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Emission Spectroscopy Using a Photoresistor as a Light Detector

From the near ultraviolet to the near infrared regions in spectroscopy, the highest sensitivity and resolution is obtained using large spectrographs with sensitive photographic film detectors. Photographic detectors are inconvenient for many purposes and photomultipliers are far more commonly used (*1*, *2*). These have their own disadvantages: photomultipliers are delicate and expensive, and they require a stable high voltage supply. In addition an amplifier is needed to convert the signal (typically 10^{-9}–10^{-3} amp) to a voltage which can drive a potentiometric recorder. For teaching purposes, both the photographic film and the photomultiplier have disadvantages.

Described here is a simple, robust yet sensitive light detector system originally devised by us for use with chemiluminescent reaction systems. The detector is a cadmium sulfoselenide photoresistor and although it is much used in exposure meters in cameras, it has not, to our knowledge, been used in spectrometry. The photoresistor has many advantages over other photodetectors but it has the disadvantage of slow response at the lowest light intensities. This makes it unsuitable for detecting transient phenomena such as scintillation counting, but it is quite satisfactory for investigating long lived emissions such as those from flames, electrical discharge lamps, and chemiluminescence.

Electrical Characteristics

A typical photoresistor has in bright light a resistance of a few ohms which rises to many megohms in darkness. The cadmium sulfoselenide type is somewhat faster in response than the older cadmium sulfide photoresistor. Much faster response is available with silicon diffused photodiodes, however they were found to be unsatisfactory because of inherent noise problems at low light intensities.

The photoresistor circuit used is shown in Figure 1 and consists of an operational amplifier, dual 15-V power supply, photoresistor, and a zero suppression potentiometer. As the light intensity on the photoresistor increases, its ohmic value decreases and there is an increased voltage across resistor *R1*. This voltage is then fed into the inverting input of the operational amplifier. There was no noticeable noise from the photoresistor and the dark current was very low. The output was fed to a 1-mV recorder but a 10-mV recorder is satisfactory for most purposes. The gain control was linear over virtually all of its range and was very convenient for setting the largest signal as a full-scale deflection on the recorder.

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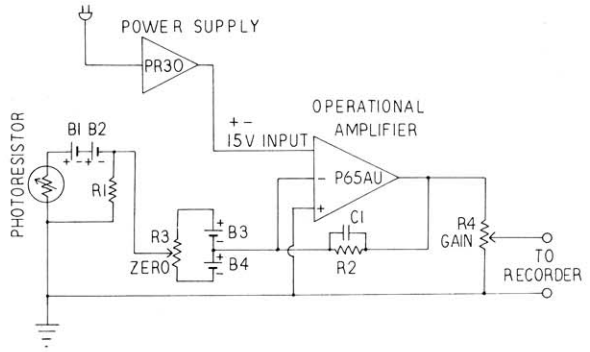

Figure 1. Amplifying circuit for photoresistor. Legend: R1, R2, 100 K metal film; C1, 0.001 mf silver mica; B1-B4, mercury cells 1.35 V, "D" size; R3, 50 K, 10-turn Helipot; R4, 50 K single turn linear taper.

The circuit shown in Figure 1 was built at a cost of approximately $150 and worked well when used with adequately grounded and shielded connecting wires. Six photocells were tested for response to mercury lines ranging from 366 to 579 nm. These were the cadmium sulfide types Clairex CL705L, Clairex CL707L, RCA SQ2520, RCA SQ2521, and cadmium sulfoselenide types Clairex CL703L and RCA SQ2545V1. Good results were obtained with the CL705L, CL707L, and SQ2520, but the best results for both sensitivity and speed of response were given by the SQ2545V1, and most of the reported results were obtained with this photocell.

Refinements such as thermostatting or the use of a chopper-stabilized operational amplifier were not found to be necessary. The photocells were operated at ambient temperature and drift was unimportant provided the room temperature remained reasonably constant.

Optical Characteristics

Atomic spectra have been measured by using the monochromator in a spectrophotometer (*3*) but in this work we used a separate monochromator. The instrument used was a Schoeffel Model QPM30S which is an inexpensive miniature quartz prism monochromator with an effective aperture of 7.6.

The published spectral response curve (*4*) for the cadmium sulfoselenide photocell shows response from 310–950 nm with a maximum at 615 nm. We obtained spectral peaks at 313 and 860 nm.

Linearity of response was measured by interposing neutral density filters in a light beam. Good linearity was obtained in the range tested which corresponded to outputs in the range 0.004–2.4 V.

The photoresistor spectrometer was used to measure three spectra of very different characteristics. The ordinary fluorescent lamp affords a good test of detec-

tion in the near ultraviolet. The neon glow lamp is a feeble source and tests resolution at low light levels. Finally the oxy-gas flame was scanned as an example of fine structure from a relatively unstable source. In the case of the neon bulb a comparison of the photoresistor with a photomultiplier was made.

Results

Spectra shown are uncorrected for the spectral response of the photoresistor (*4*, *5*).

The output of a standard 12-in. fluorescent lamp (General Electric F8T5CW) powered by a constant voltage transformer is shown in Figure 2. Mercury

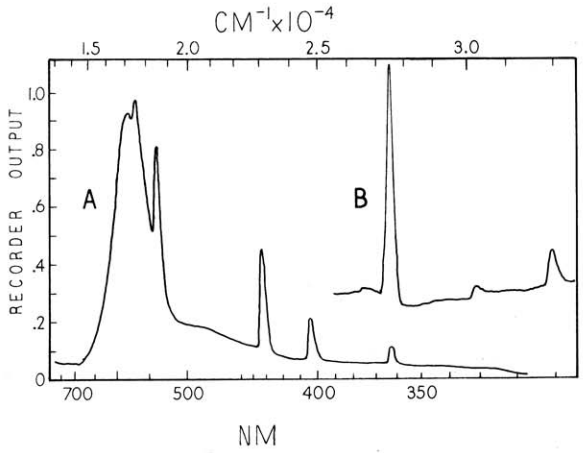

Figure 2. Spectrum of fluorescent lamp using a SQ2545V1 photoresistor. Slit width 0.03 mm, total scan time 50 min, recorder span 10 mV, gain (see Fig. 1) 12% in curve A, 100% in curve B.

lines (*6*) at 313, 334, 366, 405, 436, 546, and 579 nm are seen. The ultraviolet response of the photoresistor is well demonstrated and the fluorescent lamp was found to be most convenient for calibrating the monochromator.

The Neon Glow-Lamp

The spectrum of a General Electric NE-30 neon bulb operated by a 118-V constant voltage transformer is given in Figure 3. In addition to the well-known peaks in the orange region a weaker group of lines in the ultraviolet, centered at 345 nm, is seen. A still weaker group in the blue region, at about 425 nm, is also seen. These lines do not appear in the catalogued neon discharge spectrum (*6*) and we were unable to identify them. We

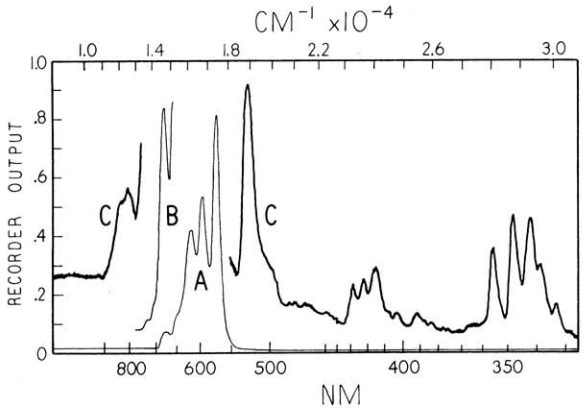

Figure 3. Spectrum of neon glow lamp using a SQ25454V1 photoresistor. Slit width 0.075 mm, total scan time 45 min, gain 100%. Recorder span 100 mV in curve A, 10 mV in curve B, 1 mV in curve C.

were also unable to find a literature description of the neon glow-lamp spectrum for purposes of comparison. However, the correlation with the discharge spectrum is reasonably good.

Although the neon bulb is a feeble source of light its spectrum shows considerable structure, and the cadmium sulfoselenide cell was tested further in two ways. First a comparison was made with a spectrum obtained with an RCA 6199 photomultiplier (S11 response) coupled to a Keithley 601 Electrometer. The results were inferior to the spectrum shown in Figure 3 and the only advantage of the photomultiplier was a decreased sensitivity to changes in room temperature.

The second test was a study of variation of scanning speed. This is a stringent test of the photoresistor because its slowness of response might result in apparent spectral degradation at higher scan speeds. Using a 0.03 mm slit width for maximum resolution, the effect of a 20-fold variation in scan speed was investigated, and the results are shown in Figure 4 for part of the neon spectrum. The sensitivity at the slow scan speed (50 min scan) is much higher than at the medium (12.5 min) or fast (2.5 min) scans but the faster scans show no loss

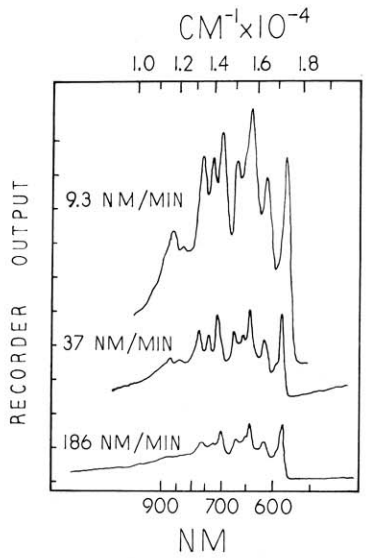

Figure 4. Portion of spectrum of neon glow lamp usng a CL703L photoresistor. Slit width 0.03 mm, scan speeds as indicated. Recorder chart speed was varied to compensate for the different scan speeds. Recorder span 1 mV, gain 33%.

in resolution. A slight wavelength lag was noted at the higher scan speeds, and this could be nullified by scanning in both directions and taking the mean of the spectral peaks measured on the monochromator.

The Oxygen-Natural Gas Flame

The emission from the flame from an ordinary hand torch for glassblowing was measured as follows. The torch was placed inside a chimney consisting of a 6-in. piece of 2-in. diam aluminum tubing, blackened inside, with a $^1/_2$ in. hole for viewing. The flame was operated with the gas full on and sufficient oxygen so that the inner cone was about $^1/_4$ in. long. Figure 5 shows the striking difference between the spectra from the inner cone and from the zone above the cone.

The Swan bands (*7*) which are due to vibrational transitions in the C_2 species are seen at 668, 644, 592, 547, 510, and 468 nm. Then comes a strong peak at 431

due to CH followed by some poorly resolved peaks also from the CH system.

Summary

The cadmium sulfoselenide photoresistor is cheap and rugged and has inherently low noise. When coupled to a simple amplification circuit the combination makes available a photocell of sensitivity comparable with that of a photomultiplier at a fraction of the cost. The photoresistor has relatively slow speed of response but this is unimportant in monitoring steady emissions if the spectral scan speed is reasonably low. The device should be useful for teaching purposes and examples of its use in atomic and molecular emission spectrometry are given.

Literature Cited

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(4) RCA Photoconductive Cells, Leaflet No. 312, July, 1969, Radio Corporation of America, Harrison, N. J.

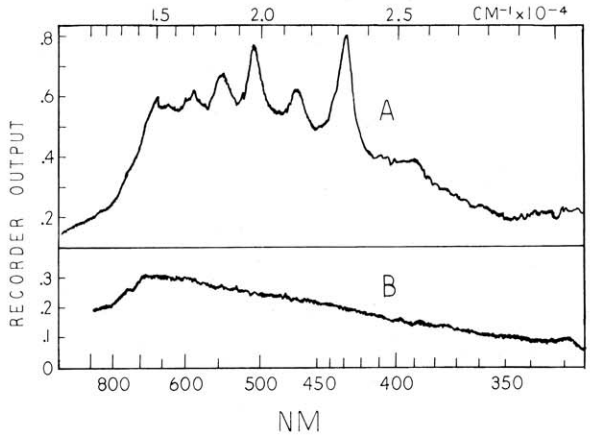

Figure 5. Spectrum of oxy-gas flame using a CL703L photoresistor. Slit width 0.15 mm, scan time 40 min. Curve A: Inner cone of flame; curve B: luminous zone above cone. Recorder span 1 mV, gain 75%.

(5) "American Institute of Physics Handbook" (2nd Ed.), McGraw-Hill Book Co., New York, **1963**.
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