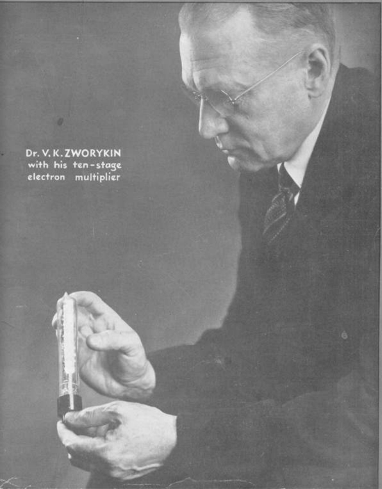
electronics

radio, communication, industrial applications of electron tubes . . . engineering and manufacture



Dr. V. K. ZWORYKIN
with his ten-stage
electron multiplier

NOVEMBER
1935

Price
50 Cents

McGRAW-HILL
PUBLISHING
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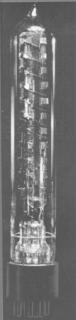

Secondary Emission

New electron multipliers that will detect, modulate, oscillate and amplify by the successive use of secondary emission with improved signal-to-noise ratio

NEW uses for the phenomenon of secondary emission were announced by Dr. V. K. Zworykin, D. A. Morton, and L. Malter at the October meeting of the New York section of the Institute of Radio Engineers. The new developments take the form of unusual vacuum tubes which make use of the fact that a single electron impinging on a specially prepared surface (or "target") can liberate as many as ten secondary electrons, thereby producing a current amplification of 10 to 1. By arranging several cascaded "stages" of such electron multiplication, tubes of extremely high gain have been produced.

In the design of conventional thermionic tubes, secondary emission from the grid or plate of the tube has been a serious handicap inasmuch as it increases the space charge and decreases the relative control of the grid on the space current. But secondary emission has been put to practical use as early as 1919. The first practical use of the effect was made by Dr. Hull, in the dynatron. The idea of amplifying a small electron current by means of secondary emission has been investigated by Slepian, Jarvis and Blair, Iams, and Farnsworth. An electron multiplier developed by the last mentioned, P. T. Farnsworth, was described in *Electronics*, August, 1934, pages 242 and 243.

The new tubes, which were developed in the Electronics Research Laboratory of the RCA Manufacturing Company in Camden, require about the same amount of power for operation as do conventional tubes (about 17 watts per ampere of emission) but they are considerably superior from the standpoint of noise.

A ten-stage tube, enlarged by 1.5 times. The tube is actually somewhat longer than the 59

In the case of the multiplier photocell, the signal-to-noise ratio is approximately 60 to 100 times greater than that of the usual photocell and thermionic amplifier, under conditions of low light intensity. In addition to this improvement in signal-to-noise ratio, the new tubes have the advantage that they can produce enormous gains in a very compact space, often in fact incorporating ten stages of amplification within the same envelope, with resulting gains of several millions. In addition, the tubes may be made to perform the different functions of modulation, oscillation and amplification within the same envelope, using different sections of the same tube. Such multipurpose tubes, although now in the experimental stage, may possibly be

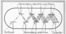

Fig. 1—Secondary emission tube—fundamental scheme

used in radio circuits, and other applications for which more conventional thermionic tubes are now used.

Multiplier Action

The general principle of the electron multiplier action is illustrated in Fig. 1. The cathode to the extreme left supplies an electron which is drawn in the direction of the arrow to the positively charged plate above it, which has a special surface having high secondary emission characteristics. There, the initial electron liberates two or more secondaries which in turn are drawn to the

Electron Multipliers

A report of the October 1935 I.R.E. meeting when Dr. V. K. Zworykin and his associates of the RCA Victor Research Laboratory demonstrated the new tubes

secondary electron emitter below where they produce still more secondaries. The process thus continues in criss-cross fashion until

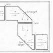

Fig. 2—A practical tube construction

the original electron has been multiplied many times. The final collector at the extreme right of the tube collects the resulting amplified current and conducts it to an external circuit where it may be used. In electron multipliers of this type each secondary electron emitter must be maintained at a potential slightly more positive than the preceding one in order to attract the electrons. However, if this procedure is followed in the tube shown in Fig. 1 the maximum positive potential must be applied to the collector at the right of the tube, and as a result any electrons from the cathode are drawn directly to the collector without impinging on the intermediate emitters. This difficulty is overcome in the mechanical design of the new tubes as is described below.

It will be seen from Fig. 1 that the requirements for high efficiency of electron multiplication are, first, a high ratio of secondary electrons emitted for each primary electron impinging on the surface; second, the collecting or drawing away of the secondary electrons from one target preparatory to focussing them on the next target; third, complete focussing of the electron beam (which would tend to diverge because of the similarity of charge) on each successive target.

The Emissive Surface

The search for a good emissive surface, that is one having a high ratio of secondary to primary electrons, has resulted in experiments with metallic elements having a low work function, and which therefore emit electrons easily. It has been found that simple metal surfaces are not as effective as composite surfaces. The most satisfactory surfaces have been those of oxidized silver, beryllium or zirconium with a caesium surface layer. The surface used in the new multiplier tubes is a caesium-caesium oxide-silver surface, produced by oxidizing a silver sheet having a matte surface, coating the silver oxide with caesium under vacuum, and then heating the surface so that the oxygen is transferred from the silver oxide to the caesium. This surface is very similar to the surface used in photoelectric cells, the only difference being that the photoelectric surface has slightly more caesium in its composition. Since the emissive surface is also a good photoelectric surface, it is not surprising that the electron multiplication principle has been applied first to the amplification of photoelectric currents. The number of secondary electrons emitted for each primary electron in such a surface depends upon the velocity with which the primary electron hits the surface. This velocity may be expressed in volts; for the surface described, the maximum secondary

Sections of the tube showing details of construction. The square plates (top) are emitters