(NASA-CR-158564) ANTI-REFLECTION COATINGS ON LARGE AREA GLASS SHEETS Quarterly Technical Report, 29 Jan. - 31 Mar. 1979 (Motorola, Inc.) 10 p HC A02/MF A01 CSCL 10A G3/44
N79-23526
Unclas 25195

DRL NO. 98

DRD NO. SE-4

# ANTI-REFLECTION COATINGS ON LARGE AREA GLASS SHEETS

QUARTERLY TECHNICAL REPORT NO. 1

MOTOROLA REPORT NO. 2366/1

DRD NO. SE-4

29 JANUARY 1979 - 31 MARCH 1979

JPL CONTRACT NO. 955339

RECEIVED NASA STI FACILITY ACCESS DEPT. MAY 1979

PREPARED BY

E. PASTIRIK

MOTOROLA INC. SEMICONDUCTOR GROUP
5005 EAST MCDOWELL ROAD
PHOENIX, ARIZONA 85005

THE JPL LOW-COST SOLAR ARRAY PROJECT IS SPONSORED BY THE U. S. DEPARTMENT OF ENERGY AND FORMS PART OF THE SOLAR PHOTOVOLTAIC CONVERSION PROGRAM TO INITIATE A MAJOR EFFORT TOWARD THE LOW-COST SOLAR ARRAYS. THIS WORK WAS PERFORMED FOR THE JET PROPULSION LABORATORY, CALIFORNIA INSTITUTE OF TECHNOLOGY BY AGREEMENT BETWEEN NASA AND DOE.

PROJECT NO. 2366

THIS REPORT WAS PREPARED AS AN ACCOUNT OF WORK SPONSORED BY THE UNITED STATES GOVERNMENT. NEITHER THE UNITED STATES NOR THE UNITED STATES DEPARTMENT OF ENERGY, NOR ANY OF THEIR EMPLOYEES,NOR ANY OF THEIR CONTRACTORS, SUBCONTRACTORS, OR THEIR EMPLOYEES, MAKES ANY WARRANTY, EXPRESS OR IMPLIED, OR ASSUMES ANY LEGAL LIABILITY OR RESPONSIBILITY FOR THE ACCURACY, COMPLETENESS OR USEFULNESS OF ANY INFORMATION, APPARATUS, PRODUCT OR PROCESS DISCLOSED, OR REPRESENTS THAT ITS USE WOULD NOT INFRINGE PRIVATELY OWNED RIGHTS.

DOE/JPL-955339-79/1
DISTRIBUTION CATEGORY UC-63
DRL NO. 98
DRD NO. SE-4

# ANTI-REFLECTION COATINGS ON LARGE AREA GLASS SHEETS

QUARTERLY TECHNICAL REPORT NO. 1

MOTOROLA REPORT NO. 2366/1

DRD NO. SE-4

29 JANUARY 1979 - 31 MARCH 1979

JPL CONTRACT NO. 955339

PREPARED BY

E. PASTIRIK

MOTOROLA INC. SEMICONDUCTOR GROUP
5005 EAST MCDOWELL ROAD
PHOENIX, ARIZONA 85005

THE JPL LOW-COST SOLAR ARRAY PROJECT IS SPONSORED BY THE U. S. DEPARTMENT OF ENERGY AND FORMS PART OF THE SOLAR PHOTOVOLTAIC CONVERSION PROGRAM TO INITIATE A MAJOR EFFORT TOWARD THE LOW-COST SOLAR ARRAYS. THIS WORK WAS PERFORMED FOR THE JET PROPULSION LABORATORY, CALIFORNIA INSTITUTE OF TECHNOLOGY BY AGREEMENT BETWEEN NASA AND DOE.

PROJECT NO. 2366

## TABLE OF CONTENTS


| SECTION | TITLE | PAGE |
|---|---|---|
| 1.0 | Summary Statement | 1 |
| 2.0 | Introduction | 1 |
| 3.0 | Technical Discussion | 2 |
| 4.0 | Projected Activities for the Next Three Months | 4 |
| 5.0 | Recommendations | 5 |
| 6.0 | Current Problem | 5 |
| 7.0 | Work Plan Status | 5 |
| 8.0 | Action Items | 5 |
| 9.0 | New Technology | 6 |
| 10.0 | Program and Documentation Milestones | 6 |

## 1.0 SUMMARY STATEMENT

This report covers the first quarter of a one-year program designed to research and perfect a method of producing antireflective coatings on large glass sheets through the use of sodium silicate hardened by exposure to acid.

To date, the requirements for a linear motion device used to produce uniform sodium silicate films have been determined. A search for a commercially available device is underway. On the basis of earlier work, sodium silicate solutions of varying concentrations have been prepared. Determinations of the physical properties relevant to film thickness are in progress. In addition, material costs are being recorded for later use in a cost analysis of the method.

All tasks of the project are proceeding according to schedule. Of the tasks, only the sodium silicate solution preparation is complete.

## 2.0 INTRODUCTION

The ultimate goal of the project is the improvement of the efficiency of photovoltaic modules through increased transmission of light by the module cover. One method of increasing transmission is by reducing the reflection of light by the module cover, a reflection which accounts for a 4% loss of transmission for each coverglass-air interface.

This study is intended to advance a known antireflection technology to the point where large area glass module covers can be treated to produce uniform, efficient, and durable antireflective films.

## 3.0 TECHNICAL DISCUSSION

### 3.1 METHOD OF PRODUCTION

The desired antireflective coating can be produced in a two-step process. The first step involves the film formation. Clean dry glass is immersed in a sodium silicate solution and is then withdrawn slowly at constant speed. An expression for film thickness produced in this way has been derived by Levich (Physicochemical Hydrodynamics, p. 674) as follows:

$$h_o = 0.93 \frac{(\mu v)^{2/3}}{\sigma^{1/6} (\rho g)^{1/2}}$$

where $h_o$ = film thickness; $\sigma$ = surface tension
$\mu$ = viscosity; $\rho$ = density
$v$ = withdrawal speed; $g$ = acceleration of gravity

Both withdrawal speed and the several physical properties of the solution influence the thickness, and therefore effectiveness, of the antireflective film. It is also anticipated that humidity of the atmosphere in contact with the film will have some effect on its thickness, and as a result provisions for a controlled atmosphere are desirable.

After withdrawal and air drying for a few moments, the glass is immersed in concentrated sulfuric acid. The acid converts the sodium silicate film to silicon dioxide and sodium sulfate. This constitutes the antireflective film. A water rinse to remove residual acid, and a drying step, complete the process. Although the sodium sulfate which is formed in the film is water soluble, its leaching away by rain (in an installed module) has been determined to cause no degradation of the film performance. In fact, a slight increase in antireflective properties is noted in films from which sodium sulfate is leached.

The process as described above is applicable to cover plates of any size, and can handle several plates at once if a suitable holder is used to support the plates during the withdrawal process.

## 3.2 SPECIFIC AREAS OF PROGRESS

In addition to the acquisition of material and supplies necessary to begin the program, progress has been made in the following tasks: Design and Construction of a Linear Drive, Preparation of Sodium Silicate Solutions, Determination of Solution Physical Properties, and Cost Analysis.

### 3.2.1 GLASS SELECTION

At present, it appears that the thin (1/16"), low iron, Lustraglas brand soda-lime glass used in our earlier study (Studies and Testing of Antireflective (AR) Coatings for Soda-Lime Glass, JPL Contract No. 954773) is unavailable. We have located the same brand of glass in a double thickness (that is, standard 3/16" thickness), and it has been ordered. The use of thin, low iron glass is desirable since its use reduces the effects of light absorption by the glass and permits easier measurement of reflection values.

### 3.2.2 DESIGN AND CONSTRUCTION OF A LINEAR DRIVE

The design requirements of a linear drive have been defined and a search is now underway for a commercial unit which will serve our purposes at a lower cost than a unit built in-house. In the event that a suitable drive is not available, the parts necessary to build such a unit are now being catalogued.

### 3.2.3 PREPARATION OF SODIUM SILICATE SOLUTIONS

The preparation of sodium silicate solutions is complete. Both the Humco silicate used in an earlier study (Studies and Testing of Antireflective Coatings for Soda-Lime Glass, Final Report, JPL Contract No. 954773) and technical grade sodium metasilicate are being used in a separate series of solutions. The sodium metasilicate is of more definite and reproducible composition than commercial silicate. In addition, some silicates produced by Diamond Shamrock are now being considered for later study.

### 3.2.4 DETERMINATION OF SOLUTION PHYSICAL PROPERTIES

The solutions prepared are now being analyzed for density and viscosity values. Measurements are not yet complete. Surface tension measurements are planned and will begin shortly.

### 3.2.5 COST ANALYSIS

The compilation of material cost data is also in progress. This will be used later in the Cost Analysis Task.

## 4.0 PROJECTED ACTIVITIES FOR THE NEXT THREE MONTHS

The next three months will see the acquisition of a linear drive unit. If such a unit is not commercially available, component parts will be ordered and assembled in-house.

The sodium silicate solution physical properties measurements will be completed and used to calculate first trial withdrawal speeds.

The production of antireflective coatings on 4" x 4" glass plates will begin, using various combinations of withdrawal speed, silicate concentration, and ambient atmosphere.

Optical performance of the antireflective coatings will be evaluated by measurements of transmission and reflection of radiation throughout the solar spectrum. This will be done using the Cary 17 Spectrophotometer in the Solar Energy R&D Optics Lab.

Coating durability will be tested by abrasion of samples.

Soil resistance of the coatings will be tested by exposure to inorganic and organic soils. Testing of detergent resistance is also planned.

Cost analysis will continue as information on processing speed, etc., becomes available.

## 5.0 RECOMMENDATIONS

No recommendations are made at this time.

## 6.0 CURRENT PROBLEMS

No problems exist at present.

## 7.0 WORK PLAN STATUS

Work is on schedule.

## 8.0 ACTION ITEMS

No urgent action is required on any item.

## 9.0 NEW TECHNOLOGY

No reportable items of new technology have been identified, as yet.

## 10.0 PROGRAM AND DOCUMENTATION MILESTONES

Activities associated with the total program are shown in the Program and Documentation Milestone Charts Figures 1 and 2 contained in Appendix 1.

# APPENDIX I

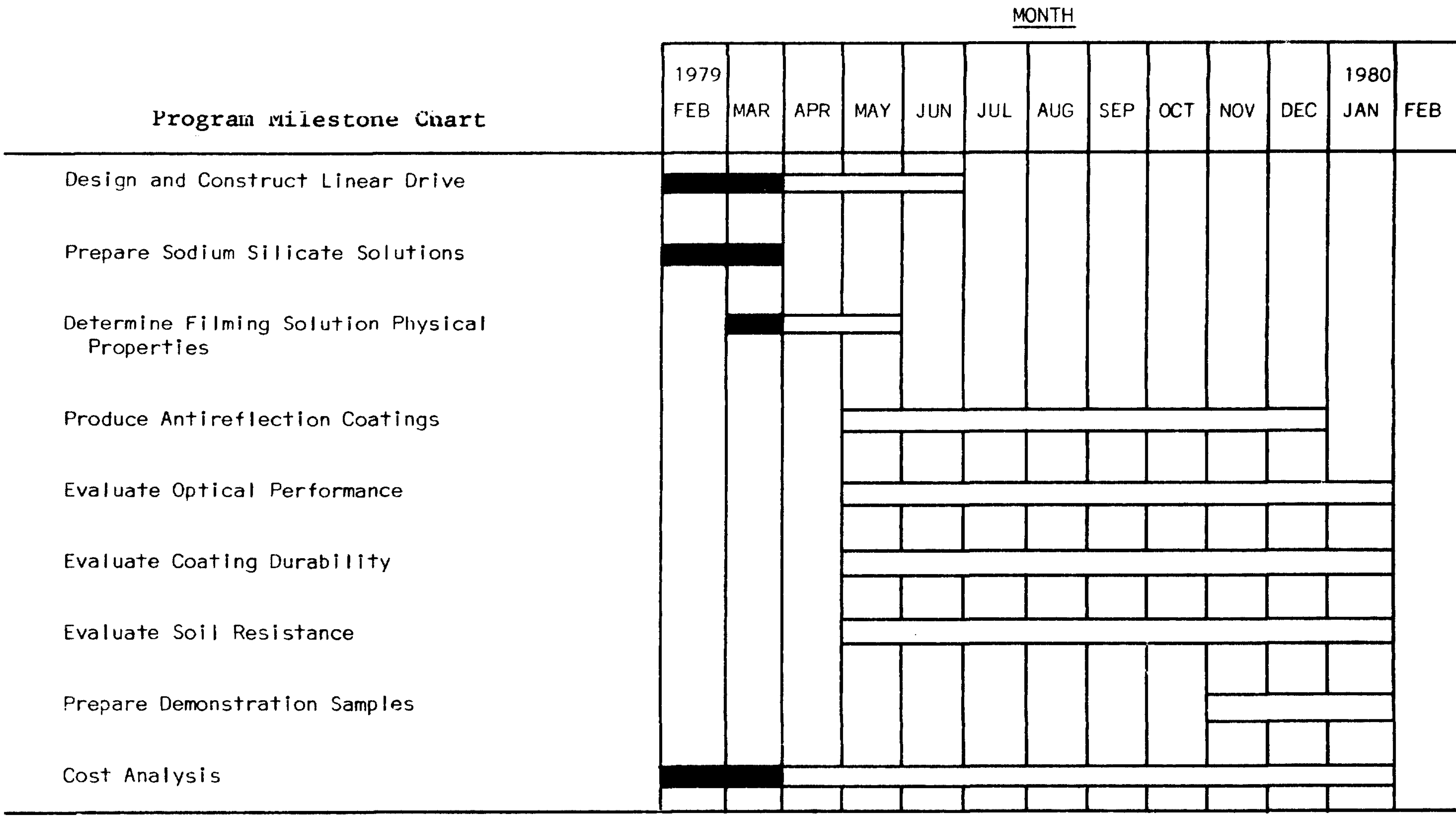
MONTH
Program Milestone Chart
1979
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
1980
JAN
FEB
Design and Construct Linear Drive
Prepare Sodium Silicate Solutions
Determine Filming Solution Physical Properties
Produce Antireflection Coatings
Evaluate Optical Performance
Evaluate Coating Durability
Evaluate Soil Resistance
Prepare Demonstration Samples
Cost Analysis

FIGURE 1

DOCUMENTATION MILESTONE CHART

| | MONTHS | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1979 FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC | 1980 JAN | FEB |
| Monthly Financial Management Report | | ▲ | △ | △ | △ | △ | △ | △ | △ | △ | △ | △ | △ |
| Technical Letter Progress Report | | ▲ | | △ | △ | | △ | △ | | △ | △ | | |
| Quarterly Technical Report | | ▲ | | | △ | | | △ | | | | | |
| Draft Final Report | | | | | | | | | | | | △ | |
| Final Report | | | | | | | | | | | | | △ |
| Program Plan | ▲ | | | | | | | | | | | | |
| Baseline Cost Estimate | ▲ | | | | | | | | | | | | |
| Chemical/Process/Equipment Cost Analysis | | | | | | | | | | | | △ | |

FIGURE 2