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SCHOTTKY BARRIER DETECTORS IN SILICON
INFRARED VIDICON RETINAE

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13. ABSTRACT Contract Monitor: Jerome H. Bloom/LQD During the period covered by this report the following steps were taken:		
<ul style="list-style-type: none"> • A sub-contract was placed with the Imaging and Display Devices Product Section of the General Electric Co. (IDD) for the design of a high beam velocity camera tube and the delivery of sample quantities. • An order was placed with the Integrated Circuits Center (IC²) of the General Electric Co. Corporate Research and Development Center for P-type and N-type retinæ for use in this program. • Characterization of existing retinæ was conducted in SSL's demountable high beam velocity vidicon camera. 		

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SCHOTTKY BARRIER DETECTORS IN SILICON INFRARED VIDICON RETINAE

I. SUMMARY

The objective of this contract is the design, fabrication, and evaluation of a 1-3 μm and a 3-5 μm infrared vidicon camera and camera system using Pd-Si Schottky barrier diode arrays, and metal-N type Schottky barrier diode arrays in sealed off camera tubes.

During the period covered by this report the following steps were taken:

- o A sub-contract was placed with the Imaging and Display Devices Product Section of the General Electric Co. (IDD) for the design of a high beam velocity camera tube and the delivery of sample quantities.
- o An order was placed with the Integrated Circuits Center (IC²) of the General Electric Co. Corporate Research and Development Center for P-type and N-type retinæ for use in this program.
- o Characterization of existing retinæ was conducted in SSL's demountable high beam velocity vidicon camera.

II. TECHNICAL DISCUSSION

A. High beam velocity vidicon camera tubes

Appendix A is the statement of work issued to the Imaging Systems Operation of IDD for the design of the camera tube.

B. Retinæ

Appendix B is the specification to which retinæ were ordered from IC². They will perform steps 1-9 on the P-type retinæ, and steps 1-10 on the N-type. Both types will then be returned to SSL for deposition of the metal pattern. A hafnium cathode is already available, and a palladium cathode has been ordered to permit this deposition. Experiments are underway to determine the best way to assure the required high retina impedance.

1. Retina impedance

In order to permit the operation of these retinæ in the storage mode, the dark current of the entire sensitive portion of the retina must be less than the equivalent input noise current of the pre-amplifier to be used (~ 2 na). To assure this, it is imperative that excess retina leakage be eliminated, and that retina temperature be as close as possible to 77°K . In the SSL demountable high beam velocity vidicon camera tube, difficulty has been encountered in achieving actual retina temperatures below 120°K , even though the temperature of the retina holder is approximately 90°K . The problem has been shown to be poor thermal contact between the retina and the cold finger necessitated by the need to maintain high electrical isolation between them. The retina holder is being redesigned to correct this.

To determine whether excess leakage is a problem with existing retinæ, the metal array of several of these structures was overcoated with silver to permit actual I-V-T measurements. These showed substantial excess leakage attributed to peripheral effects, and indicated the need for a field plate on the retina to suppress this. Work was begun on developing techniques for putting such field plates on retinæ.

III. PLANS FOR NEXT PERIOD

The design of the high beam velocity vidicon tube will be completed. Initial delivery of retinæ are expected. The new retina holder for the demountable vidicon will be installed and evaluated. Retina characterization will continue.

IV. FISCAL INFORMATION

Of the total funds of \$152,133 authorized through 30 June 1974, approximately 88% was expended during the first three months.

STATEMENT OF WORK

The Imaging Systems Operation (I.S.O.) of the General Electric Company shall design and fabricate demonstration units of camera tubes for use in infrared imaging, incorporating retinæ to be supplied to I.S.O. by Space Sciences Laboratory (SSL).

I. CAMERA TUBE DESIGN

The required camera tube is of the general class of tubes known as vidicons. It differs from other vidicons in several respects, however. I.S.O. will evaluate the requirements of this particular type of camera tube and recommend a design incorporating the combination of features judged by them to be best for the intended application. Upon approval of this design by the technical monitor from SSL, this design shall be incorporated into four demonstration tubes to be fabricated by I.S.O. and supplied to SSL for testing. It is anticipated that this design shall be completed one month after the program starts.

The chief features of the required design are:

A. Electron Gun

The electron gun section of the camera tube must be capable of supplying high beam currents while at the same time baffling the retina from thermal radiation from the hot cathode.

1. Beam Current

Beam current in excess of 500 nA is required at filament power levels compatible with long life of the cathode.

2. Cathode Baffle

Thermal radiation from the hot cathode must be prevented from falling directly on the retina. Also, the exit aperture of this baffle should be capable of being cooled during tube operation with an appropriate cryogen such as liquid nitrogen.

B. Electron Optics

The electron optics for the proposed tube must have minimum shading to realize the uniformity expected from the new type retinæ to be used. For this reason, electrostatic

deflection and magnetic focusing have been selected, as employed in the FPS^(1,2) vidicon. The chief features of the required electron optics are as follows:

1. Resolution

Initially, high spatial resolution is not a primary goal. Resolution comparable with standard all-magnetic vidicon is acceptable. If, however, the design recommended will preclude high spatial resolution from being obtained at a later date, this point should be made clear in the design review to be conducted upon completion of the design phase.

2. Focus

I.S.O. will design the focus coils to be used in connection with these tubes, and supply one with each sample tube. These coils should be designed to permit cryogen to be supplied to the retina holder so that the retina can be cooled to its operating temperature of 90°K (or less), and so that the exit aperture of the cathode baffle can be cooled to a temperature sufficiently low to prevent thermal radiation from the cathode from discharging the retina. Permafocuss may be used if desired.

3. Retina Assembly

The retina assembly will consist of the following:

a. Cooled Filter

A cooled filter, either band pass or long pass, to be supplied by SSL. The diameter will be approximately 1" (actual value to be determined to be compatible with retina cooler, tube diameter, etc.).

b. Retina

Retinae will also be supplied by SSL. Contact will be made to the retina by means of an annular ring contact on the window side.

c. Mesh

The beam will land on the retina with a relatively high energy (~ 300 volts). Secondaries will thus be generated, charging the retina surface positive. These secondaries must be collected by a mesh and prevented from falling back on the target and discharging it.

This is done by a conducting mesh, situated immediately above (on the beam side) of the retina surface. This mesh has high transparency to the incident beam, should be spaced 0.002" to 0.005" (or less) from the retina surface, and be electrically isolated from this surface over the temperature range to which the retina will be subjected. 750 L.P.I. mesh is preferred, but other sizes will be considered.

d. Cylindrical Collector

Secondaries emitted by the mesh must also be collected. This will be done by a cylindrical electrode 1-3/8" in diameter and 1/2" to 1" long located between the end of the deflection pattern and the mesh. This collector, as well as the mesh and the target, must be electrically isolated from each other and the rest of the tube, and available at the window end of the tube.

4. Target Readout

High beam velocity vidicons, for which the name Deltacon⁽³⁾ has been suggested, employ direct target readout, so that no return beam readout is necessary. Parasitic capacitance between target, mesh, and collector leads must be minimized.

C. Tube Preparation

The finished tube, incorporating the required electron gun, electron optics, and retina assembly, will be prepared in a manner in keeping with its intended application. For example, the following steps must be taken:

1. Window Material

Water free quartz must be used for the entrance window to avoid the strong water band absorption at approximately 2.7 μm .

2. Minimize Visible Light Leakage

Visible light must be prevented from striking the retina during tube operation.

3. Vacuum

The tubes must be evacuated and sealed off in a manner in keeping with good camera tube practice. Care must be taken to avoid poisoning the retina if a getter is used.

4. Size, Weight, etc.

Size, weight and power requirements of the tubes should be minimized, commensurate with achieving the required performance specifications.

5. Temperature Monitoring

Means shall be provided for monitoring the temperature of the retina assembly. It is also desirable to provide means for monitoring the temperature of the exit aperture of the cathode baffle.

II. DESIGN VERIFICATION

Using the I.S.O. demountable system to simulate the performance of finished, sealed off tubes, scans will be performed of a cathodo-luminescent phosphor, and of a conventional SbS_3 target to verify scan uniformity, resolution, etc. The actual tests to be performed and measurements to be made will be recommended by I.S.O. and agreed to and observed by SSL personnel.

III. DESIGN EVALUATION REPORT

A written report will be submitted by I.S.O. to SSL for eventual submission to the government, describing the final design in detail. Proprietary features previously developed and employed in the design of this tube need not be described. This report will be delivered one month after the first sample tube.

IV. SAMPLES

Upon submission of a design by I.S.O. and approval by SSL, retinæ will be ordered by SSL for delivery to I.S.O. The first sample tube will be delivered to SSL one month after receipt of the retinæ by I.S.O. The remaining three tubes shall be delivered to SSL at a rate of one per month thereafter.

V. SCHEDULE

See Page 5.

V. SCHEDULE

TASK	Weeks A. R. O.																													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
1. Design	△			▽																										
2. Design Verification					⇨																									
3. Design Acceptance						⇨																								
4. Order Retinae						⇨																								
5. Retinae Fabrication						△							▽																	
6. Sample Tubes																		⇨				⇨				⇨				
7. Design Report																						⇨								

- △ Start
- ▽ Complete
- ⇨ Major Item Event

VI. FINANCIAL REPORTS

At the beginning of the program a spending plan will be submitted to SSL. Thereafter, monthly spending reports will be submitted showing variations from this plan.

V. REFERENCES

1. K. Schlesinger and R. A. Wagner, "A Mixed-Field Type of Vidicon," IEEE Trans. Electron Devices, Vol. ED-14, No. 3, pp. 163-170, March 1967.
2. I. T. Saldi and K. Schlesinger, "The F.P.S. Vidicon," Optical Spectra, February 1970, pp. 53-56.
3. J. P. Spratt and R. F. Schwarz, "Metal-Silicon Schottky Diode Arrays as Infrared Vidicon Retinae," presented at the 1973 International Electron Devices Meeting, Washington, D.C.

APPENDIX B

PROCESS DESCRIPTION INFRARED VIDICON RETINAE

I. $\text{Pd}_2\text{Si}/\text{P-Si}$ RETINA

1. PREPARE TWO LOTS EACH (5 WAFERS EACH PER LOT) OF $[100]$ P-TYPE SILICON, 2 INCH DIAMETER WAFERS, LAPPED AND CHEMICALLY POLISHED ON BOTH FACES, OF 3 OHM-CM SILICON. PREPARE TWO LOTS EACH (5 WAFERS EACH PER LOT) OF $[100]$ P-TYPE SILICON, 2 INCH DIAMETER WAFERS, LAPPED AND CHEMICALLY POLISHED ON BOTH FACES, OF 10 OHM-CM SILICON.
2. ON ONE LOT OF THE 3 OHM-CM MATERIAL GROW A $5\text{ }\mu\text{m}$ THICK EPITAXIAL LAYER, P-TYPE, 3 OHM-CM RESISTIVITY.
3. ON ONE LOT OF THE 10 OHM-CM MATERIAL GROW A $5\text{ }\mu\text{m}$ THICK EPI-TAXIAL LAYER, P-TYPE, 10 OHM-CM RESISTIVITY.
4. GROW A THERMAL OXIDE, $5000\text{ }\text{\AA}$ THICK, ON BOTH FRONT AND BACK SURFACES OF WAFER.
5. ANNEAL OXIDE. SLOW COOL.
6. REMOVE OXIDE FROM RECTANGULAR SECTION ON BACK OF WAFER APPROXIMATELY $0.1'' \times 0.5''$, WITH LARGER DIMENSION ALIGNED ALONG RADIUS OF WAFER AND EXTENDING INWARD FROM EDGE OF WAFER.
7. DEPOSIT ALUMINUM ON BACK OF WAFER OVER ABOVE OXIDE CUT.
8. ALLOY ALLUMINUM INTO WAFER AND REMOVE EXCESS ALUMINUM LEFT ON REMAINING OXIDE.
9. PROTECTING ALUMINUM, REMOVE OXIDE IN PATTERN CONSISTING OF $8\text{ }\mu\text{m}$ SQUARES ON $10\text{ }\mu\text{m}$ CENTERS. PATTERN IS 34 mm IN DIAMETER.

10. DEPOSIT PALLADIUM ONTO HOT WAFER, FORMING Pd_2Si . AFTER PALLADIUM THICKNESS OF 5000 \AA HAS BEEN DEPOSITED, STOP DEPOSITION AND LET WAFERS REMAIN AT DEPOSITION TEMPERATURE OF 270°C FOR FIVE MINUTES.
11. MEASURE DIODE I-V CHARACTERISTIC BETWEEN PALLADIUM AND ALUMINUM AT 77°K .
12. ETCH OFF UNREACTED PALLADIUM, PROTECTING ALUMINUM DURING ETCH.

II. $\text{HfSi}/\text{N-Si}$ RETINA

1. PREPARE TWO LOTS EACH (5 WAFERS EACH PER LOT) OF $\langle 100 \rangle$ N-TYPE SILICON, 2 INCH DIAMETER WAFERS, LAPPED AND CHEMICALLY POLISHED ON BOTH FACES, OF 3 OHM-CM SILICON. PREPARE TWO LOTS EACH (5 WAFERS EACH PER LOT) OF $\langle 100 \rangle$ N-TYPE SILICON, 2 INCH DIAMETER WAFERS, LAPPED AND CHEMICALLY POLISHED ON BOTH FACES, OF 10 OHM-CM SILICON.
2. ON ONE LOT OF THE 3 OHM-CM MATERIAL GROW A $5 \mu\text{m}$ THICK EPITAXIAL LAYER, N-TYPE, 3 OHM-CM RESISTIVITY.
3. ON ONE LOT OF THE 10 OHM-CM MATERIAL GROW A $5 \mu\text{m}$ THICK EPITAXIAL LAYER, N-TYPE, 10 OHM-CM RESISTIVITY.
4. GROW A THERMAL OXIDE, 5000 \AA THICK, ON BOTH FRONT AND BACK SURFACES OF WAFER.
5. ANNEAL OXIDE. SLOW COOL.

6. REMOVE OXIDE FROM RECTANGULAR SECTION ON BACK OF WAFER APPROXIMATELY 0.1" x 0.5", WITH LARGER DIMENSION ALIGNED ALONG RADIUS OF WAFER AND EXTENDING INWARD FROM EDGE OF WAFER.
7. DIFFUSE PHOSPHORUS INTO BACK OF WAFER THROUGH ABOVE CONTACT CUT.
8. DEPOSIT ALUMINUM ON BACK OF WAFER OVER ABOVE OXIDE CUT.
9. ALLOY ALUMINUM INTO WAFER AND REMOVE EXCESS ALUMINUM LEFT ON REMAINING OXIDE.
10. PROTECTING ALUMINUM, REMOVE OXIDE IN PATTERN CONSISTING OF 8 μm SQUARES ON 10 μm CENTERS. PATTERN IS 34 mm IN DIAMETER.
11. DEPOSIT HAFNIUM ONTO 200°C WAFER TO A THICKNESS OF 5000 Å.
12. SINTER HAFNIUM FOR 10 MINUTES AT 700°C IN HYDROGEN.
13. MEASURE DIODE I-V CHARACTERISTIC BETWEEN HAFNIUM AND ALUMINUM AT 77°K.
14. ETCH OFF UNREACTED HAFNIUM, PROTECTING ALUMINUM DURING ETCH.