup. Med. Environ. Health*, **21**(4), 269–275.
- [4] ZAHARIEV V. (2020) Radiation-induced Tissues and Organs Damage Sofia, *Zvezdy*, (in Bulgarian).
- [5] ZABUNOV S., G. MARDIROSSIAN, G. JELEV. Pen embodying ionizing radiation sensor detecting the direction towards the radiation source, BG/P/2024/113946, 08.08.2024, Patent office of Republic of Bulgaria.
- [6] ZABUNOV S., G. MARDIROSSIAN, G. JELEV. Wristwatch embodying ionizing radiation sensor detecting the direction towards the radiation source, BG/P/2024/113947, 12.08.2024, Patent office of Republic of Bulgaria.
- [7] Low cost digital pocket dosimeter, Japan Patent Office, Document Number: JP2004528568A, 16.09.2004.
- [8] ZABUNOV S., G. MARDIROSSIAN, G. JELEV. Ionizing radiation sensor with scintillators and photodiodes, BG/P/2024/113941, 02.08.2024, Patent office of Republic of Bulgaria.
- [9] NELSON J. WATERBURY. Combined digital and analog timepiece and radiation monitor assembly, United States Patent Office, US Patent Number 4733383, 22.03.1988.

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