ISSN 0027-1314, Moscow University Chemistry Bulletin, 2007, Vol. 62, No. 4, pp. 197–199. © Allerton Press, Inc., 2007.
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A New Method of Recording Diffraction Patterns in Gas-Phase Electron Diffraction

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Received October 2, 2006

Abstract—A new design of the recording unit of an electron diffractometer for gas-phase electron diffraction has been suggested, in which a fixed luminescent screen is used instead of photo plates. The diffraction pattern of a compound displayed on the screen is input to a reading device with contact photographic recording and is transmitted to a computer as digital two-dimensional intensity maps.

DOI: 10.3103/S0027131407040050

In gas-phase electron diffraction, there has long been a need to discard the routine photographic method of recording the diffraction pattern and to switch to a new method having higher sensitivity and resolution, ensuring a large linear sensitivity range (several orders of magnitude), and making it possible to avoid laborious processing of photo plates [1]. The Imaging Plates (IP) system was developed by the Fuji company [2] and has been widely used for recording different types of radiation (X-ray, electron, neutron, ultraviolet, and visible). The system consists of the three components [3].

A special film for recording radiation has a flexible base (polyester) coated with a layer of fine crystalline $BaF(Br,I):Eu^{2+}$.

A reader, which scans the exposed film and obtains a digital two-dimensional map of the absorbed radiation.

An eraser, which erases information from the exposed film and prepares it for new measurements.

As compared to the photographic method, the IP system has the following advantages [4]:

(i) The sensitivity is 10- to 100-fold higher than for photo plates.

(ii) The linear sensitivity range is five to six orders of magnitude, whereas photo plates ensure no more than two orders of magnitude.

(iii) The film can be repeatedly used (more than 1000 cycles) and chemical treatment is not necessary.

IIjima and Suzuki were the first to use the IP system in gas-phase electron diffraction in 1998 [5].They reported that the IP system is 100 times more sensitive than photo films. However, this high sensitivity is achieved only at a voltage of 200 kW on the electron diffractometer. At higher and lower voltages, the sensitivity sharply decreases and loses up to four-fifths of its maximal value.

Although chemical treatment is unnecessary, the IP film should be exposed to laser light (λ = 633 nm) and then to UV light (λ = 390 nm) to be ready for the next cycle of measurements. In addition, this equipment is very expensive.

In this context, a new design of the recording unit, with a fixed screen coated with a layer of an appropriate phosphor instead of a photo plate, seems to be promising. An electron beam is scattered by the molecules of a compound and produces a diffraction pattern on the luminescent screen. The screen brightness depends on the energy of electrons, i.e., on the accelerating voltage and the scattering angle of the incident beam.

The diffraction pattern displayed on the luminescent screen is input to a reading device and is transmitted to a computer for further processing.

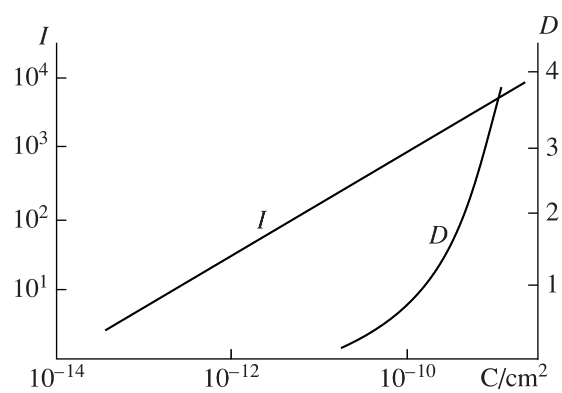

Fig. 1. Sensitivity vs. electron dose (C/cm^2) according to [5]: I is the intensity of Fuji imaging plate at V = 200 kV, and D is the optical density of the Fuji FG film.

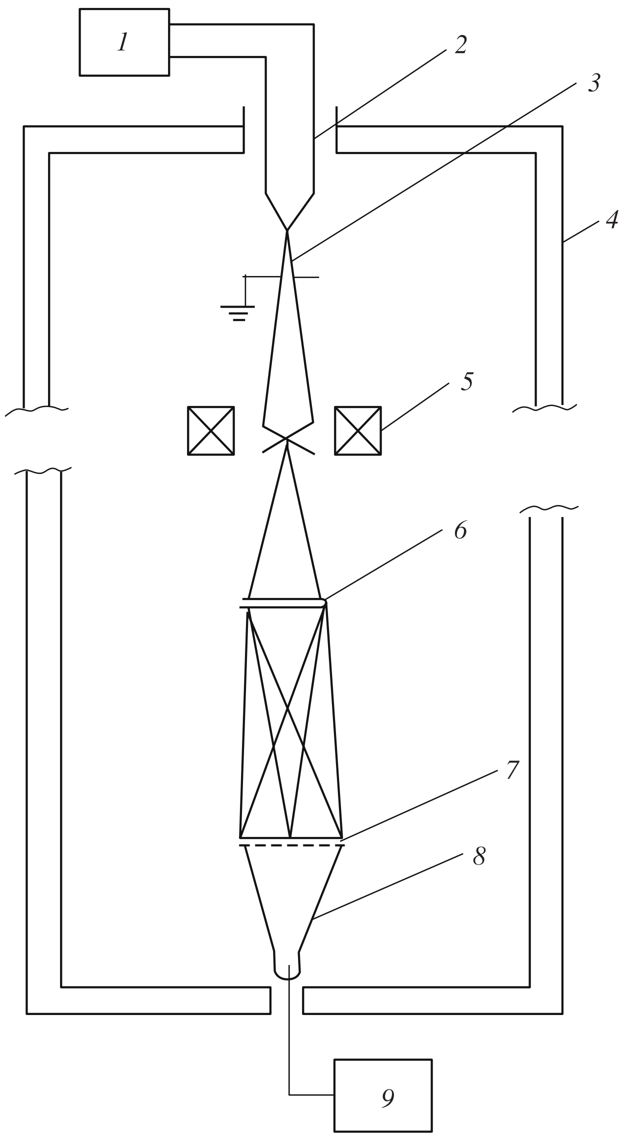

Fig. 2. Scheme of an electron diffractometer: *1* is the high-voltage source, *2* is the electron gun, *3* is the electron beam, *4* is the electron diffractometer column, *5* are electromagnetic lenses, *6* is the sample, *7* is the luminescent screen, *8* is the reader with contact photographic recording, and *9* is the computer.

The major properties of the phosphors determining whether they are suitable for screens for different purposes are [6]:

(i) the color of luminescence,

(ii) the afterglow time,

(iii) the luminescence brightness under certain excitation conditions,

(iv) the resistance to electron irradiation,

(v) the resolution.

Comparison of technical data on different phosphors [7] allowed us to conclude that rare earth phosphors, i.e., regular phosphors with a high concentration of an activator (up to several percents), are preferable for our purposes. Such phosphors are the most current-stable.

The choice of the luminescence color of the screen is, first of all, determined by the spectral sensitivity of the radiation receiver, so that the spectral sensitivities of the luminescent screen and reader should be strictly consistent.

As for the afterglow time, the choice of a screen is determined by the data update rate; however, inasmuch as the diffraction pattern emerging on the luminescent screen is uploaded to a computer for further processing, the requirement for the screen to have a long afterglow time is not strict.

An important characteristic of the screen excited by an electron beam is its resistance to electron irradiation. A measure of the phosphor resistance to electron irradiation at currents that do not lead to irreversible screen burning can be the screen resource, i.e., the density of the electric charge introduced by the beam at which the initial brightness decreases by half. The largest screen resource (100) is observed for phosphors of the $Y_3Al_{15}O_{12}$:Ce type.

In summary, we can draw the conclusion that, in their chemical composition, afterglow time, screen resource, and other parameters, rare earth phosphors are best suited to the purpose. In this work, a KLZ-2 phosphor ZnS–Gd:Th,Tb was used.

The second step of the work intimately associated with the choice of a phosphor for the screen is the choice of an appropriate reading device whose properties (spectral sensitivity, resolution, and other parameters) correspond to the properties of the luminescent screen.

Comparison of the technical data on high-resolution cathode ray tubes [7–9] shows that a 11LK7A tube is preferable. This tube is used in special-purpose devices with contact photographic recording. A 13LK17A tube can also be used. The small dimensions of these tubes (length, 315 mm; weight, no more than 700 g) make it possible to mount them in the recording unit of an electron diffractometer.

Thus, the suggested new method of recording electron diffraction patterns not only retains all advantages of IP caused by the use of the luminescent layer but also circumvents some difficulties due to the use of a reader with contact photographic recording.

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