N87-16397

SILICON MATERIAL TASK REVIEW

CONSULTANT

J. H. Lorenz

Introduction

1974/75 FLAT-PLATE SOLAR ARRAY PROJECT WAS FUNDED

IMPORTANT PART OF THE RENEWABLE ENERGY PLAN

SILICON WAS SELECTED AS IT WAS THE ONLY FIELD TESTED PV MATERIAL

POLYSILICON, AS THE BASE MATERIAL FOR SEMICONDUCTORS, WAS AVAILABLE, SO ALL FSA TASKS COULD BEGIN WORK

SEMICONDUCTOR POLYSILICON SOLD FOR $60 - $70 PER KILOGRAM WITH IMPURITIES IN THE PARTS PER MILLION

SOLAR CELLS COULD BE MADE FROM "LESS PURE" SILICON

PROBLEM WAS TO DEFINE THIS TERM AND DEVISE PROCESSES TO MAKE THE DESIRED SILICON

GOALS OF THE SILICON MATERIAL TASK WERE:

TO ESTABLISH SILICON MATERIAL PROCESSES WITH A PURITY ADEQUATE FOR THE PV CELL REQUIREMENTS

WITH A MARKET PRICE OF $10 PER KILOGRAM (1975 $)

($19 IN 1985 $)

SCALABLE TO 1000 TONS/YEAR PRODUCTION PLANTS

FSA Project: Silicon Material Task

OBJECTIVES:

TO EVALUATE TECHNOLOGIES, NEW AND OLD

TO DEVELOP THE MOST PROMISING TECHNOLOGIES

TO ESTABLISH PRACTICALITY OF THE PROCESSES TO MEET PRODUCTION, ENERGY USE, AND ECONOMIC CRITERIA

TO DEVELOP AN INFORMATION BASE ON IMPURITIES IN POLYSILICON AND TO DETERMINE THEIR EFFECTS ON SOLAR CELL PERFORMANCE

APPROACH:

1. DETERMINE PROCESS FEASIBILITY

   16 CONTRACTS WERE ISSUED: TO INDUSTRY, UNIVERSITIES AND NON-PROFIT GROUPS TO WORK ON PROCESSES, IMPURITIES AND SPECIFICATIONS -- ON A LABORATORY SCALE

2. MILESTONES WERE SET - FOR FORCED SELECTION OF THE PROCESSES

   TO FUND THE MOST PROMISING THROUGH PROCESS DEVELOPMENT

   TO DEMONSTRATE PRACTICALITY OF THE PROCESSES

   TO MEET SCALE-UP, ENERGY USE AND ECONOMIC CRITERIA

3. ESTABLISH TECHNICAL READINESS OF THE INTEGRATED PROCESS THROUGH YEAR LONG OPERATION OF A PILOT PLANT -- TO OBTAIN OPERATING DATA, OPTIMIZE DESIGN PARAMETERS, CONFIRM PRODUCT PURITY

FSA Project: Silicon Material Task (Cont'd)

4. FUND SUPPORT PROGRAMS FOR THE TASK:

ON HYDROCHLORONATION OF SILICON

(FIRST STAGE OF UCC PROCESS)

DR. J. MUI AT MIT AND LATER HIS OWN COMPANY

DATA ON MATERIALS, CATALYSTS, RATES

ON ACADEMIC STUDIES OF SILICON AEROSOLS AND FLUIDIZED BED MODELS AT JPL, CAL TECH AND WASHINGTON UNIVERSITY

TECHNICAL CONSULTANTS TO AID THE CONTRACTORS AND JPL

ON IMPURITY EFFECTS IN SILICON

Contractors for Process Development on Silicon

A. FOR SEMICONDUCTOR GRADE SILICON

HEMLOCK SEMICONDUCTOR CORP.	DICHLOROSILANE CVD
J C SCHUMACHER CO.	BROMOSILANE CVD/FB
UNION CARBIDE CORP.	SILANE PROCESS
JET PROPULSION LAB.	PYROLYZING SILANE

B. FOR SOLAR GRADE SILICON

AEROCHEM RESEARCH LABS.	SILANE/SILICON PLASMA JET
	Na/HALIDE FLAME
	IMPACTION REACTOR
BATTELLE COLUMBUS LABS.	Zn/SIL TET
DOW CORNING CORP.	DIRECT ARC FURNACE
MOTOROLA INC.	SiF2 TRANSPORT
SRI INTERNATIONAL INC	Na/SIL TET
TEXAS INSTRUMENTS INC.	CARBOTHEMIC REDUCTION SiO2
	ROTARY CHAMBER/TCS/FB
WESTINGHOUSE ELECTRIC CORP.	PLASMA ARC HEATER PROCESS NA/SIL TET

United States Polysilicon Production Capacity
(Metric Tons)

	1983	1984	1985	1986	1987	1988	1990
1. Union Carbide							
Washougal	50	100	120	120	120	120	120
Moses Lake	-	-	700	1200	1600	2400	2400
2. Hemlock(SEH, Mitsubishi)	1000	1200	1200	1400	1400	1400	2000
3. Ethyl Corp	1/86 $45M Houston				500	1000	1000
4. Monsanto	230	230	230	230	230	230	-
5. Motorola	100	100	100	100	100	-	-
6. Texas Ins.	350	350	350	350	-	-	-
7. Nippon Kokan	140	200	200	200	200	200	-

PILOT PLANTS

1. Great Lakes	-	-	-	20	20	20	1000
2. Schumacher Oceanside	-	-	-	40	40	1000	1000
3. Bunnington Rochester	-	-	-	-	-	-	1000

PLANNING

1. Alcan, Canada
2. Pasadena Group
3. ALCOA

Accomplishments for the Project

- RESULTED IN THE DEVELOPMENT AND COMMERCIALIZATION OF A NOVEL PROCESS FOR MAKING SILANE AND HIGH QUALITY SEMICONDUCTOR GRADE POLYCRYSTALLINE SILICON --THE UNION CARBIDE SILANE TO SILICON PROCESS

- ATTRACTED WORLD WIDE ATTENTION TO THE JPL/DOE PROJECT--DUE TO THE QUALITY OF THE PROCESSES IN THE TASK

- UCC PROCESS RECEIVED 12 NASA SPECIAL RECOGNITION AWARDS CHIEF DESIGN ENGINEER (BILL BRENEMAN) WAS HONORED WITH 1985 PIONEER AWARD OF THE AMERICAN INSTITUTE OF CHEMISTS

- SILANE PART OF THE UCC PROCESS WAS COMPLETED THROUGH THE FEASIBILITY VERIFICATION IN A 100 TON PER YEAR PILOT PLANT

- ASSURED ADEQUATE CAPACITY IN THE U. S. FOR PURE SILANE FOR THE DOE/SERI AMORPHOUS SILICON R &D PROGRAM AND FOR FUTURE PRODUCTION

- PROVIDED A TECHNOLOGY BASE FOR POSSIBLE DEPOSITION PROCESSES -- EVEN THOUGH THE GOAL OF $10/KG SILICON WAS NOT REALIZED: UCC & JPL ON FLUIDIZED BEDS; CAL TECH ON FREE-SPACE DEPOSITION PARTICLE GROWTH

- MADE THE DIRECTORS OF UCC TAKE NOTICE -- RESULTING IN THE COMMERCIALIZATION WITH A 1200 TON PER YEAR PLANT

Accomplishments for the Project (Cont'd)

- CONFIRMED, WITH HEMLOCK'S WORK, THAT DICHLOROSILANE HAS SOME ADVANTAGES OVER TCS DEPOSITION

- DEFINED THE EFFECTS OF IMPURITIES IN SILICON ON SOLAR CELL PERFORMANCE (WESTINGHOUSE AND MONSANTO)

- PRESENTED THE RELATIVE ECONOMICS OF THE POTENTIALS OF THE SILICON PROCESSES, INCLUDING COMPARISON WITH THE TCS/CVD SEMICONDUCTOR PROCESS

Accomplishments for Electronics in General

- HELPED PUT THE U. S. IN POSITION FOR A LEADERSHIP ROLE IN PURE POLYSILICON PRODUCTION

	POLYSILICON CAPACITIES TONS PER YEAR	
	UNITED STATES	WORLD
1976	950	1804
1986	3600	E 3120
	(1200)	J 1200

- CATALYZED THE INTEREST OF COMPANIES TO GET INTO SILICON
  - SCHUMACHER HAS A 40 TON PILOT PLANT
  - ETHYL CORP. HAS ANNOUNCED A PILOT PLANT BASED ON SILANE
  - FOUR OTHER COMPANIES IN U S ARE CONSIDERING POLYSILICON
- CONFIRMED HIGH PRESSURE, HIGH TEMPERATURE CHEMICAL REACTIONS COULD BE ENGINEERED
- DETAILED IN THE HEMLOCK CONTRACT A POSSIBLE IMPROVEMENT OF THE TCS/CVD PROCESS -- BY USING DICHLOROSILANE AND THE RECYCLING OF THE SIL TET (1ST STEP IN UCC PROCESS)
- UCC PROCESS HAS THE POTENTIAL TO PROVIDE THE MOST PURE POLYSILICON FOR PV OR SEMICONDUCTOR USE
- PROVIDED A PURE SOURCE OF SILANE FOR ALL USES AND ASSURED THE U. S. A LEADERSHIP ROLE IN SILANE
- SPURRED CURRENT SILANE SUPPLIERS TO IMPROVE THEIR QUALITY FOR BOTH PV AND SEMICONDUCTOR USE

Yet to be Done

A. TO MEET THE GOAL

(GOVERNMENT FUNDING WILL BE NEEDED FOR THIS WORK)

FSA PROJECT DID NOT ACHIEVE ITS GOAL -- NOR DID THE MATERIALS TASK

TO ACHIEVE THE LOW COST SILICON, A LOW COST DEPOSITION PROCESS MUST BE FULLY DEVELOPED -- THE FLUIDIZED BED TECHNIQUE LOOKS PROMISING, BUT NEEDS ENGINEERING WORK ON MATERIAL OF CONSTRUCTION, OPTIMUM CONDITIONS FOR GROWTH AND DETERMINATION OF PRODUCT PURITY

THE FREE SPACE REACTOR DEPOSITION COULD BE LOWEST COST, IF THE PARTICLES COULD BE GROWN TO A LARGER SIZE.

B. TO EXPAND THE USE OF THE TECHNOLOGIES

(INDUSTRY WILL DO THIS WORK)

OTHER COMPANIES HAVE OR ARE LOOKING AT THE TECHNOLOGY IN THE FIELD OF ELECTRONICS

AVAILABILITY OF PURE SILANE IN LARGE VOLUMES WILL ENCOURAGE INVESTIGATION OF OTHER USES

INTEGRATION OF PARTS OF THESE PROCESSES INTO THE ELECTRONICS AREA HYDROGENATION, DICHLOROSILANE

Conclusions

- PART OF THE OBJECTIVES OF THE MATERIAL TASK WERE ACHIEVED
- TECHNOLOGY DATA BASES WERE ESTABLISHED FOR THE UNFINISHED DEPOSITION WORK
- THE U S HAS ENHANCED THEIR LEADERSHIP IN POLYCRYSTALLINE SILICON
- TECHNOLOGY OF VALUE TO THE WORLD-WIDE ELECTRONICS INDUSTRY HAS BEEN ESTABLISHED AND PUBLISHED
- THE MATERIAL TASK IS A PRIME EXAMPLE OF THE PROPER USE OF GOVERNMENT FUNDING OF HIGH COST, HIGH RISK RESEARCH AND DEVELOPMENT