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MOTOROLA REPORT NO. 2365/1

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17 JANUARY 1979 - 31 MARCH 1979

JPL CONTRACT NO. 955324

PREPARED BY

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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.

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TABLE OF CONTENTS

1.0 SUMMARY STATEMENT

This report covers the first quarter of a one-year program to investigate the production of patterned etch resistant wax coatings on solar cell substrates by printing.

Master molds for printing plates have been produced for the plates. The resist wax is being studied to determine its relevant physical properties. A printing device is currently in design, and material costs are being compiled as a first step in a cost analysis task.

All phases of the project are proceeding according to schedule. No specific phases have yet been completed.

2.0 INTRODUCTION

The aim of this project is to research an alternate to photoresist processing as presently practiced and applied to the production of photovoltaic devices. The alternate method, printing of a wax resist pattern, is designed to offer advantages of low cost and high production rates, along with the possibility of recycle of used material.

3.0 TECHNICAL DISCUSSION

3.1 PROBLEMS ASSOCIATED WITH CURRENT TECHNOLOGY

Present solar-cell processing makes use of photoresist (PR), a light-sensitive material, to produce etch-resistant, patterned coatings on the cell substrate material. Subsequent operations etch the cell or some overlying material - e.g. silicon oxide, silicon nitride - to provide openings for metallization, definition of mesa areas, etc. The photoresist is then removed and discarded along with the chemicals used for its development and removal.

The use of photoresist presents a number of problems. The material itself is expensive. Being light sensitive, PR processing areas must be illuminated by yellow safety light and must also be carefully temperature- and humidity-controlled. The photographic process by which the PR is patterned is time consuming, and calls for expensive exposure equipment and carefully prepared photographic glass plates bearing the intended pattern image (or its photographic negative). Moreover, the PR mixtures available are non-reuseable. Once applied and processed, the PR undergoes irreversible chemical alteration and must be chemically destroyed in order to effect removal from the substrate surface. Other disadvantages are also encountered. PR contains organic solvents, such as xylene, which are released to the atmosphere during use; some PR mixtures generate gas during storage, causing pressure build-up in the container and causing the container to burst; and virtually all have limited shelf life.

The purpose of this project is to investigate the replacement of PR use and processing by an alternate method - the use of an inert wax as an etch resist to be applied to solar cell substrates in patterned form by means of a printing technique. The time-consuming exposure of PR can thus be eliminated, along with the requirements for temperature and humidity control, safety illumination, and the expense of the PR itself. If in addition the wax can be recyclable, the quantity (and expense) of waste materials will be greatly reduced.

3.2 SPECIFIC AREAS OF PROGRESS

The work done to date involves initial preparation of materials and acquisition of supplies, as well as progress in the following tasks: Master Mold Development, Wax Physical Properties Research, Printing Device Design, Cost Analysis.

3.2.1 MASTER MOLD DEVELOPMENT

Master molds for printing plates have been produced by a Motorola metal etch facility. At present, copper, steel, and aluminum masters have been prepared in both positive (pattern areas raised) and negative (non-image areas raised) versions. Glass master plates are now in preparation. The plates prepared from the masters will be used in a printing method known as letterset, in which raised areas of the plate will bear wax which will be transferred to the cell substrate on contact (Figure 1). The printing plates themselves will be produced by molding a substance such as silicone rubber to the surface of the master and then separating the molded plate from its master (Figure 2).

Also originally planned for study was intaglio printing, in which wax is borne by depressions in the plate, the raised plate areas being resistant to wax wetting. Surface tension of the wax would cause "beading" of the wax in the depressions, resulting in wax protruding above the raised plate areas (Figure 3). Trials of this technique showed that the masking wax had insufficient surface tension to cause the required beading. In addition, a durable wax antiwetting agent for the raised plate portions was not found. Stray droplets of wax on raised plate portions also contributed to the problems associated with this method. In view of the impracticalities involved, the intaglio technique has been dropped from further consideration.

An alternate method of lithographic printing is being investigated. This involves the use of printing plates constructed of metals which are selectively wet with oily or aqueous solutions, thus allowing a flat plate to pick up wax only in designated areas. The plate preparation is rather involved and this study is being pursued as one of secondary importance.

Figure 1

LETTERPRESS PRINTING TECHNIQUE

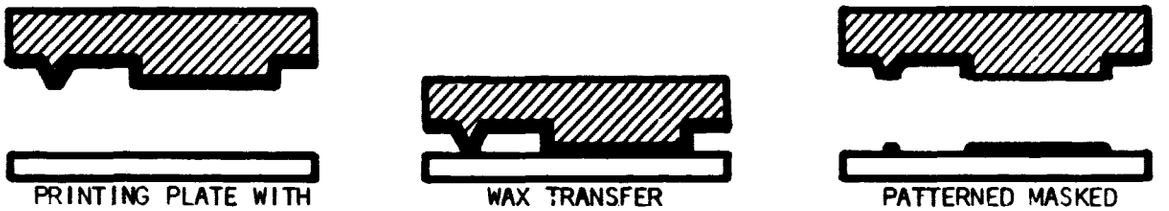


Figure 2

PRINTING PLATE PRODUCTION

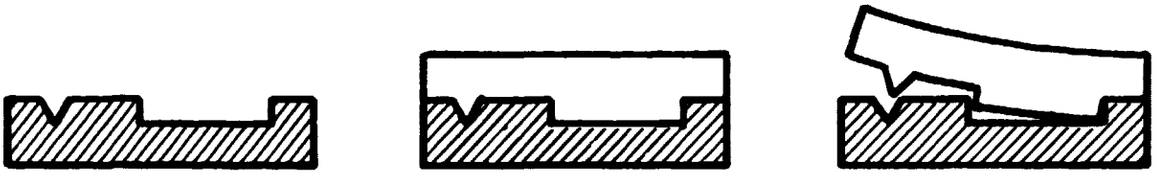
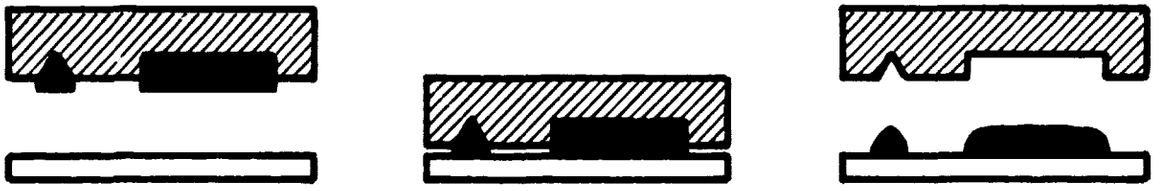


Figure 3

INTAGLIO PRINTING TECHNIQUE



3.2.2 WAX PHYSICAL PROPERTIES RESEARCH

Studies for the determination of wax physical properties are continuing. The first investigation is on wax adhesion to wafer surfaces. This study is incomplete but suggests that wax creep may be a problem on textured bare silicon wafers. The problem may have a solution by the addition of fillers or thickeners to the wax. A search for an effective filler is under way.

The wax selected for use in solvent-wax masking solutions, Multiwax 195M, melts at 90°C, forming a low viscosity liquid which is easily handled. The availability of inexpensive equipment to attain and maintain the modest melting temperature of this wax is an additional advantage.

The problem of wax removal from wafer surfaces has also been addressed. It has been found that wax can be removed from cell surfaces by immersion of the cells in hot water, during which the wax melts and floats to the surface in an easily removed layer. The process is incomplete when pure water at its boiling point is used; about 70% of the applied wax is removed. Addition of dense salts such as ammonium sulfate to the water raises the boiling temperature and density of the water so that more complete removal results. Wax removed in this way can be separated from the water and reused. Removal by organic solvents is also possible. If desired, wax can be recovered, and the solvent purified, for reuse by simple distillation.

3.2.3 PRINTING DEVICE DESIGN

The design of a printing press has begun. The first model is intended to be of simple form, allowing evaluation of plate performance without unnecessary mechanical complication.

In its earliest form, the device will consist of a vacuum wafer chuck over which is suspended the printing plate. Contact between the plate and wafer will be made by lowering the plate by means of a screw drive. Initial testing of the performance of different plate materials will be made using

this device. Modifications which are necessary to increase convenience or utility will be incorporated into the design of improved models at a later date.

3.2.4 COST ANALYSIS

Material costs are being compiled for later use in the analysis.

4.0 PROJECTED ACTIVITIES FOR THE NEXT THREE MONTHS

The production of master molds for printing plates is expected to be completed within the next few days. Candidate materials for printing plates have been and are being selected and printing plate production will begin.

Wax physical properties are still being determined. Additional work will be permormed on the alteration of wax properties through the use of fillers and thickeners in the wax mix. These efforts need to be done on the basis of information gained in printing trials which are scheduled to begin in one month.

Wax resist performance will also begin in one month. The wax will be applied to commonly used silicon wafers, and wafers bearing oxide and nitride layers. Both polished and pyramidally textured wafers will be used. The masked wafers will then be exposed to all common etchants and the masking performance noted.

Cost analysis will continue. Further material costs will be tabulated, along with the costs for the photoresist methods now in use.

5.0 RECOMMENDATIONS

No recommendations are necessary.

6.0 CURRENT PROBLEMS

Other than the discovery that intaglio printing is unsuitable for wax printing, no problems have been encountered.

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 Figure 1 and 2 contained in Appendix 1.

APPENDIX I

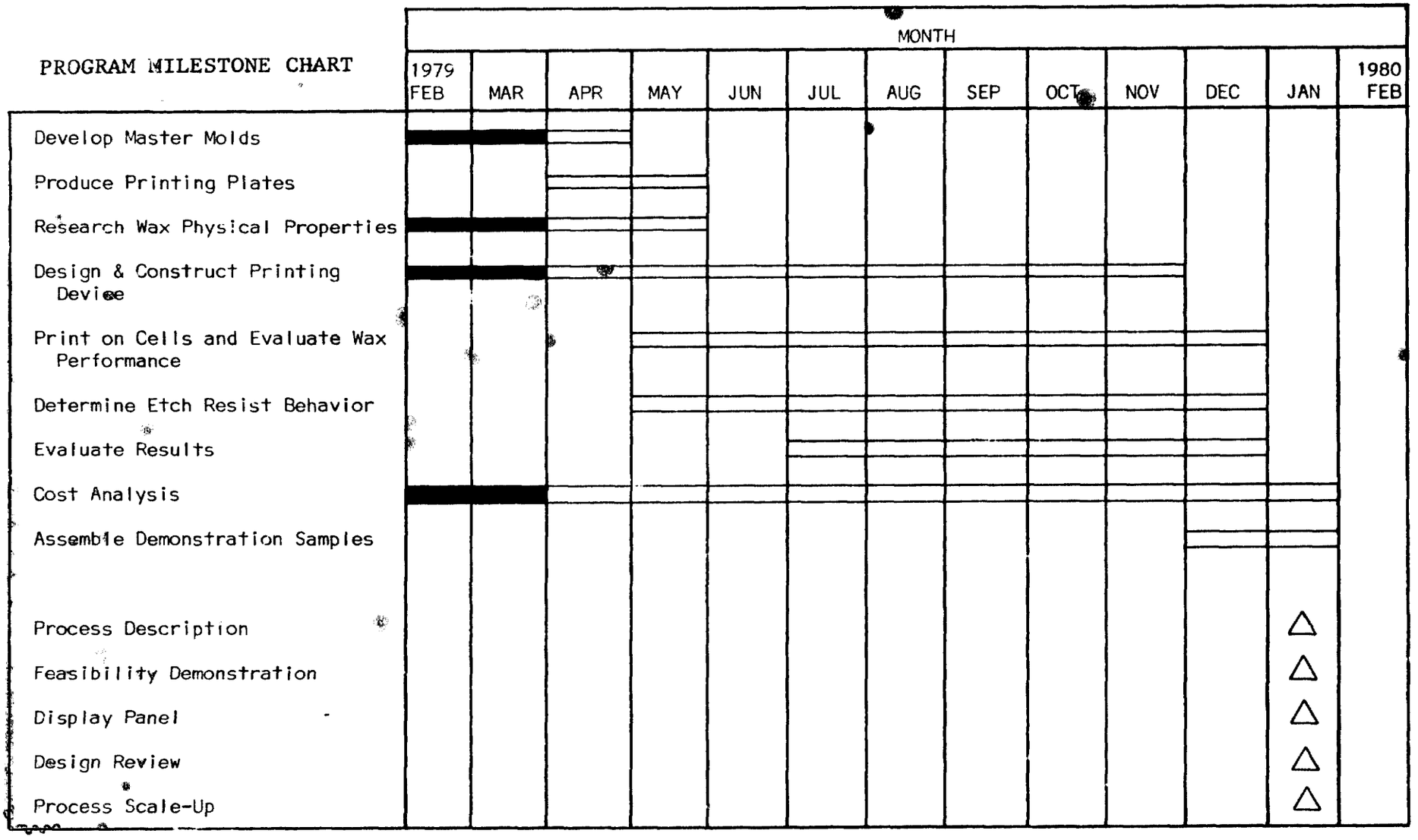

PROGRAM MILESTONE CHART
MONTH
1979 FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
JAN
1980 FEB
Develop Master Molds
Produce Printing Plates
Research Wax Physical Properties
Design & Construct Printing Device
Print on Cells and Evaluate Wax Performance
Determine Etch Resist Behavior
Evaluate Results
Cost Analysis
Assemble Demonstration Samples
Process Description
Feasibility Demonstration
Display Panel
Design Review
Process Scale-Up

FIGURE 1

DOCUMENTATION MILESTONE CHART

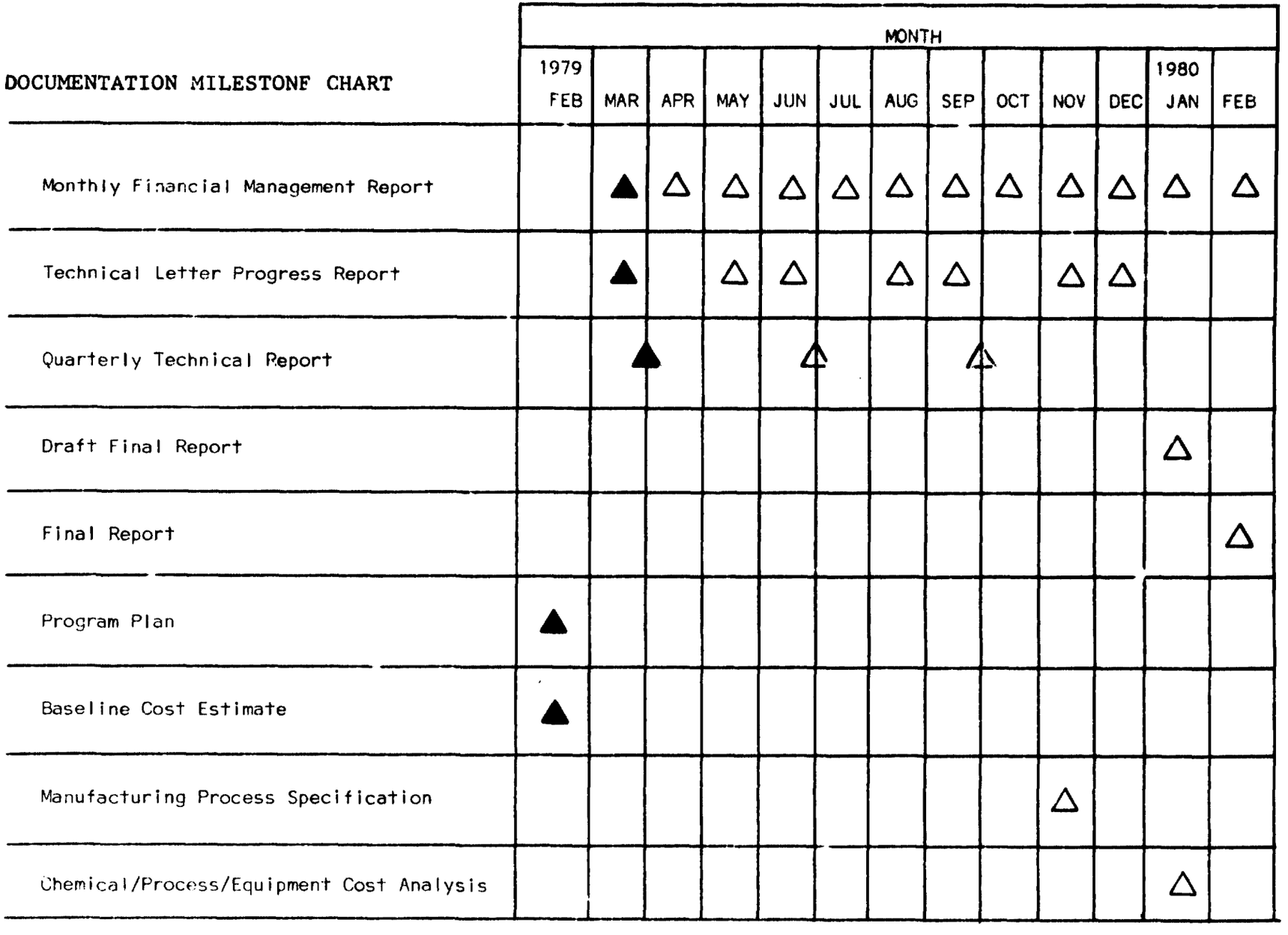


FIGURE 2