REVIEW AND EVALUATION OF PAST SOLAR CELL DEVELOPMENT EFFORTS

by

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ABSTRACT

The work performed to date on the historical documentation phase of Contract NASW-1427 is described. The literature search objectives and methods are detailed. The indexing system used to provide easy access to the material which has been assembled is described. A bibliography is given which lists papers and reports that have been obtained, and also those that have been determined to be required and have not yet been obtained.

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SUMMARY

The end product of this contract will be a review of the past research effort in the field of photovoltaic solar energy converter cells, and recommendations to further research and development efforts which would have a good chance of significant future advancements in this field. To arrive at these recommendations, all of the available information on relevant research and development efforts will be assembled. An evaluation and analysis of this material will provide the foundation on which recommendations for future research efforts can be based.

This report covers work which has been done during the period June 1, 1966 through November 30, 1966. This work has been concerned wholly with gathering technical information in the form of papers published in scientific journals and conference proceedings, and of government reports. The publications obtained have all been read in their entirety, and an abstract of the content of each item has been prepared.

An index system has been established to organize the material. This index has been set up so as to provide easy access to the information needed to perform the evaluation and analysis phases of the contract.

This report lists all of the papers and reports that have been obtained, read, and abstracted during the reporting period. Lists are also included of papers and reports that have been determined to be relevant to the work but have not yet been read.

I. HISTORICAL DOCUMENTATION

A. Objectives and Scope

The objective of the work which has been performed during the reporting period has been to assemble published results of past research efforts into all aspects of the photovoltaic effect and its exploitation in solar energy converting devices. This basic material is to be analyzed and evaluated during later phases of this contract. It is important for this historical documentation to be as broad and as thorough as possible, so that it can form a sound foundation on which later work can be based.

The subject field that is being covered includes publications on the experimental and theoretical aspects of the photovoltaic effect and of devices utilizing this effect. It also includes contributions to related fields that have a bearing on photovoltaic devices and their application to solar energy conversion under space or terrestrial conditions. One example of such related work is that done on radiation damage in semiconductors, since this has a vital bearing on space applications.

Temporally, the search field covers the entire period during which scientific work has been reported on the photovoltaic effect. This period starts at 1839, the year of publication of Becquerel's work on photovoltaic effects at electrodes in electrolytic solutions, and extends right up to the present time.

The publications field which is being researched includes published scientific and engineering journals, in all languages. It also includes reports of conferences and published speeches. Reports on all U.S. Government-sponsored work in the field are being examined; this includes not only the rather recent work done by NASA and the Armed Services, but also research performed by the National Bureau of Standards since the early part of this century.

B. Methods

1. Journal Publications. -- For papers published in journals, the search method has been to use references to find earlier relevant work. Starting from personal collections of reprints of papers, which of necessity are of more recent date, the search has progressed in reverse chronological order. Naturally, this is a process which does not produce a rigidly defined search pattern, and it has been found that, during the early phases of such a program, considerable gaps can exist in the coverage which this process provides. However, these gaps are being eliminated by detailed work which is presently being performed, and it appears that there will ultimately be no problem in providing complete coverage of all published work.

2. Government Reports. -- To deal with the large number of reports on Government-sponsored research and development, a computerized index has been employed. This is maintained by the Astro-Electronics Division of RCA and is based on the Power Information Center's (PIC) indexing system. The index was used to catalogue contract numbers and PIC file numbers for all work on photovoltaics, and the original PIC file was then consulted to determine which reports were needed. These reports are currently being obtained. In addition, a number of reports on Government-sponsored work have already been examined. These reports have been obtained from sources within RCA.

It is believed that the PIC file coverage is 80% to 90% complete. To cover the gaps, NASA's Scientific and Technical Information Facility will be consulted.

The work of the National Bureau of Standards is freely referenced in published papers and has provided good coverage of this source of information.

C. Index

To structure the material which is being accumulated, an index system has been established. All papers and reports are read in their entirety, and an abstract is then prepared. Identification of the paper (authors, place of publication of paper or report and contract number), together with the abstract, are typed onto multiple sets of index cards to allow the paper or report to be filed under all of the relevant index headings.

1. Authors (alphabetical, all papers)
2. Theory
3. Silicon and germanium cells
4. Compound semiconductor cells
5. Thin-film cells
6. Space applications (including all work on radiation effects)
7. Terrestrial applications
8. Papers published prior to 1940, (these are not filed under any of the other subject headings).

Each paper is filed under all of the subjects to which it is relevant, so that a strong cross-indexing is being established.

Copies of all of the papers and reports which have been read are kept and filed alphabetically by the author's last name (or the first-named author of co-authored papers and reports). The following sections contain a listing of the publications and government reports which have been catalogued so far. This listing is not yet complete and will be expanded further.

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Radiation Effects on Silicon Solar Cells, General Atomic Division, General Dynamics Corporation, John Jay Hopkins Laboratory for Pure and Applied Science, Third Quarterly Progress Report Covering the Period June 1, 1962 through August 31, 1962. Project 258.00, NASA, Contract No. NAS 7-91, June 14, 1962, GACD-3223, Copy No. 101.

Radiation Effects on Silicon Solar Cells, General Atomic, Division of General Dynamics, Final Report, Contract NAS 7-91, NASA, February 15, 1963, GA-3872.

E. Government-Sponsored Research on Which Reports Are Being Sought

The following list of contracts has been obtained from the PIC index, and these have been determined to be relevant to the project.

Single-Crystal Cells

PIC No.	Contract No.	Directing Agency	Agency Location	Material
105	AF33(616)-7946	AF	WP	UNSP
117	AF33(616)-8415	AF	WP	UNSP
119	AF33(616)-7346	AF	WP	UNSP
130	AF19(604)-7306	AF	CRL	SI
132	AF19(604)-5995	AF	CRL	MAT
161	AF33(657)-7649	AF	WP	SI
162	AF33(616)-6615	AF	WP	GAAS
164	AF33(616)-7786	AF	WP	UNSP
312	NAS 5-3788	NASA	GDD	MAT
314	NAS 5-3805	NASA	GDD	MAT
371	AF33(616)-8198	AF	WP	SI
460	DA36-039 SC-87461	USAEL	MOM	UNSP
461	DA36-039 SC-88913	USAEL	MOM	UNSP
468	DA36-039 SC-87408	USAEL	MOM	MAT
469	DA36-039 SC-87381	USAEL	MOM	CDTE
470	None	USAEL	MOM	SI
549	AF33(657)-8527	AF	WP	MAT
581	NAS 5-814	NASA	DC	SI
598	NASW-6	NASA	JPL	SI

Single-Crystal Cells (Cont'd.)

PIC No.	Contract No.	Directing Agency	Agency Location	Material
640	NObs 84801	BUSHP	DC	
645	DA36-039 SC-85250	USAEL	MOM	SI
659	AF33(616)-6235	AF	WP	SIGA
667	None	USAEL	MOM	SI
668	None	USAEL	MOM	MAT
685	NAS 5-3560	NASA	GDD	SI
701	DA36-39 SC-85242	USAEL	MON	SI
720	AF33(657)-8490	AF	WP	GAAS
738	NAS 9-476	NASA	HUS	SI
746	DA36-039 SC-90777	USAEL	MON	MAT
764	AF33(615)-1049	AF	WP	SI
765	NAS 7-91	NASA	GDD	SI
815	AF33(615)-1097	AF	WP	SI
817	AF33(657)-10527	AF	WP	SI
835	AF33(600)-8921	AF	WP	GAAS
884	NAS 3-2776	NASA	LEW	MAT
934	NAS 5-3429	NASA	GDD	AUX
996	AF33(657)-11274	AF	WP	SI
1036	None	NASA	ARC	SI
1040	None	NASA	ARC	GAAS
1044	None	NASA	LRC	MAT
1050	NAS 3-6466	NASA	LEW	GAAS
1051	NAS 3-4177	NASA	LEW	CDS
1053	NSG-555	NASA	LEW	GAP
1087	NAS 3-6014	NASA	LEW	GAP
1094	AT(30-1)-3377	AEC	DC	UNSP
1107	None	NASA	GDD	SI
1127	DA28-043-AMC-00005(E)	USAEL	MOM	SI
1141	None	NASA	GDD	SI
1143	None	NASA	GDD	SI
1157	NAS 5-9006	NASA	GDD	GAAS
1169	AF33(657)-08974	AF	WP	GAAS
1192	NAS 2-2600	NASA	ARC	GAAS
1204	AF33(615)-2292	AF	WP	SI
1234	AF19(628)-3836	AF	CRL	SI
1257	PO-951132	NASA	JPL	UNSP
1260	None	NASA	JPL	SI
1261	None	NASA	JPL	AUX
1262	None	NASA	JPL	AUX
1275	AF33(615)-2141	AF	DC	AUX
1292	None	NASA	LEW	SI
1293	None	NASA	LEW	SI
1339	NA5-9210	NASA	GDD	SI
1353	951247	NASA	JPL	MAT
1356	AF33(615)-2750	AF	WP	SI
1357	AF33(615)-3223	AF	WP	SI

Single-Crystal Cells (Cont'd.)

PIC No.	Contract No.	Directing Agency	Agency Location	Material
1359	NAS 5-9141	NASA	GDD	MAT
1361	NAS 7-409	NASA	ARC	SI
1364	NAS 5-3558	NASA	GDD	SI
1365	NAS 5-3559	NASA	GDD	SI
1366	NAS 5-3686	NASA	GDD	MAT
1367	NGR 40-002-026	NASA	GDD	MAT
1368	NGR 39-009-042	NASA	GDD	SI
1369	NAS 5-9580	NASA	GDD	MAT
1370	NAS 5-9627	NASA	GDD	MAT
1415	NAS 7-428	NASA	DC	SI
1448	AF33(615)-3462	AF	WP	HIVG
1453	NAS 2-2564	NASA	ARC	SI
1458	None	NASA	GDD	SI
1528	NAS 9-5266	NASA	HUS	SI

Thin Film Cells

115	AF33(616)-7528	AF	WP	CDS
122	None	NASA	LEW	CDS
126	AF33(616)-7415	AF	WP	CDS
462	DA36-039 SC-88981 DA36-039-AMC-00115(E)	USAEL	MOM	SI
550	AF33(616)-7865 AF33(616)-7910	AF	WP	MAT
559	AF33(616)-8308 AF33(616)-7183	AF	WP	CDTE
560	AF33(616)-7482	AF	WP	CDTE
673	AF33(657)-7919	AF	WP	CDS
787	AF33(657)-7916 AF33(616)-6548	AF	WP	CDTE
797	AF33(657)-9975 AF33(615)-1248	AF	WP	CDS
829	AF33(657)-10601	AF	WP	CDS
830	None	AF	WP	MAT
931	NAS 3-2493	NASA	LEW	CDS
961	NAS 3-2795 NAS 7-203	NASA	LEW	CDS
1052	NAS 3-6008	NASA	LEW	CDS
1057	AF33(615)-1578	AF	WP	CDS
1119	NAS 3-6461 NAS 3-2795	NASA	LEW	CDS
1150	NSG-573	NASA	GDD	CDS
1188	NAS 3-6464	NASA	LEW	CDS
1203	AF33(615)-2259	AF	WP	GAAS

Thin Film Cells (Cont'd.)

PIC No.	Contract No.	Directing Agency	Agency Location	Material
1280	AF33(615)-2695	AF	WP	CDTE
1374	NAS 3-7631 NAS 3-4177	NASA	LEW	CDS
1413	NAS 3-8502	NASA	LEW	CDS
1451	AF33(615)-3253	AF	WP	CDS
1524	NAS 3-8510	NASA	LEW	GAAS

Key to Abbreviations

Contracting Agencies:

AF	Air Force
NASA	National Aeronautics and Space Administration
USAEL	U. S. Army Electronics Command
BUSHP	Bureau of Ships
AEC	Atomic Energy Commission

Agency Locations:

WP	Wright-Patterson Air Force Base
CRL	Cambridge Research Laboratories
GDD	Goddard Space Flight Center
MOM	Fort Monmouth
DC	Washington D. C.
JPL	Jet Propulsion Laboratory
HUS	Houston, Texas
ARC	Ames Research Center
LEW	Lewis Research Center

Materials:

UNSP	Unspecified
SI	Silicon
MAT	Materials Research
GAAS	GaAs
CDTE	CdTe
SIGA	Silicon and GaAs

The following reports are also being sought; they have been determined to be relevant using sources other than the PIC index.

Final Report on Contract NAS5-613 (September 1961).
Space Technology Laboratories, Report No. EM1021, MR-13; October 20, 1961.
U.S. Naval Research Laboratory Memorandum Report 1005.
WADC Technical Report 57-770, December 1957.

III. CONCLUSIONS

During the reporting period a large number of papers and reports that are relevant to the work has been assembled. In the earlier part of the historical period covered, there are a number of required papers published in journals which are not readily available, and this has prevented a historical account from being included in this report. However, steps have been taken to obtain this material, and it is anticipated that a complete coverage of the important published work will be obtained.

Government contracts for research and development in the field of interest have been listed by use of the PIC files, and requests for the reports on this work are being submitted to the appropriate agencies. Some of these reports have already been obtained through other channels. To ensure complete coverage of all government-sponsored projects, use of the NASA Scientific and Technical Information Facility is planned, and it is believed that this will assure complete coverage of this work.