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A CdS Analog Triode

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Attempts to design a solid state triode that operates in close analogy to the vacuum triode date well back in the history of solid state physics[1]). The closest approach have been the unipolar transistor and the proposed analog transistor. The analog transistor in the originally proposed form[2]) has not, to the writer's knowlege, ever been realized. It is the purpose of this letter to describe an analog triode which makes use of the modulation of a space-charge-limited current through an insulator precisely analogous to the modulation of a space-charge-limited current in a vacuum triode.

Smith and Rose[3]) have demonstrated space-charge-limited current flow in CdS analogous to that in a vacuum tube when an indium or gallium electrode was used as electron emitting cathode. To obtain an analog triode an electron retaining (blocking) control grid electrode is necessary by which the electron space charge and with it the space-charge-limited current is modulated. Tellurium was found to be a suitable material to form a blocking control grid.

The CdS analog triode is shown in Fig. 1. An indium cathode and a tellurium grid and anode are evaporated onto a 10 micron thick CdS single crystal. The choice of the anode material is not critical and tellurium was used for convenience of application. The contact area of each of these electrodes is about 1 mm^2. The contact geometry is not optimized since only a demonstration of the operation of the device was aimed.

The dark resistivity of the CdS crystal when measured at very low voltages where the current flow is due to carriers thermally generated in the volume of the crystal exceeds 10^{12} ohm.cms. At larger voltage when biased as indicated in Fig. 1 a large electron current due to excess electrons injected from the indium cathode is drawn between cathode and anode as observed by Smith and Rose[3]). The current is limited only by the injected negative space charge built up in the crystal. When a negative bias is applied to the grid the negative space charge barrier is enhanced and the anode current flow is accordingly reduced.

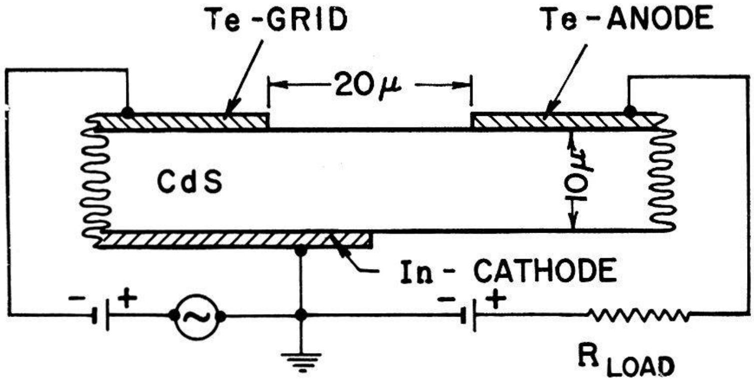

Fig. 1
Cross section through CdS analog triode with basic circuit connections

In Fig. 2 the dc – output characteristics are given. The input dc – grid resistance is larger than 10^{11} ohms; the input capacitance is about 10 $\mu\mu$f. While the voltage amplification is about unity, current and power amplification are in the order of 10^4 to 10^5.

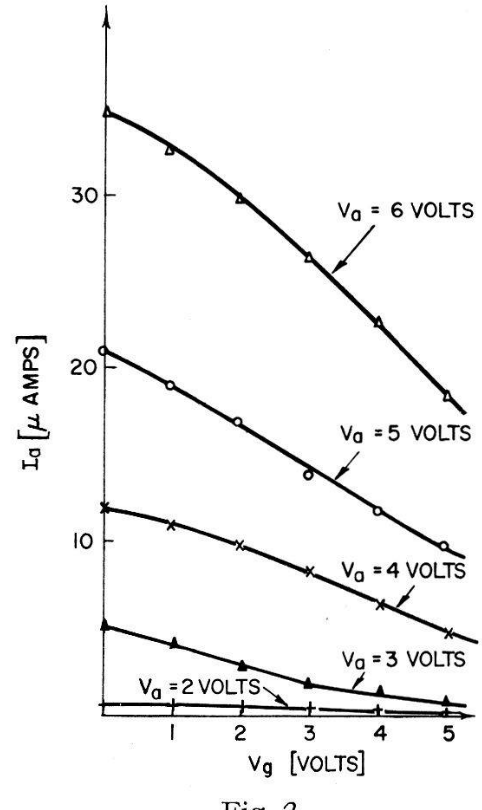

Fig. 2
Anode current I_a as a function of grid voltage V_g for several anode voltages V_a

The ac – performance is shown in Fig. 3. The upper frequency limitation is probably due to trapping of the modulated space charge but the precise mechanism is not clear. The enhanced response at 1000 c/s is

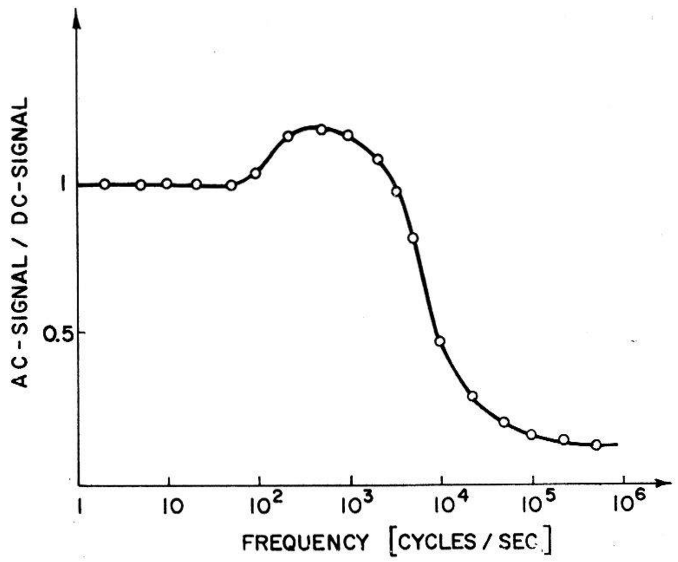

Fig. 3
Ratio of *ac* to *dc* – output signal as a function of frequency at $V_a = 6$ volts, $V_g = 3$ volts, $\Delta V_g = \pm 1$ volt

accounted for by a transient overshoot of about a millisec in the change of the anode current when a negative step voltage is applied to the grid.

In a vacuum tube the movement of positive ions adds only little to the space-charge-limited current. In an insulator by simultaneous injection of electrons from the cathode and holes from the anode a two-carrier space-charge-limited current far in excess to the one-carrier current can be drawn[4]) thus leading to a great enhancement of the anode current and probably resulting in a major improvement of the performance of the device.

A detailed paper is in press in the RCA Review.

References

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