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Thin-Film Ultraviolet Detector and Spectrometer

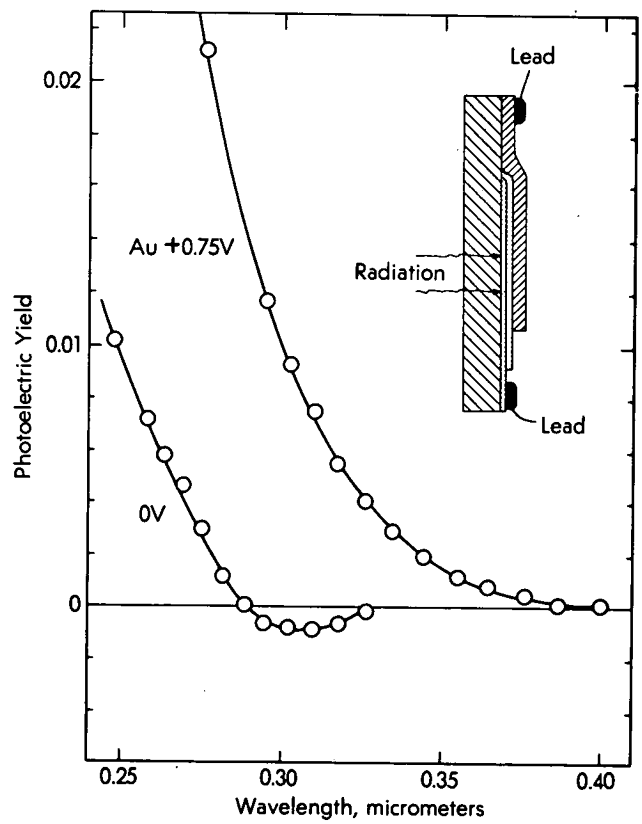
Results of a systematic investigation of the electrical properties of metal–insulator–metal (MIM) composites have confirmed earlier theoretical suggestions that these structures can be effective detectors of ultraviolet (UV) radiation. The structures are simple sandwiches of two very thin layers of metal separated by a thin insulating layer and supported on a suitable substrate, as indicated in the diagram. Suitable devices may be fabricated in any desired configuration by conventional masking techniques.

MIM devices exhibit large photoyields (>1%) in the UV portion of the spectrum, and can be used with or without an applied bias. Without bias, the devices can be operated as simple dc radiation detectors but, since spectral responses can be shifted by application of bias, they can also be operated as spectrometers.

A typical MIM device for use in the ultraviolet is formed on a quartz substrate; the base electrode material, aluminum, is deposited at a thickness of 3 to 6 nm and overcoated with a 3- to 6-nm insulating layer of aluminum oxide or aluminum nitride capped with a counter electrode layer of gold, lead, magnesium, or aluminum several hundred nm thick. Electrical leads are connected to the counter electrode and the base electrode.

The diagram also illustrates the response of an Al–AlN–Au structure. At zero applied voltage, a small negative current is observed near threshold which corresponds to a small contribution from the aluminum electrode (photoexcited holes); the reverse process becomes completely negligible when a positive bias voltage is applied across the device (Au electrode positive). The primary effect of positive bias voltage is a shift in the threshold for photoexcitation of holes. Thus, for the Al–AlN–Au structure, the threshold is shifted from 0.328 to 0.409 micrometer.

Although it is doubtful that MIM-structure photoyields can ever approach the high values typical of



quantum detectors (20%), a net advantage in detection of UV can be realized with MIM devices because of their high internal impedance (e.g., 10^8 ohms); the output signal is proportional to the photocurrent

(continued overleaf)

multiplied by the impedance, while the noise is proportional to the square root of the impedance. Moreover, MIM devices are simple and rugged, and they can be readily fabricated in imaging arrays.

When a MIM device of the type under discussion is used as a spectrometer, a dc bias is impressed across it together with a small harmonic potential of angular frequency ω; the total voltage output appearing across the device is measured by standard phase-lock amplifier techniques at harmonic frequencies ω, 2ω, and 3ω, etc. The third harmonic term contribution to the total voltage output permits determination of the photon flux at a given wavelength, and the second harmonic term provides a sensitive means for detecting the total photon flux over the sensitive range of the device.

The advantage of using internal modulation instead of external chopping of incident radiation often more than outweighs the handicap of lower photon yields.

Reference:

Lewicki, G., and Maserjian, J.: Electrical Characteristics of AlN Insulating Films in the Thickness Range 40 to 150 Å. Metallurgical Transactions, vol. 2, March 1971, p. 673.

Patent status:

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to:

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(NPO-11432)