Subcontractor for costs incurred in excess of the estimated NREL share set forth in Paragraph 2 above.

4. Pursuant to the clause entitled "Limitation of Funds" in Appendix B, the amount of $750,000.00 has been allotted and is available for payment of NREL's estimated share of allowable costs under this letter subcontract. It is estimated that the allotted amount will cover work under this letter subcontract through December 31, 2002.

5. The amount of $750,000.00, presently obligated by NREL with respect to this letter subcontract, may be unilaterally increased by NREL by written notice to the Subcontractor, and may be increased or decreased by written agreement of the parties by formal modification of this letter subcontract.

6. The giving of any notice by either party under this letter Subcontract or the clauses entitled "Limitation of Funds" and "Limitation of Costs" in Appendix B, as applicable, shall not be construed to waive or impair any rights of NREL to terminate this letter subcontract under the provisions of the termination clause(s) contained in Appendix B.

7. The "Limitations of Funds" clause contained in Appendix B shall be operable during such time that NREL incrementally allots additional funds to this letter subcontract as set forth above. (The Limitations of Cost clause shall be inoperable during such time.)

8. The "Limitations of Cost" clause contained in Appendix B shall become operable at such time that NREL allots to this letter subcontract an amount equal to the total estimated NREL cost share set forth above. (The Limitations of Funds clause shall be inoperable at such time.)

C. **Subcontract Definitization**

1. A cost sharing definitized subcontract is contemplated. The Subcontractor has begun negotiating with the Subcontract Administrator the terms of a definitized subcontract that will include:

   a. Satisfactory completion of a Pre-award Audit of the Indirect Rates and Accounting System of Evergreen Solar, Inc.

   b. The following appendices which also apply to the work done under this letter subcontract, except payment shall be governed by Paragraph D of this letter subcontract:

      (1) Appendix A, Statement of Work, dated 09/18/02;

      (2) Appendix B-1, Standard Terms and Conditions for a Cost Sharing Subcontract, dated 07/24/00;

      (3) Appendix C-2 Intellectual Property Provisions for a Domestic Small Business, dated 10/22/98; and,

(4) Appendix D-1, Clauses for Subcontracts in Excess of $500,000, dated 07/28/00.

c. All clauses required by law on the date of execution of the definitive subcontract, and,

d. Any other mutually agreeable clauses, terms, and conditions. If determined necessary by the Subcontract Administrator, the Subcontractor agrees to submit a revised proposal and cost or pricing data supporting its proposal.

2. The schedule for definitizing this letter subcontract is as follows:

Begin negotiations of the Definitized Subcontract:	Date of Execution of Letter Subcontract
Certificate of Current Cost or Pricing Data:	Upon Completion of Negotiations
Execute Definitized Subcontract:	Three (3) Months from Date of Execution of Letter Subcontract

3. If agreement on a definitized subcontract to supersede this letter subcontract is not reached by the target date in Paragraph 2 above, or within any extension granted by NREL, the Subcontract Administrator may determine a reasonable cost for this letter subcontract in accordance with Subpart 15.4 and Part 31 of the Federal Acquisition Regulation (FAR), as supplemented by Part 931 of the Department of Energy Acquisition Regulation (DEAR), subject to Subcontractor appeal as provided in the Disputes clause of Appendix B-1. In any event, the Subcontractor shall proceed with completion of the letter subcontract, subject only to the Limitation of NREL Liability clause.

a. In the event agreement on a definitized subcontract is not reached, and after the Subcontract Administrator's determination of cost, the subcontract shall be governed by:

(1) Appendix A, Statement of Work, dated 09/18/02;

(2) Appendix B-1, Standard Terms and Conditions for Cost Sharing Subcontracts, dated 07/24/00;

(3) Appendix C-2, Intellectual Property Provisions for a Domestic Small Business, dated 10/22/98; and,

(4) Appendix D-1, Clauses for Subcontracts in Excess of $500,000, dated 07/28/00.

b. All clauses required by law as of the date of the Subcontract Administrator's determination; and

c. Any other clauses, terms and conditions mutually agreed upon.

d. To the extent consistent with Subparagraph 3.a. above, all clauses, terms and

conditions included in this letter subcontract shall continue in effect, except those that by their nature apply only to a letter subcontract.

D. Payments of Allowable Costs Before Definitization

1. Reimbursement rate. Pending the placing of the definitized subcontract referred to in this letter subcontract, NREL shall promptly reimburse the Subcontractor for all allowable costs under this letter subcontract at the following rates:

   a. One hundred percent (100%) of approved costs representing progress payments to lower-tier subcontractors under fixed-price subcontracts; provided, that NREL's payments to the Subcontractor shall not exceed eighty percent (80%) of the allowable costs of those lower-tier subcontractors.

   b. One hundred percent (100%) of approved costs representing cost reimbursement lower-tier subcontracts; provided, that NREL's payments to the Subcontractor shall not exceed eighty-five percent (85%) of the allowable costs of those lower-tier subcontractors.

   c. Eighty-five percent (85%) of all other approved costs.

2. Limitation of Reimbursement. To determine the amounts payable to the Subcontractor under this letter subcontract, the Subcontract Administrator shall determine allowable costs in accordance with the applicable cost principles in Part 31 of the FAR as supplemented by Part 931 of the DEAR. The total reimbursement made under this paragraph shall not exceed eighty-five percent (85%) of the maximum amount of NREL's liability, as stated in this letter subcontract.

3. Invoicing. Payments shall be made promptly to the Subcontractor when requested as work progresses but (except for small business concerns) not more often than every two weeks, in amounts approved by the Subcontract Administrator. The Subcontractor may submit to an authorized representative of the Subcontract Administrator, in such form and reasonable detail as the representative may require, an invoice in an **ORIGINAL AND ONE (1) COPY**, supported by a statement of the claimed allowable cost incurred by the Subcontractor in the performance of this letter subcontract. Invoices shall be submitted to:

   National Renewable Energy Laboratory
   Attn: Ms. Carolyn Lopez, Contracts Associate
   MS 2713, 1617 Cole Blvd.
   Golden, CO 80401-3393

   Each invoice shall indicate the current and cumulative costs incurred broken down by cost categories (cost elements). The cost category for lower-tier subcontracts shall indicate the total costs incurred for each lower-tier subcontract.

   An authorized official of the Subcontractor shall sign the following certification on each invoice submitted for payment:

"I certify that this invoice is correct and proper for payment, and reimbursement for these costs has not and will not be received under any other Government contract or subcontract or other source of Government funds.

_____ _____

Authorized Official Date"

4. Allowable Costs. For the purpose of determining allowable costs, the term "costs" includes:

   a. Those recorded costs that result, at the time of the request for reimbursement, from payment by cash, check, or other form of actual payment for items or services purchased directly for the subcontract;

   b. When the Subcontractor is not delinquent in payment of costs of letter subcontract performance in the ordinary course of business, costs incurred, but not necessarily paid, for:

      (1) Materials issued from the Subcontractor's stores inventory and placed in the production process for use on the subcontract;

      (2) Direct labor;

      (3) Direct travel;

      (4) Other direct in-house costs; and

      (5) Properly allocable and allowable indirect costs as shown on the records maintained by the Subcontractor for purposes of obtaining reimbursement under Government contracts or subcontracts; and

   c. The amount of progress payments that have been paid to the Subcontractor's lower-tier subcontractors under similar cost standards.

5. Audit. At any time before final payment, the Subcontract Administrator may have the Subcontractor's invoices and statements of costs audited. Any payment may be (a) reduced by any amounts found by the Subcontract Administrator not to constitute allowable costs, or (b) adjusted for overpayments or underpayments made on preceding invoices.

6. Waiver of Facilities Capital Cost of Money. The Subcontractor did not include facilities capital cost of money as a proposed cost of this letter subcontract. Therefore, it is an unallowable cost under this letter subcontract.

E. Indirect Rates

1. In accordance with the clause entitled "Allowable Costs", the following rates shall be applied as ceiling rates to the allowable costs for the recovery of indirect costs against this letter subcontract

if upon completion, finalization and negotiation of the actual indirect rates for the appropriate periods covered by this letter subcontract, the actual indirect rates exceed the following ceiling rates:

Category	Letter Subcontract Period Covered	Rate	Base
Labor Overhead	10/01/01 through 12/31/02	25%	Direct Labor
G&A	10/01/01 through 12/31/02	30%	Total Costs minus equipment

2. The Subcontractor is cautioned that NREL shall not be obligated to reimburse the Subcontractor for indirect or direct costs incurred in excess of the allotted amount set forth above. This shall also apply to overruns created by an indirect rate fluctuation that the Subcontractor, as a prudent businessperson, should have been aware of, and should have informed NREL of, at the time.

F. Date of Incurrence of Cost

The Subcontractor shall be entitled to reimbursement for costs incurred in a total amount not to exceed $800,000.00 ($400,000.00 NREL cost share and $400,000.00 subcontractor cost share) on or after October 1, 2001 which, if incurred after this subcontract has been entered into, would have been reimbursable under the provisions of this subcontract.

G. Subcontractor Acquired Property and Title

Unless otherwise specified herein, all material, supplies, and equipment shall be procured with funds allocated as the Subcontractor's Cost Share participation. Therefore, title to such materials, supplies, and equipment shall remain with the Subcontractor. The retention of title to such materials, supplies, and equipment with the Subcontractor shall be subject to the conditions below.

A. The Subcontractor shall not charge depreciation, amortization, or use charges for the equipment, supplies, or materials under any other Federal Government contract, subcontract, cooperative agreement, or grant either currently or in the future.

B. Said equipment, supplies, or materials shall be used for the benefit of research and development under this subcontract and any extension hereto.

H. Order of Precedence

Any inconsistency in this letter subcontract, shall be resolved by giving precedence in the following order:

1. This Letter Subcontract Schedule;

2. Statement of Work (Appendix A);

3. Standard Terms and Conditions (Appendix B-1);

4. Intellectual Property Provisions (Appendix C-2);

5. Clauses for Subcontracts in Excess of $500,000 (Appendix D-1);

6. Other provisions of this letter subcontract whether incorporated by reference or otherwise; and,

7. The Subcontractor's technical proposal, if incorporated in this letter subcontract by reference or otherwise.

I. Letter Subcontract Administration Responsibilities

1. Signature Authority: This subcontract may only be modified by a formal modification signed by an authorized official of NREL.

2. Subcontract Administration Responsibilities: The authorized official of NREL has designated Christie Johnson, as the Subcontract Administrator for this subcontract with the responsibilities for subcontract administration and negotiation of any modifications to this subcontract. The Subcontract Administrator's telephone number is (303) 384-7394.

3. Technical Monitoring Responsibilities: The authorized official of NREL has designated Dave Mooney, as the Technical Monitor for this subcontract with the responsibilities of monitoring the technical work or services to be performed under this subcontract. The Technical Monitor does not have the authority to make any commitments or authorize any changes which may affect the subcontract's cost, scope of work, terms, or conditions. Any such changes shall be referred to the Subcontract Administrator designated in Paragraph B above. The Technical Monitor's telephone number is (303) 384-6782.

J. Key Personnel

1. It having been determined that the individuals, whose names appear below, are necessary for the successful performance of this subcontract, the Subcontractor agrees to assign or have assigned such individuals to the performance of the work under this subcontract and shall not reassign or remove any of them without the consent of the Subcontract Administrator by modification to this subcontract:

Name	Project Title	Telephone No.
Dr. Jack Hanoka	Principal Investigator	(508) 357-2221
Rich Chleboski	Vice President	(508) 357-2221

2. Whenever, for any reason, one or more of the designated key personnel designated above, is unavailable for assignment for work under this subcontract, the Subcontractor shall, with the approval of the Subcontract Administrator, replace such individual with an individual of substantially equal abilities and qualifications.

K. Rights to Proposal Data

Except for technical data contained on the pages (none) of the subcontractor's proposal dated 10/09/00, which are asserted by the Subcontractor as being proprietary data, it is agreed that, as a condition of the award of this subcontract, and notwithstanding the provisions of any notice appearing on the proposal, the Government and NREL shall have the right to use, duplicate, disclose and have others do so for any purpose whatsoever, the technical data contained in the proposal upon which this subcontract is based.

IN WITNESS WHEREOF, the parties hereto have executed this letter subcontract effective as of the date executed by NREL below.

Sincerely,

Christie Johnson
Sr. Subcontract Administrator

ACCEPTED: EVERGREEN SOLAR, INC.	AUTHORIZED: MIDWEST RESEARCH INSTITUTE NATIONAL RENEWABLE ENERGY LABORATORY DIVISION
BY: Richard McCullough	BY: Daniel J Lomell
TITLE: Vice President	TITLE: Director, Contracts & Business Services
DATE: 09/27/02	DATE: 09/27/02

Appendix A

Statement of Work for Evergreen Solar, Inc.

Innovative Approaches to Low Cost Module Manufacturing of String Ribbon Si PV Modules

ZDO-2-30628-09

September 18, 2002

1.0 BACKGROUND

The U.S. Department of Energy (DOE), in cooperation with the U.S. Photovoltaics (PV) Industry, has the objective of retaining and enhancing U.S. leadership in the world market. To further this objective, the Photovoltaic Manufacturing Technology (PVMaT) project was initiated in FY 1990 to form a partnership between DOE and the U.S. PV industry, assisting in the improvement of module manufacturing processes and in the substantial reduction of module manufacturing cost. The goals of the project were to improve PV manufacturing processes and products for terrestrial applications, accelerate PV manufacturing cost reduction, lay the foundation for significantly increased production capacity, and assist the U.S. industry in retaining and enhancing its world leadership role in the commercial development and manufacture of terrestrial PV systems. The focus of the program emphasized research and development (R&D) manufacturing process issues.

Four solicitations have been completed since inception of the PVMaT Project and a fifth solicitation is near completion. These solicitations addressed, respectively: (1) process-specific R&D on PV module manufacturing (open only to companies that completed successfully a preliminary problem-definition phase; (2) generic research on problems of interest to all, or to a large portion of the PV industry; (3) process-specific R&D on PV module manufacturing; (4) product-driven PV manufacturing R&D addressing process-specific problems, as well as manufacturing improvements for balance-of-systems (BOS) components and system design improvements; and (5) PV module manufacturing technology and PV system and component technology.

The FY2000 solicitation, "PV Manufacturing R&D — In-Line Diagnostics and Intelligent Processing in Manufacturing Scale-Up," was a continuation of the PV Manufacturing R&D Project that focused on further accelerating the PVMaT achievements and was designed to be impartial to various PV technologies and manufacturing approaches. The goals are to improve PV manufacturing processes and products while reducing costs and providing a technology foundation that supports significant manufacturing scale-up (100-MW level). Letters of Interest under this solicitation were to address areas of work that could include, but were not be limited to, issues such as improvement of module manufacturing processes; system and system component packaging, system integration, manufacturing and assembly; product manufacturing flexibility; and balance-of-system development including storage and quality control. The primary emphasis was on new and improved in-line diagnostics and monitoring with real-time feedback for optimal process control and increased yield in the fabrication of PV modules, systems, and other system components.

During this subcontract, Evergreen Solar, Inc. (hereafter referred to as "Evergreen" in this document) will address the goals of improved PV manufacturing processes and products while reducing costs and providing a technology foundation that supports significant manufacturing scale-up. To accomplish these goals, EVERGREEN will focus their efforts on their second-generation technology. These advances would be: further cost reduction in the production of wafers by the String Ribbon technique; high efficiency wrap-around contact solar cells; development and deployment of the manufacturing technology to make frameless modules based on polymers developed in Evergreen Solar's first PVMaT contract (1995 – 1997); and the culmination of all these developments- monolithic modules. These developments will be accompanied with extensive use of manufacturing science techniques especially in the areas of diagnostics and statistical process control. EVERGREEN will also work toward PVMaT goals by developing quality assurance and ES&H programs in keeping with local, State, and Federal regulations as applicable.

2.0 OBJECTIVE

The objective of this subcontract over its three-phase duration is to continue the development of EVERGREEN's String Ribbon Si PV technology resulting in an advanced generation of crystalline silicon PV module manufacturing technology applied to a virtually continuous fully integrated manufacturing line. The final goal of this line will be the production of frameless modules using wrap-around contacts on String Ribbon solar cells and made in a monolithic module configuration. Specific objectives include methods for improving surface and bulk quality of as-grown ribbon, techniques for wrap-around solar cell efficiency improvement, extensive reliability testing under accelerated conditions, developing low cost manufacturing to make frameless modules in general and monolithic modules in particular, and in line diagnostics throughout the production line. To further the high efficiency work, close interaction with Prof. Rohatgi's group at Georgia Tech will be pursued.

3.0 SCOPE OF WORK

The subcontract shall consist of three phases and will be incrementally funded. EVERGREEN shall complete the investigations described in the following tasks and provide a detailed summary of this work in its reports and deliverables.

PHASE I

During Phase I, EVERGREEN shall perform R&D needed to affect improvements in ribbon growth and cell and module manufacture. These efforts shall address the scale-up of a previously developed laboratory scale technique to a production worthy doping method, growth of surface oxide free ribbon, improved starting lifetime of as-grown string ribbon, 12% efficient wrap-around cells, and device improvements on wrap-around cells. EVERGREEN shall design and develop a prototype machine to apply wrap-around decals. They shall develop necessary in-line diagnostics to support crystal growth. Evergreen shall also perform work leading to backskin materials cost reduction and develop and use methods for accelerated testing of monolithic modules to demonstrate desired stability. For all of these efforts Evergreen shall develop the quality assurance and ES&H programs required in keeping with local, state, and federal regulations as applicable. EVERGREEN shall report all progress from this Phase I task-oriented research through reporting requirements detailed in Sections 4, 5, and 6.

3.1 Task 1 Scale-Up Of A Production Worthy Doping Method

EVERGREEN shall scale-up the laboratory scale technique already developed to a scale suitable for manufacturing feedstock silicon using liquid spin-on dopants. To accomplish this task, Evergreen shall demonstrate a mixing method with satisfactory uniformity, develop a suitable solvent drying procedure and develop equipment which will not contaminate the feedstock silicon. This task is expected to result in a production worthy doping method and apparatus that produces satisfactory ribbon growth and cell efficiencies.

3.2 Task 2 Growth Of Surface Oxide Free Ribbon-1

EVERGREEN shall find a simple optical method to detect surface oxide on Si ribbon as it grows and develop an easily implementable method that provides data needed for in-situ correction. To accomplish this task, Evergreen shall develop a detailed characterization of surface oxide layers and develop a simple method for optical detection. This task is expected to result in the development of an optical method for collecting data needed to implement real-time corrective action during crystal growth (see task 11 in Phase II) that can eliminate all etch steps between growth and diffusion for Si ribbon.

3.3 Task 3 Improve Starting Lifetime Of As-Grown String Ribbon -1

EVERGREEN shall improve the starting lifetime of as-grown string ribbon through better purification of hot zone component materials to reduce transition metals and the development of coatings that are more impermeable for hot zone components. DLTS shall be used to verify the lifetime improvements. To accomplish this task, Evergreen shall investigate coatings to reduce permeability, investigate improved purification methods for graphite parts, investigate new configurations in hot zone parts, perform in-house lifetime measurements, obtain DLTS results through university contacts, and obtain string ribbon characterization through interaction with Georgia Tech. This task is expected to result in improvement in starting lifetime through reduced transition metals in string ribbon.

3.4 Task 4 12% Efficient Wrap-around Cell

EVERGREEN shall improve cell-processing leading to a 12% efficient wrap-around cell. Evergreen will achieve the efficiency gains in this task by both improvements in starting lifetime (Task 3) and advances in cell processing, especially plasma nitride passivation and firing through contacts. To accomplish this task, Evergreen shall perform cell processing of higher lifetime material, optimization of plasma nitride processes, and optimization of metallization firing processes. This task is expected to result in 12% wrap-around cells.

3.5 Task 5 Improve Devices Through Lowered Series Resistance And Increased Shunt Resistance

EVERGREEN shall develop techniques to improve their wrap-around cell by achieving lowered series resistance through changes in finger cross section and increased shunt resistance through materials science studies on pastes and dielectric layers. To accomplish this task, Evergreen will develop methods to improve finger cross section, perform Ag paste studies to improve wrap around ribbon edge, investigate appropriate dielectric layers, and develop methods for reduction of edge leakage. This task is expected to result in improved fill factors for 120 sq. cm. wrap-around contact cells

3.6 Task 6 Design And Develop A Prototype Machine To Apply Wrap-around Decals

EVERGREEN shall develop a concept and prototype machine for applying wrap-around solar cells that will lead higher manufacturing line volume and yield. To accomplish this task, Evergreen shall develop a concept for prototype machine, design a prototype machine, develop the prototype machine, and test the prototype machine. This task is expected to result in the testing of a prototype decal application machine that will be the basis for development of a high volume production machine.

3.7 Task 7 In-Line Diagnostics-1

EVERGREEN shall develop a central database for in-line diagnostics in the crystal growth area to automatically generate SPC charts using the software package called RS View 32. To accomplish this task, Evergreen shall develop a data network for all new crystal growth machines, add bulk resistivity and laser cutter data to the network, and develop real time process monitoring using SPC charts. This task is expected to result in improved process control in the crystal growth area.

3.8 Task 8 Backskin Materials Cost Reduction

EVERGREEN shall develop processes to reduce cost of the backskin material by formulating thinner sheets of this material and then apply appropriate qualification tests, as well as in house accelerated tests, to the thinner sheets. To accomplish this task, Evergreen shall formulate thinner backskin, cross-link thinner backskin sheets, conduct qualification tests with thinner material, and perform in-house accelerated testing This task is expected to result in the development of a process to reduced backskin cost.

3.9 Task 9 Accelerated Testing Of Monolithic Modules

EVERGREEN shall study appropriate inks and printing properties and perform accelerated testing to establish the long term stability of the electrical bonds for material used in adhesive and conducting bars. To accomplish this task, Evergreen shall study

various conductive inks, establish suitable printing properties for conductive material, and conduct accelerated testing of conductive material contacts. This task is expected to result in the development of practical printing method for the conductive material chosen, the demonstration of long term stability for contacts, and the demonstration of long term viability by the monolithic module.

PHASE II

During Phase II, EVERGREEN shall continue to perform R&D needed to affect improvements in ribbon growth and cell and module manufacture. Evergreen's Phase II efforts shall address further improvement in the starting lifetime of as-grown string ribbon, continued work on growth of surface oxide free ribbon, continued improvements on wrap-around cells leading to 13% efficiency, the design, development, and initial testing of a machine to apply wrap-around decals, development of a continuous lamination process, design and development of manufacturing processes and equipment to make frameless modules, development of a manufacturing process to make monolithic modules, and the design of a robotic pick and place machine. In addition, Evergreen shall continue improving their in-line diagnostics capability through completion of the design for automating the collection and analysis of bulk resistivity measurements and the monitoring of module making machines. For all of these efforts Evergreen shall develop the quality assurance and ES&H programs required in keeping with local, state, and federal regulations as applicable. Evergreen shall report all progress from this Phase II task-oriented research through reporting requirements detailed in sections 4, 5, and 6.

3.10 Task 10 Improve Starting Lifetime Of As-Grown String Ribbon -2

EVERGREEN shall continue to improve the starting lifetime of as-grown string ribbon through better control of thermal and mechanical perturbations to minimize dislocation formation. To accomplish this task, Evergreen shall make use of vibration control and more uniform thermal environment to obtain lower dislocation content. Evergreen shall redesign their crystal growth hot zone to improve the thermal uniformity, design and develop techniques for vibration damping during growth, and perform dislocation density mapping to guide other efforts in this task. This task is expected to result in higher starting lifetimes through reduced dislocation density.

3.11 Task 11 Growth Of Surface Oxide Free Ribbon-2

EVERGREEN shall develop a better understanding of oxygen ingress from the exit slits and convection in the region around the hot zone through a better understanding of convection in the hot zone. In addition, Evergreen shall design new techniques to utilize the improved understanding of oxygen ingress and reduce the oxygen available that creates undesired oxide on newly grown ribbon. To accomplish this task, Evergreen shall redesign their Ar introduction techniques and develop methods to

reduce convection in the hot zone region. This task is expected to result in oxide free ribbon and eliminate all etch steps between growth and diffusion for Si ribbon.

3.12 Task 12 13 % Wrap-around Cells

EVERGREEN shall improve efficiency through optimized nitride passivation for both front and rear surfaces and development of a method to form a good back contact. To accomplish this task, Evergreen shall develop, deploy, and test a boat for double sided passivation and develop and test Al paste that can fire through nitride. This task is expected to result in 13 % wrap-around cells.

3.13 Task 13 Design, Develop, and Test a Production-worthy Machine to Apply Wrap-around Decals

EVERGREEN shall design, develop, and test a machine to apply wrap-around decals for high volume production rates on the order of 1000 cells/hr. The design shall make use of an Allen Bradley PLC that will feed process data into a central computer. This task is expected to result in the development of a production-worthy machine that automates the application of wrap-around decals.

3.14 Task 14 Continuous Lamination Process

EVERGREEN shall develop a continuous, non-vacuum lamination process that eliminates cell cracking and which is suitable for high volume production. To accomplish this task, Evergreen shall find process conditions (such as roller temperature, pre heat temperature, speed, and roller pressure) whereby cell cracking is eliminated. Evergreen shall then develop suitable process conditions for high volume manufacturing. This task is expected to result in a high volume, continuous non-vacuum lamination process.

3.15 Task 15 Develop a Manufacturing Process to Make Frameless Modules

EVERGREEN shall develop a low-cost, manufacturable technique to make frameless modules though close interaction with vendors and manufacturing personnel. To accomplish this task, Evergreen shall study alternative methods to modify their backskin for higher impermeability and study alternative methods to form a backskin edge. This task is expected to result in the development of a viable manufacturing process for frameless modules.

3.16 Task 16 Design Manufacturing Equipment to Make Frameless Modules

EVERGREEN shall design, develop and test low-capital cost equipment for high volume manufacturing of frameless modules. To accomplish this task, Evergreen shall design a suitable backskin modification machine for improved impermeability backskin, test the

backskin modification machine for output with improved impermeability, design a machine to form sealed leads from the module, and test the machine to form the sealed leads. This task is expected to result in the design, development and testing of a backskin modification machine and design, development, and testing of a machine to form sealed electrical leads from the module.

3.17 Task 17 Develop a Manufacturing Process to Make Monolithic Modules

EVERGREEN shall develop a cost-effective, manufacturing method to control backskin shrinkage. To accomplish this task, Evergreen shall explore possible methods to control shrinkage, identify and select a promising method, and develop and test this method for adequacy in a manufacturing process. This task is expected to result in a method to control backskin shrinkage suitable for manufacturing.

3.18 Task 18 Design a Robotic Pick and Place Machine

EVERGREEN shall design a robotic pick and place machine that can accurately position a wrap-around cell on the printed backskin. To accomplish this task, Evergreen shall identify a robot with desired properties and design a machine with that robot to perform the required pick and place activities needed to position the cell on the backskin. This task is expected to result in a pick and place machine with positional accuracy of plus or minus 0.005".

3.19 Task 19 In-Line Diagnostics-2

EVERGREEN shall develop the necessary processes and equipment to incorporate bulk resistivity measurement into the automatic laser cutting station. Such equipment to perform the measurements, done manually during the Phase I, shall be designed to automatically perform the required measurements on the as grown wafers. In the module area, processes and equipment necessary to incorporate RSView into the machine designs shall also be developed and tested. This task is expected to result in in-line diagnostics for bulk resistivity measurement and automated monitoring of module making machines.

PHASE III

During Phase III, EVERGREEN shall continue to perform R&D needed to affect improvements in ribbon growth and cell and module manufacture. Evergreen's Phase III efforts shall address the demonstration of improved starting lifetime of as-grown string ribbon from a production-capable system, continued improvements on wrap-around cells leading to 14% efficiency, continued testing and fine tuning to demonstrate manufacturing line worthiness for a decal application machine. Evergreen shall also design and develop an improved small high voltage module, debug, test, and fine-tune

module manufacturing equipment used for frameless, monolithic modules, debug, test, and fine-tune a robotic pick and place machine for automated monolithic module layout, and continue improved automation of their manufacturing line with design, development, and testing of a network for collection of all data at a central point for advanced in-line diagnostics. And finally Evergreen shall demonstrate their state of the art manufacturing capability to make monolithic modules. EVERGREEN shall report all progress from this Phase III task-oriented research through reporting requirements detailed in Sections 4, 5, and 6.

3.20 Task 20 Demonstrate Improved Starting Lifetime On Production-Capable System

EVERGREEN shall demonstrate the results of the work on impurity reduction (Task 3) and dislocation reduction (Task 10) on a production crystal growth system so as to produce a higher average and tighter distribution of starting lifetime. Presently the lifetimes vary from <1 to >10 microseconds. The goal here will to eliminate the lower end of the distribution. This task is expected to result in starting lifetimes of 5 to >10 microseconds.

3.21 Task 21 14% Efficient Wrap-around Contact Cells

EVERGREEN shall combine advances made in Tasks 12 and 20 to routinely make 14% cells. To accomplish this task, Evergreen shall make cells utilizing the advances developed during Phase II to produce cells on production-worthy equipment developed for performing tasks 12 and 20. This task is expected to result in 14% wrap-around contact cells.

3.22 Task 22 Fine-Tune And Test Wrap-around Decal Application Machine

EVERGREEN shall demonstrate, fine-tune, and test a production worthy wrap-around decal application machine with a goal of achieving throughput of 1000 cells/hr at > 95% yield. To accomplish this task, Evergreen shall execute an iterative process of fine-tuning and testing their wrap-around decal application machine at high volume. This task is expected to result in a complete debugging of their wrap-around decal application machine and a demonstration of production-worthiness.

3.23 Task 23 Design And Develop An Improved Small, High Voltage Module

EVERGREEN shall design and develop a high voltage small monolithic module suitable for automated production. To accomplish this task, Evergreen shall demonstrate the viability of laser cutting large wrap-around cells into smaller wrap-around cells, demonstrate adequate reliability for these smaller cells, and show automation capability for finishing the small high-voltage module. This task is expected to result in the demonstration of a manufacturing process capable of producing a high voltage, small module product.

3.24 Task 24 Debug And Test Module Manufacturing Equipment Used To Produce Frameless, Monolithic Modules

EVERGREEN shall develop, debug, and test production size module manufacturing equipment used to produce frameless, monolithic modules. Evergreen shall demonstrate production worthy speed (time to form a completed module) and quality with a yield of 99%. This task is expected to result in demonstration of speed, quality, and yield for the processes and equipment developed in Tasks 15, 16, and 17.

3.25 Task 25 Develop, Debug, And Test Robotic Pick And Place Machine

EVERGREEN shall develop, debug, and test the robotic pick and place machine designed in task 18. Evergreen shall demonstrate positional accuracy estimated to be plus or minus 0.005" or as determined from additional tests with actual equipment. This task is expected to result in a robotic pick and place machine satisfying manufacturing requirements

3.26 Task 26 In Line Diagnostics-3

EVERGREEN shall continue improved automation of their manufacturing line with design, development, and testing of a network for collection of all data at a central point for advanced in-line diagnostics. To accomplish this task, Evergreen shall bring together the inputs from RSView on all the machines used to make frameless and monolithic modules and integrate these inputs into a real-time response system for machine control. This task is expected to result in in-line diagnostics for real time control for frameless and monolithic module manufacturing.

3.27 Task 27 Demonstrate State Of The Art Si Ribbon Manufacturing Capability To Make Monolithic Modules

EVERGREEN shall demonstrate the automated production of monolithic modules through the delivery of test results from the manufacturing line based on process improvements developed in the subcontract. The test shall be an actual run and the goal shall be a 99% yield from a run of 100 consecutive modules. This task is expected to result in a demonstration of the production of a frameless, monolithic module produced from highly automated, cost-effective high yield string ribbon Si manufacturing equipment and provide NREL data to characterize the improvements made by Evergreen under this subcontract.

4.0 PROGRAM PLAN

The subcontracted research shall be conducted at EVERGREEN. The research shall be carried out according to the Task Schedule outlined below. All Milestones, Deliverables, and Reporting Requirements shall be met by EVERGREEN according to the schedules detailed in the appropriate sections that follow.

4.1 TASK SCHEDULE

Task Schedules are broken down into separate Phase I, Phase II, and Phase III efforts to correspond to the three phases of the subcontract. EVERGREEN shall perform these tasks according to the following phased schedules:

PHASE I

EVERGREEN shall perform and complete Tasks 1 through 9 during Phase I of this subcontract according to the following schedule:

Months	S	O	N	D	J	F	M	A	M
Task 1	X	X	X	X	X				
Task 2	X	X	X	X					
Task 3	X	X	X	X	X	X	∇		
Task 4									
Task 5	X	X	X	X	X	X	∇		
Task 6	X	X	X	X	X	X			
Task 7	X	X	X	X	X	X	∇		
Task 8	X	X	X	X	X	X	∇		
Task 9	X	X	X	X	X	X	∇		
Monthly Reports		15th	15th	15th	15th	15th	15th		
Annual Report							draft 15th		Final 30th

PHASE II

EVERGREEN shall perform and complete Tasks 10 through 19 during Phase II of this subcontract according to the following schedule:

Months	A	M	J	J	A	S	O	N	D	J	F	M	A	M
Task 10	X	X	X	X	X	X	X	X	X	X	X	▽		
Task 11	X	X	X	X	X	X								
Task 12						X	X	X	X	X	X	▽		
Task 13	X	X	X	X	X	X	X	X	X	X	X	▽		
Task 14			X	X	X	X	X	X	X					
Task 15			X	X	X	X	X	X	X	X	X			
Task 16					X	X	X	X	X	X	X	▽		
Task 17						X	X	X	X	X	X			
Task 18				X	X	X	X	X	X					
Task 19							X	X	X	X	X	▽		
Monthly Reports	15th	15th	15th	15th	15th	15th	15th	15th	15th	15th	15th	15th		
Annual Report												draft 15th		final 30th

Phase III

EVERGREEN shall perform and complete Tasks 20 through 27 during Phase III of this subcontract according to the following schedule:

Months	A	M	J	J	A	S	O	N	D	J	F	M	A	M
Task 20							X	X	X	X	X	▽		
Task 21										X	X	▽		
Task 22	X	X	X	X	X	X	X	X	X	X	X	▽		
Task 23			X	X	X	X	X	X						
Task 24			X	X	X	X	X	X	X	X	X	▽		
Task 25	X	X	X	X	X	X								
Task 26									X	X	X	▽		
Task 27									X	X	X	▽		
Monthly Reports		15th	15th	15th	15th	15th	15th	15th	15th	15th	15th	15th		
Annual Report												draft 15th		Final 30th

4.2 MILESTONES

Milestones are broken down into Phase I, Phase II, and Phase III milestones to correspond to the three phases of the subcontract. EVERGREEN shall perform tasks 1 through 27 in order to meet milestones and deliverables according to the below schedule. Although Milestones are shown as due by the end of three month periods, Evergreen shall regularly report on Milestone progress in its Monthly Reports due on the 15th of each month.

PHASE I

Milestones due no later than October 31, 2002

m-1.1.1	Demonstrate process steps for uniform mixing of dopant	(Task 1)
m-1.1.2	Grow ribbon with doped feedstock using demonstrated mixing procedure	(Task 1)
m-1.1.3	Demonstrate a suitable solvent drying procedure	(Task 1)
m-1.1.4	Show suitable transport in feeder	(Task 1)
m-1.1.5	Complete chemical and optical characterization of surface oxide	(Task 2)
m-1.1.6	Demonstrate feasibility of a simple optical method for oxide determination	(Task 2)
m-1.1.7	Concept for prototype decal application machine completed	(Task 6)
m-1.1.8	Design for prototype machine completed	(Task 6)
m-1.1.9	Thinner backskin sheets formulated	(Task 8)

Milestones due no later than October 31, 2002

m-1.2.1	Install mixing equipment	(Task 1)
m-1.2.2	Grow ribbon using feedstock mixed in new equipment	(Task 1)
m-1.2.3	Show no negative impact on efficiency from new doping process	(Task 1)
m-1.2.4	Identify contact cross section changes for screen printing	(Task 5)
m-1.2.5	Decision on whether or not to study alternative printing method	(Task 5)
m-1.2.6	Dielectric layers selected	(Task 5)
m-1.2.7	Prototype machine developed and tested	(Task 6)
m-1.2.8	Demonstrate cross-linked thinner backskin sheets	(Task 8)
m-1.2.9	Choose conductive ink for printing onto backskin	(Task 9)
m-1.2.10	Demonstrate ease of printing of conductive material	(Task 9)

Milestones due no later than January 31, 2003

m-1.3.1	Demonstrate coating with reduced permeability	(Task 3)
m-1.3.2	Network for all new crystal growth machines established	(Task 7)
m-1.3.3	Bulk resistivity and laser cutting data connected to the network	(Task 7)
m-1.3.4	Initiate qualification tests	(Task 8)
m-1.3.5	Initiate in-house accelerated testing	(Task 8)
m-1.3.6	Demonstrate adequate performance under thermal cycling	(Task 9)
m-1.3.7	Demonstrate adequate performance under humidity freeze	(Task 9)

Milestones due no later than, March 31, 2003

m-1.4.1	Test graphite parts for improved purification	(Task 3)
m-1.4.2	Test novel hot zone parts' configurations	(Task 3)
m-1.4.3	Demonstrate lifetime gains from M-1.3.1-M-1.3.3	(Task 3)
m-1.4.4	Verify M-1.3.4 with DLTS	(Task 3)
m-1.4.5	R and D cells from Ga. Tech with efficiency > 15.5%	(Task 3)
m-1.4.6	Optimize plasma nitride process	(Task 4)
m-1.4.7	Optimize metallization firing process	(Task 4)
m-1.4.8	Demonstrate fabrication of 120 sq. cm., 12% wrap-around cells	(Task 4)
m-1.4.9	Demonstrate reduced series resistance	(Task 5)
m-1.4.10	Demonstrate increased shunt resistance	(Task 5)
m-1.4.11	Demonstrate process monitoring using SPC charts	(Task 7)
m-1.4.12	Complete accelerated testing	(Task 8)
m-1.4.13	Complete accelerated tests	(Task 9)

PHASE II

Milestones due no later than June 30, 2003

m-2.1.1	Demonstrate reduced oxygen in hot zone	(Task 11)
m-2.1.2	Design for alternate method to introduce Ar into the hot zone	(Task 11)
m-2.1.3	Production-worthy decal application machine designed	(Task 13)
m-2.1.4	Establish parameters for glass/encapsulant lamination	(Task 14)
m-2.1.5	Identify method to modify backskin for higher impermeability	(Task 15)

Milestones due no later than September 30, 2003

m-2.2.1	Establish hot zone redesign	(Task 10)
m-2.2.2	Demonstrate growth of oxide free ribbon	(Task 11)
m-2.2.3	Establish parameters for cell/backskin lamination	(Task 14)
m-2.2.4	Develop method to modify backskin	(Task 15)
m-2.2.5	Complete design of backskin modification machine	(Task 16)
m-2.2.6	Complete identification of pick and place robot	(Task 18)

Milestones due no later than December 31, 2003

m-2.3.1	Complete design and implementation of vibration damping	(Task 10)
m-2.3.2	Complete design and deployment of boat for double sided passivation	(Task 12)
m-2.3.3	Demonstrate adequate firing through of Al paste	(Task 12)
m-2.3.4	Decal application machine developed and tested	(Task 13)
m-2.3.5	Establish process for full module lamination	(Task 14)
m-2.3.6	Identify method to form backskin edge	(Task 15)
m-2.3.7	Complete development of backskin modification machine	(Task 16)
m-2.3.8	Decision on monolithic module manufacturing method	(Task 17)
m-2.3.9	Complete design of pick and place machine	(Task 18)
m-2.3.10	Complete design for automatic bulk resistivity measurement	(Task 19)

Milestones due no later than March 31, 2004

m-2.4.1	Complete dislocation maps	(Task 10)
m-2.4.2	Demonstrate fabrication of 13% cells	(Task 12)
m-2.4.3	Establish data processing for decal application machine	(Task 13)
m-2.4.4	Develop method to form backskin edge	(Task 15)
m-2.4.5	Complete design of machine to form sealed leads	(Task 16)
m-2.4.6	Complete development of machine to form sealed leads	(Task 16)
m-2.4.7	Complete development of monolithic module manufacturing method	(Task 17)
m-2.4.8	Complete development of automatic bulk resistivity measurement	(Task 19)
m-2.4.9	Complete incorporation of RS View in module machine designs	(Task 19)

PHASE III

Milestones due no later than June 30, 2004

m-3.1.1	Complete debug of robotic pick and place machine	(Task 25)

Milestones due no later than September 30, 2004

m-3.2.1	Complete debug of wrap-around decal application machine	(Task 22)
m-3.2.2	Demonstrate viability of laser cutting small cells from large cells	(Task 23)
m-3.2.3	Complete running of robotic pick and place machine	(Task 25)
m-3.2.4	Complete demonstration of positional accuracy and repeatability	(Task 25)

Milestones due no later than December 31, 2004

m-3.3.1	Demonstrate impurity reduction on production machine	(Task 20)
m-3.3.2	Demonstrate dislocation reduction on production machine	(Task 20)
m-3.3.3	Complete reliability studies on high-voltage small modules	(Task 23)
m-3.3.4	Complete automation for high-voltage small modules	(Task 23)
m-3.3.5	Complete speed and quality demonstration for manufacture of frameless, monolithic module	(Task 24)

Milestones due no later than March 31, 2005

m-3.4.1	Demonstrate starting lifetimes of 5 to >10 microseconds	(Task 20)
m-3.4.2	Advances made in Tasks 12 and 20 brought together	(Task 21)
m-3.4.3	Demonstrate 14% wrap-around contact cells	(Task 21)
m-3.4.4	Complete testing of wrap-around decal application machine	(Task 22)
m-3.4.5	Complete yield demonstration for manufacture of frameless, monolithic module	(Task 24)
m-3.4.6	Complete development of RS View on all automated machines for modules	(Task 26)
m-3.4.7	Complete integration of all inputs into a central collection point	(Task 26)
m-3.4.8	Complete demonstration of manufacturing capability	(Task 27)
m-3.4.9	Demonstrate capability to make 100 modules at a yield 99%	(Task 27)

5.0 DELIVERABLES/REPORTING REQUIREMENTS

EVERGREEN shall prepare and submit reports and deliverables in accordance with the following Sections. EVERGREEN shall also supply NREL with samples of EVERGREEN cells and modules for collaborative and analytical efforts with NREL as directed by the technical monitor. In addition, EVERGREEN shall supply, according to the schedule indicated, the following representative samples of the current best device/material design and fabrication procedures:

5.1 DELIVERABLES

The Deliverables under this subcontract are divided into Phase I, Phase II, and Phase III deliverables to correspond to the three phases of the subcontract. EVERGREEN shall provide deliverables according to the following schedule:

PHASE I

No.	Deliverable Description	Quantity	Due Date
D-1.1.1	Report on results for scaling up process for uniform mixing of dopant. (Task 1)	2	October 31, 2002
D-1.1.2	One sample of 3" wide ribbon grown per M-1.1.2. (Task 1)	1	October 31, 2002
D-1.1.3	Report on a suitable solvent drying procedure. (Task 1)		October 31, 2002
D-1.1.4	Report on suitable transport of doped feedstock in feeder. (Task 1)		October 31, 2002
D-1.1.5	Report on chemical and optical characterization of surface oxide. (Task 2)		October 31, 2002
D-1.1.6	Report on feasibility of a simple optical method for oxide determination. (Task 2)		October 31, 2002
D-1.1.7	Ribbon sample grown without any surface oxide. (Task 2)	1	October 31, 2002
D-1.1.8	Report describing concept for prototype decal application machine. (Task 6)		October 31, 2002
D-1.1.9	Report describing design for prototype machine. (Task 6)		October 31, 2002
D-1.1.10	Example of thinner backskin sheets. (Task 8)		October 31, 2002

D-1.2.1	Report on installation of mixing equipment. (Task 1)		October 31, 2002
D-1.2.2	One sample of 3" wide doped ribbon. (Task 1)	1	October 31, 2002
D-1.2.3	Two 12% cells made with feedstock doped with new doping process. (Task 1)	2	October 31, 2002
D-1.2.4	Report on finger cross section through screen-printing. (Task 5)		October 31, 2002
D-1.2.5	Report on decision to study alternative printing methods. (Task 5)		October 31, 2002
D-1.2.6	Report on dielectric layers selected. (Task 5)		October 31, 2002
D-1.2.7	Report on development and testing of prototype machine. (Task 6)		October 31, 2002
D-1.2.8	One cell from prototype machine. (Task 6)	1	October 31, 2002
D-1.2.9	Example of cross-linked thinner backskin . (Task 8)		October 31, 2002
D-1.2.10	Report on ink choice. (Task 9)		October 31, 2002
D-1.2.11	One sample of printed conductive material on backskin. (Task 9)		October 31, 2002
D-1.3.1	Report on coating with reduced permeability. (Task 3)		January 31, 2003
D-1.3.2	Report on establishment of network for new crystal growth machines. (Task 7)		January 31, 2003
D-1.3.3	Report on resistivity and laser cutting data added to the network. (Task 7)		January 31, 2003
D-1.3.4	Report on initiation of in-house accelerated tests and qualification tests. (Task 8)		January 31, 2003
D-1.3.5	One backskin sample. (Task 8)	1	January 31, 2003
D-1.3.6	Report on performance under thermal cycling and humidity freeze. (Task 9)		January 31, 2003
D-1.3.7	Report on completed accelerated tests. (Task 9)		January 31, 2003
D-1.4.1	Report on tests of improved purification graphite parts. (Task 3)		March 31, 2003

D-1.4.2	Report on novel hot zone parts' configurations. (Task 3)		March 31, 2003
D-1.4.3	Report on lifetime gains (and DLTS verification) from M-1.3.1-M-1.3.3. (Task 3)		March 31, 2003
D-1.4.4	One >15% R&D cell. (Task 3)	1	March 31, 2003
D-1.4.5	Report on optimization of plasma nitride process. (Task 4)		March 31, 2003
D-1.4.6	Report on optimization of metallization firing process. (Task 4)		March 31, 2003
D-1.4.7	One 120 sq. cm., 12% wrap-around cell and I-V Data. (Task 4)	1	March 31, 2003
D-1.4.8	Report on reduced series and shunt resistance. (Task 5)		March 31, 2003
D-1.4.9	One cell demonstrating device improvements due to contact improvements. (Task 5)	1	March 31, 2003
D-1.4.10	Report on real time process monitoring using SPC charts. (Task 7)		March 31, 2003
D-1.4.11	One sample of printed conductive material on backskin. (Task 9)	1	March 31, 2003

PHASE II

No.	Deliverable Description	Quantity	Due Date
D-2.1.1	Report on reduced oxygen in hot zone. (Task 11)		June 30, 2003
D-2.1.2	Report on design for alternate method to introduce Ar. (Task 11)		June 30, 2003
D-2.1.3	Report on design of production-worthy decal application machine. (Task 13)		June 30, 2003
D-2.1.4	Report on parameters for glass/encapsulant lamination. (Task 14)		June 30, 2003
D-2.1.5	Report on choice of method to modify backskin. (Task 15)		June 30, 2003
D-2.2.1	Report on hot zone redesign. (Task 10)		September 30, 2003
D-2.2.2	Report on redesign of ambient gas flow pattern. (Task 11)		September 30, 2003

D-2.2.3	One oxide free ribbon sample. (Task 12)	1	September 30, 2003
D-2.2.4	Report on parameters for cell/backskin lamination. (Task 14)		September 30, 2003
D-2.2.5	Report on method to modify backskin. (Task 15)		September 30, 2003
D-2.2.6	Report on design of backskin modification machine. (Task 16)		September 30, 2003
D-2.2.7	Report on identification of pick and place robot. (Task 18)		September 30, 2003
D-2.3.1	Report on design and implementation of vibration damping. (Task 10)		December 31, 2003
D-2.3.2	Report on design and deployment of boat for double sided passivation. (Task 12)		December 31, 2003
D-2.3.3	Report on adequate firing through of Al paste. (Task 12)		December 31, 2003
D-2.3.4	Report on development and testing of decal application machine. (Task 13)		December 31, 2003
D-2.3.5	Report on hot roll lamination process for full module. (Task 14)		December 31, 2003
D-2.3.6	One typical full module produced with hot roll lamination process. (Task 14)	1	December 31, 2003
D-2.3.7	Report on choice of method to form backskin edge. (Task 15)		December 31, 2003
D-2.3.8	Report on development of backskin modification machine. (Task 16)		December 31, 2003
D-2.3.9	Report on design of a machine to form sealed leads. (Task 16)		December 31, 2003
D-2.3.10	Report on decision for monolithic module manufacturing method. (Task 17)		December 31, 2003
D-2.3.11	Report on pick and place machine design. (Task 18)		December 31, 2003
D-2.3.12	Report on design of automatic bulk resistivity measurement. (Task 19)		December 31, 2003
D-2.4.1	Report on improved lifetimes and dislocation maps. (Task 10)		March 31, 2004
D-2.4.2	One 13% wrap-around cell. (Task 12)	1	March 31, 2004

D-2.4.3	One sample from and report on decal application machine with data processing. (Task 13)		March 31, 2004
D-2.4.4	One sample from and report on decal application machine with data processing. (Task 13)	1	March 31, 2004
D-2.4.5	Report on process to make frameless modules. (Task 15)		March 31, 2004
D-2.4.6	Report on manufacturing equipment for frameless modules. (Task 16)		March 31, 2004
D-2.4.7	Report on development of monolithic module manufacturing method for shrinkage control. (Task 17)		March 31, 2004
D-2.4.8	One sample demonstrating monolithic module manufacturing method for shrinkage control. (Task 17)	1	March 31, 2004
D-2.4.9	Report on development of automatic bulk resistivity measurement. (Task 19)		March 31, 2004
D-2.4.10	Report on incorporation of RS View in module machine designs. (Task 19)		March 31, 2004

PHASE III

No.	Deliverable Description	Quantity	Due Date
D-3.1.1	Report on debug of robotic pick and place machine. (Task 25)		June 30, 2004
D-3.2.1	Report on debug of wrap-around decal application machine. (Task 22)		September 30, 2004
D-3.2.2	Small cells cut from larger cell with laser. (Task 23)	6	September 30, 2004
D-3.2.3	Report on running of robotic pick and place machine. (Task 25)		September 30, 2004
D-3.2.4	Report on demonstration of positional accuracy and repeatability. (Task 25)		September 30, 2004
D-3.3.1	Report on impurity reduction on production machine. (Task 20)		December 31, 2004
D-3.3.2	Report on dislocation reduction on production machine. (Task 20)		December 31, 2004

D-3.3.3	Report on reliability of high-voltage small modules. (Task 23)		December 31, 2004
D-3.3.4	Report on completion of automation for high-voltage small modules. (Task 23)		December 31, 2004
D-3.3.4	Two prototype high-voltage small modules. (Task 23)	2	December 31, 2004
D-3.3.5	Report on speed and quality demonstration. (Task 24)		December 31, 2004
D-3.4.1	Report on starting material lifetimes of 5 to >10 microseconds. (Task 20)		March 31, 2005
D-3.4.1	One sample of starting material with lifetimes of 5 to >10 microseconds. (Task 20)	1	March 31, 2005
D-3.4.2	Report on advances made in Tasks 12 and 20 brought together. (Task 21)		March 31, 2005
D-3.4.3	Report on 14% wrap-around contact cells. (Task 21)		March 31, 2005
D-3.4.3	Two typical cells characterizing efforts for 14% wrap-around cells. (Task 21)	2	March 31, 2005
D-3.4.4	Report on testing (yield and throughput) of wrap-around decal application machine. (Task 22)		March 31, 2005
D-3.4.5	Report on yield demonstration. (Task 24)		March 31, 2005
D-3.4.6	Report on development of RS View on all automated machines for modules. (Task 26)		March 31, 2005
D-3.4.7	Report on integration of all inputs into a central collection point. (Task 26)		March 31, 2005
D-3.4.8	Report on demonstration of manufacturing capability. (Task 27)		March 31, 2005
D-3.4.9	Report on module fabrication yield. (Task 27)		March 31, 2005
D-3.4.10	Two monolithic modules typical of 100 module run sent to NREL. (Task 27)	2	March 31, 2005

Deliverables that are not reports shall be sent to the Technical Monitor at the following address:

National Renewable Energy Laboratory
ATTENTION: David Mooney, MS#3214
1617 Cole Boulevard
Golden, Colorado 80401

with a copy of the transmittal letter sent to the Contract Administrator at:

National Renewable Energy Laboratory
ATTENTION: Christie Johnson, MS#2713
1617 Cole Boulevard
Golden, Colorado 80401

Deliverables identified as reports in the above schedule in this section may be delivered as attachments to the Monthly Technical Status Report (MTSR) corresponding to the final month for the quarter in which that report deliverable is due. If an MTSR is not due in the final month of the quarter (as is the case at the end of each phase when an annual or the final report is due), the deliverable reports due at that time shall be delivered one item with separate sections. In any of these cases, each deliverable report shall be clearly identifiable as a distinct section.

5.2 PRESENTATIONS AND PUBLICATIONS

Evergreen Solar, Inc. shall attend NREL Subcontractor Annual Review Meetings to be held at a place and time specified by NREL. Evergreen Solar, Inc. shall present a complete discussion of work performed under this subcontract at such meetings and submit one reproducible master copy of the presentation material prior to this review, as specified by the NREL Technical Monitor.

Presentations at scientific meetings and publications of research results in scientific journals are encouraged by the PV Manufacturing R&D Project, but must be approved in advance by the NREL Subcontract Administrator. Any costs to NREL that are to be incurred as a result of such presentations/publications must be included in the negotiated cost of the subcontract. The subcontractor is responsible for obtaining NREL's technical approval. Before a representative of Evergreen Solar, Inc. submits or presents a publication concerning the research effort under this subcontract (e.g., abstract, reprint of manuscript, etc.), Evergreen Solar, Inc. shall **submit two (2) copies to the NREL Technical Monitor, one (1) copy to each of the Technical Monitoring Team (TMT) members, and one (I) copy to the Contract Administrator.**

Evergreen Solar, Inc. is reminded that the **technical approval** requirements, as specified above, also apply to reports requiring distribution outside of NREL.

Evergreen Solar, Inc. shall also be prepared to respond to requests for written information in summary form as required by the Technical Monitor to meet obligations to DOE. Such requests include, but are not limited to, Program Summaries (annually, 1-2 pages) and Summary Annual Reports (2-3 pages). These are the usual requested annually, and NREL does not at this time expect any others during the contract. They are in addition to other reporting requirements (below).

5.3 REPORTING REQUIREMENTS

Evergreen Solar, Inc. shall furnish reports in accordance with the "Required Reports," Section 5.4. These reports shall be sent to the NREL Technical Monitor at the following address:

National Renewable Energy Laboratory
ATTENTION: David Mooney, MS#3214
1617 Cole Boulevard
Golden, Colorado 80401

with one copy of the report, and a copy of the transmittal letter to the Technical Monitor, being sent to the Contract Administrator at:

National Renewable Energy Laboratory
ATTENTION: Christie Johnson, MS#2713
1617 Cole Boulevard
Golden, Colorado 80401

Technical monitoring will be performed by NREL/Sandia Personnel and will be in compliance with DOE PV Manufacturing R&D project and NREL Procurement requirements. One copy of these reports shall also be sent to the Technical Monitoring Team Members as described in Section 5.4, with a copy of their transmittal letters sent to the Technical Monitor.

5.4 REQUIRED REPORTS

Evergreen Solar, Inc. shall be required to prepare and submit the following reports indicated below. If the period of performance for this subcontract begins during the first through the fifteenth of a month, then that month is considered the first full month of the subcontract for reporting purposes. If the period of performance for this subcontract begins during the sixteenth through the end of the month, then the first full month of the subcontract for reporting purposes is the following month. For example, if the period of

performance start date is January 10, then January is the first full month for reporting purposes: whereas, if the period of performance start date is January 20, then February is the first full month for reporting purposes.

A. MONTHLY TECHNICAL STATUS REPORT:

The Monthly Technical Status Report shall be formatted to communicate to NREL an assessment of subcontract status, explain variances and problems, report on the accomplishment of performance milestones and/or program deliverables, and discuss any other achievements or areas of concern. This report should be three to six pages written in a letter format with emphasis placed on the status rather than a description of the progress. An introductory paragraph will be included in each monthly report that provides a highlight of the month's activities. **Copies of this report are due on or before fifteen (15) days after completion of each month** [two (2) copies to the NREL Technical Monitor (TM), one (1) copy to each of the Technical Monitoring Team (TMT) members, and one (1) copy to the NREL Contract Administrator].

B. ANNUAL TECHNICAL PROGRESS REPORT

The Annual Technical Progress Reports shall be structured as formal technical reports, both in draft and final version, which describe all significant work performed during each phase of the subcontract. **Copies of the draft Annual Technical Progress Report are due on or before fifteen (15) days prior to the completion date for each phase's research effort under this subcontract** [two (2) copies for the NREL Technical Monitor (TM), one (1) copy for each of the Technical Monitoring Team (TMT) members, one (1) copy for the NREL TMT member, and one (1) copy for the NREL Contract Administrator]. The subcontractor shall make any corrections or revisions per NREL direction, which may include technical or editorial comments. The subcontractor shall be allowed fifteen (15) days after receipt of NREL's recommendations and/or comments to make these corrections and submit copies of the final version to NREL. The final version shall consist of **three (3) copies of the Annual Technical Progress Report** [one (1) master copy with original graphics, one (1) electronic copy with graphics (for posting on NREL's web site, see **B1** Guidelines below), and one (1) reproducible copy] **for the NREL Technical Monitor (TM), and one (1) reproducible copy for the NREL Contract Administrator.** If the subcontracted effort in the following phase is not authorized and funded by NREL, then that phase's Annual Technical Progress Report shall be designated as the Final Technical Report (see description below) and the period of performance for that phase shall be extended by three months to allow for the completion of this report as the Final Technical Report.

B1 – Electronic Format Guidelines:

List of format options to choose from for the electronic master.

(1) Preferably, reports should include embedded graphics, such that they can be easily converted to a PDF format. Submit a word processing file prepared by one of the following: (a) WordPerfect or (b) MS Word (Mac, DOS, or windows).

(2) If graphics cannot be embedded in the report file NREL prefers one of the following graphics formats: EPS, TIF, GIF, WPG, CGM, WMF, or PCT.

(3) If presenting a portable document file (.PDF) format, please keep the file manageable, not beyond 1MB.

C. FINAL TECHNICAL REPORT

The Final Technical Report is to be structured as a formal technical report, both in draft and final version, which describes all significant work performed during the entire subcontract's period of performance. **Copies of the draft Final Technical Report are due on or before fifteen (15) days after the final phase's completion date for active research under this subcontract** [two (2) copies for the NREL Technical Monitor (TM), one (1) copy for each of the Technical Monitoring Team members, and one (1) copy for the NREL Contract Administrator]. The subcontractor shall make any corrections or revisions per NREL direction, which may include technical or editorial comments. The subcontractor shall be allowed fifteen (15) days after receipt of NREL's recommendations and/or comments to make corrections and submit copies of the final version to NREL. The final version shall consist of **three (3) copies of the Final Technical Report** [one (1) master copy with original graphics, one (1) electronic copy with graphics (for posting on NREL's web site), and one (1) reproducible copy] **for the NREL Technical Monitor (TM), and one (1) reproducible copy for the NREL Contract Administrator.** The subcontractor shall follow one of the formats (listed above in Section B1, Annual Technical Progress Report) for the electronic copies of the final version of this report.

6.0 PERFORMANCE EVALUATION

The performance of Evergreen Solar, Inc. will be monitored and evaluated by the following means:

i) Monthly Technical Status Reports consisting of a report of program status relative to milestone and program schedules (3-6 pages);
ii) Annual Technical Progress Reports;
iii) A Final Technical Report covering work done under the subcontract;
iv) Up to two On-Site Visits by a PV Manufacturing R&D project selected evaluation team to Evergreen Solar, Inc. per phase – these visits shall entail presentations and demonstrations by Evergreen Solar, Inc.; and
v) Participation by Evergreen Solar, Inc. in up to two contractor Program Review Meetings per Phase as designated by PV Manufacturing R&D project management personnel.

During the subcontract, on-site presentations and demonstration reviews will be conducted by a PV Manufacturing R&D project review committee consisting of members selected by PV Manufacturing R&D project management staff. These meetings will be critical program evaluation points. The progress of Evergreen Solar, Inc. will be assessed at this time by reviewing past accomplishments and future program plans.

The progress of Evergreen Solar, Inc. will also be monitored by telephone conversations and by possible additional on-site visits by the NREL technical evaluation team at the discretion of the NREL technical monitor for the subcontract.

Appendix A

Statement of Work for Evergreen Solar, Inc.

Innovative Approaches to Low Cost Module Manufacturing of String Ribbon Si PV Modules

ZDO-2-30628-09

June 19, 2002

1.0 BACKGROUND

The U.S. Department of Energy (DOE), in cooperation with the U.S. Photovoltaics (PV) Industry, has the objective of retaining and enhancing U.S. leadership in the world market. To further this objective, the Photovoltaic Manufacturing Technology (PVMaT) project was initiated in FY 1990 to form a partnership between DOE and the U.S. PV industry, assisting in the improvement of module manufacturing processes and in the substantial reduction of module manufacturing cost. The goals of the project were to improve PV manufacturing processes and products for terrestrial applications, accelerate PV manufacturing cost reduction, lay the foundation for significantly increased production capacity, and assist the U.S. industry in retaining and enhancing its world leadership role in the commercial development and manufacture of terrestrial PV systems. The focus of the program emphasized research and development (R&D) manufacturing process issues.

Four solicitations have been completed since inception of the PVMaT Project and a fifth solicitation is near completion. These solicitations addressed, respectively: (1) process-specific R&D on PV module manufacturing (open only to companies that completed successfully a preliminary problem-definition phase; (2) generic research on problems of interest to all, or to a large portion of the PV industry; (3) process-specific R&D on PV module manufacturing; (4) product-driven PV manufacturing R&D addressing process-specific problems, as well as manufacturing improvements for balance-of-systems (BOS) components and system design improvements; and (5) PV module manufacturing technology and PV system and component technology.

The FY2000 solicitation, "PV Manufacturing R&D — In-Line Diagnostics and Intelligent Processing in Manufacturing Scale-Up," was a continuation of the PV Manufacturing R&D Project that focused on further accelerating the PVMaT achievements and was designed to be impartial to various PV technologies and manufacturing approaches. The goals are to improve PV manufacturing processes and products while reducing costs and providing a technology foundation that supports significant manufacturing scale-up (100-MW level). Letters of Interest under this solicitation were to address areas of work that could include, but were not be limited to, issues such as improvement of module manufacturing processes; system and system component packaging, system integration, manufacturing and assembly; product manufacturing flexibility; and balance-of-system development including storage and quality control. The primary emphasis was on new and improved in-line diagnostics and monitoring with real-time feedback for optimal process control and increased yield in the fabrication of PV modules, systems, and other system components.

During this subcontract, Evergreen Solar, Inc. (hereafter referred to as "Evergreen" in this document) will address the goals of improved PV manufacturing processes and products while reducing costs and providing a technology foundation that supports significant manufacturing scale-up. To accomplish these

goals, EVERGREEN will focus their efforts on their second-generation technology. These advances would be: further cost reduction in the production of wafers by the String Ribbon technique; high efficiency wrap-around contact solar cells; development and deployment of the manufacturing technology to make frameless modules based on polymers developed in Evergreen Solar's first PVMaT contract (1995 –1997); and the culmination of all these developments- monolithic modules. These developments will be accompanied with extensive use of manufacturing science techniques especially in the areas of diagnostics and statistical process control. EVERGREEN will also work toward PVMaT goals by developing quality assurance and ES&H programs in keeping with local, State, and Federal regulations as applicable.

2.0 OBJECTIVE

The objective of this subcontract over its three-year duration is to continue the development of EVERGREEN's String Ribbon Si PV technology resulting in an advanced generation of crystalline silicon PV module manufacturing technology applied to a virtually continuous fully integrated manufacturing line. The final goal of this line will be the production of frameless modules using wrap-around contacts on String Ribbon solar cells and made in a monolithic module configuration. Specific objectives include methods for improving surface and bulk quality of as-grown ribbon, techniques for wrap-around solar cell efficiency improvement, extensive reliability testing under accelerated conditions, developing low cost manufacturing to make frameless modules in general and monolithic modules in particular, and in line diagnostics throughout the production line. To further the high efficiency work, close interaction with Prof. Rohatgi's group at Georgia Tech will be pursued.

3.0 SCOPE OF WORK

The subcontract shall consist of three one-year phases and will be incrementally funded. EVERGREEN shall complete the investigations described in the following tasks and provide a detailed summary of this work in its reports and deliverables.

PHASE I - First Year

During Phase I, EVERGREEN shall perform R&D needed to affect improvements in ribbon growth and cell and module manufacture. These efforts shall address development of a production worthy doping method, growth of surface oxide free ribbon, improved starting lifetime of as-grown string ribbon, 12% efficient wrap-around cells, and device improvements on wrap-around cells. EVERGREEN shall design and develop a prototype machine to apply wrap-around decals. They shall develop necessary in-line diagnostics to support crystal growth. Evergreen shall also perform work leading to backskin materials cost reduction and develop and use methods for accelerated testing of monolithic modules to demonstrate desired stability. For all of these efforts Evergreen shall develop the quality assurance and ES&H programs required in keeping with local, state, and federal regulations as applicable. EVERGREEN shall report all progress from this Phase I task-oriented research through reporting requirements detailed in Sections 4, 5, and 6.

3.1 Task 1 Development Of A Production Worthy Doping Method

EVERGREEN shall develop a new doping method for feedstock silicon using liquid spin-on dopants.

To accomplish this task, Evergreen shall demonstrate a mixing method with satisfactory uniformity, develop a suitable solvent drying procedure and develop equipment which will not contaminate the feedstock silicon. This task is expected to result in a production worthy doping method and apparatus that produces satisfactory ribbon growth and cell efficiencies.

3.2 Task 2 Growth Of Surface Oxide Free Ribbon-1

EVERGREEN shall find a simple optical method to detect surface oxide on Si ribbon as it grows and develop an easily implementable method that provides data needed for in-situ correction. To accomplish this task, Evergreen shall develop a detailed characterization of surface oxide layers and develop a simple method for optical detection. This task is expected to result in the development of an optical method for collecting data needed to implement real-time corrective action during crystal growth (see task 11 in Phase II) that can eliminate all etch steps between growth and diffusion for Si ribbon.

3.3 Task 3 Improve Starting Lifetime Of As-Grown String Ribbon -1

EVERGREEN shall improve the starting lifetime of as-grown string ribbon through better purification of hot zone component materials to reduce transition metals and the development of coatings that are more impermeable for hot zone components. DLTS shall be used to verify the lifetime improvements. To accomplish this task, Evergreen shall investigate coatings to reduce permeability, investigate improved purification methods for graphite parts, investigate new configurations in hot zone parts, perform in-house lifetime measurements, obtain DLTS results through university contacts, and obtain string ribbon characterization through interaction with Georgia Tech. This task is expected to result in improvement in starting lifetime through reduced transition metals in string ribbon.

3.4 Task 4 12% Efficient Wrap-around Cell

EVERGREEN shall improve cell-processing leading to a 12% efficient wrap-around cell. Evergreen will achieve the efficiency gains in this task by both improvements in starting lifetime (Task 3) and advances in cell processing, especially plasma nitride passivation and firing through contacts. To accomplish this task, Evergreen shall perform cell processing of higher lifetime material, optimization of plasma nitride processes, and optimization of metallization firing processes. This task is expected to result in 12% wrap-around cells.

3.5 Task 5 Improve Devices Through Lowered Series Resistance And Increased Shunt Resistance

EVERGREEN shall develop techniques to improve their wrap-around cell by achieving lowered series resistance through changes in finger cross section and increased shunt resistance through materials science studies on pastes and dielectric layers. To accomplish this task, Evergreen will develop methods to improve finger cross section, perform Ag paste studies to improve wrap around ribbon edge, investigate appropriate dielectric layers, and develop methods for reduction of edge leakage. This task is expected to result in improved fill factors for 120 sq. cm. wrap-around contact cells

3.6 Task 6 Design And Develop A Prototype Machine To Apply Wrap-around Decals

EVERGREEN shall develop a concept and prototype machine for applying wrap-around solar cells that will lead higher manufacturing line volume and yield. To accomplish this task, Evergreen shall develop a concept for prototype machine, design a prototype machine, develop the prototype machine, and test the prototype machine. This task is expected to result in the testing of a prototype decal application machine that will be the basis for development of a high volume production machine

3.7 Task 7 In-Line Diagnostics-1

EVERGREEN shall develop a central database for in-line diagnostics in the crystal growth area to automatically generate SPC charts using the software package called RS View 32. To accomplish this task, Evergreen shall develop a data network for all new crystal growth machines, add bulk resistivity and laser cutter data to the network, and develop real time process monitoring using SPC charts. This task is expected to result in improved process control in the crystal growth area.

3.8 Task 8 Backskin Materials Cost Reduction

EVERGREEN shall develop processes to reduce cost of the backskin material by formulating thinner sheets of this material and then apply appropriate qualification tests, as well as in house accelerated tests, to the thinner sheets. To accomplish this task, Evergreen shall formulate thinner backskin, cross-link thinner backskin sheets, conduct qualification tests with thinner material, and perform in-house accelerated testing This task is expected to result in the development of a process to reduced backskin cost.

3.9 Task 9 Accelerated Testing Of Monolithic Modules

EVERGREEN shall study appropriate inks and printing properties and perform accelerated testing to establish the long term stability of the electrical bonds for material used in adhesive and conducting bars. To accomplish this task, Evergreen shall study various conductive inks, establish suitable printing properties for conductive material, and conduct accelerated testing of conductive material contacts. This task is expected to result in the development of practical printing method for the conductive material chosen, the demonstration of long term stability for contacts, and the demonstration of long term viability by the monolithic module.

PHASE II - Second Year

During Phase II, EVERGREEN shall continue to perform R&D needed to affect improvements in ribbon growth and cell and module manufacture. Evergreen's Phase II efforts shall address further improvement in the starting lifetime of as-grown string ribbon, continued work on growth of surface oxide free ribbon, continued improvements on wrap-around cells leading to 13% efficiency, the design, development, and initial testing of a machine to apply wrap-around decals, development of a continuous lamination process, design and development of manufacturing processes and equipment to make frameless modules, development of a manufacturing process to make monolithic modules, and the design of a robotic pick and place machine. In addition, Evergreen shall continue improving their in-line diagnostics capability through completion of the design for automating the collection and analysis of bulk resistivity measurements and the monitoring of module making machines. For all of these efforts Evergreen shall develop the quality

assurance and ES&H programs required in keeping with local, state, and federal regulations as applicable. Evergreen shall report all progress from this Phase II task-oriented research through reporting requirements detailed in sections 4, 5, and 6.

3.10 Task 10 Improve Starting Lifetime Of As-Grown String Ribbon -2

EVERGREEN shall continue to improve the starting lifetime of as-grown string ribbon through better control of thermal and mechanical perturbations to minimize dislocation formation. To accomplish this task, Evergreen shall make use of vibration control and more uniform thermal environment to obtain lower dislocation content. Evergreen shall redesign their crystal growth hot zone to improve the thermal uniformity, design and develop techniques for vibration damping during growth, and perform dislocation density mapping to guide other efforts in this task. This task is expected to result in higher starting lifetimes through reduced dislocation density

3.11 Task 11 Growth Of Surface Oxide Free Ribbon-2

EVERGREEN shall develop a better understanding of oxygen ingress from the exit slits and convection in the region around the hot zone through a better understanding of convection in the hot zone. In addition, Evergreen shall design new techniques to utilize the improved understanding of oxygen ingress and reduce the oxygen available that creates undesired oxide on newly grown ribbon. To accomplish this task, Evergreen shall redesign their Ar introduction techniques and develop methods to reduce convection in the hot zone region. This task is expected to result in oxide free ribbon and eliminate all etch steps between growth and diffusion for Si ribbon.

3.12 Task 12 13 % Wrap-around Cells

EVERGREEN shall improve efficiency through optimized nitride passivation for both front and rear surfaces and development of a method to form a good back contact. To accomplish this task, Evergreen shall develop, deploy, and test a boat for double sided passivation and develop and test Al paste that can fire through nitride. This task is expected to result in 13 % wrap-around cells.

3.13 Task 13 Design, Develop, and Test a Production-worthy Machine to Apply Wrap-around Decals

EVERGREEN shall design, develop, and test a machine to apply wrap-around decals for high volume production rates on the order of 1000 cells/hr. The design shall make use of an Allen Bradley PLC that will feed process data into a central computer. This task is expected to result in the development of a production-worthy machine that automates the application of wrap-around decals.

3.14 Task 14 Continuous Lamination Process

EVERGREEN shall develop a continuous, non-vacuum lamination process that eliminates cell cracking and which is suitable for high volume production. To accomplish this task, Evergreen shall find process conditions (such as roller temperature, pre heat temperature, speed, and roller pressure) whereby cell cracking is eliminated. Evergreen shall then develop suitable process conditions for high volume manufacturing. This task is expected to result in a high volume, continuous non-vacuum

lamination process.

3.15 Task 15 Develop a Manufacturing Process to Make Frameless Modules

EVERGREEN shall develop a low-cost, manufacturable technique to make frameless modules though close interaction with vendors and manufacturing personnel. To accomplish this task, Evergreen shall study alternative methods to modify their backskin for higher impermeability and study alternative methods to form a backskin edge. This task is expected to result in the development of a viable manufacturing process for frameless modules.

3.16 Task 16 Design Manufacturing Equipment to Make Frameless Modules

EVERGREEN shall design, develop and test low-capital cost equipment for high volume manufacturing of frameless modules. To accomplish this task, Evergreen shall design a suitable backskin modification machine for improved impermeability backskin, test the backskin modification machine for output with improved impermeability, design a machine to form sealed leads from the module, and test the machine to form the sealed leads. This task is expected to result in the design, development and testing of a backskin modification machine and design, development, and testing of a machine to form sealed electrical leads from the module.

3.17 Task 17 Develop a Manufacturing Process to Make Monolithic Modules

EVERGREEN shall develop a cost-effective, manufacturing method to control backskin shrinkage. To accomplish this task, Evergreen shall explore possible methods to control shrinkage, identify and select a promising method, and develop and test this method for adequacy in a manufacturing process. This task is expected to result in a method to control backskin shrinkage suitable for manufacturing.

3.18 Task 18 Design a Robotic Pick and Place Machine

EVERGREEN shall design a robotic pick and place machine that can accurately position a wrap-around cell on the printed backskin. To accomplish this task, Evergreen shall identify a robot with desired properties and design a machine with that robot to perform the required pick and place activities needed to position the cell on the backskin. This task is expected to result in a pick and place machine with positional accuracy of plus or minus 0.005".

3.19 Task 19 In-Line Diagnostics-2

EVERGREEN shall develop the necessary processes and equipment to incorporate bulk resistivity measurement into the automatic laser cutting station. Such equipment to perform the measurements, done manually during the Phase I, shall be designed to automatically perform the required measurements on the as grown wafers. In the module area, processes and equipment necessary to incorporate RSView into the machine designs shall also be developed and tested. This task is expected to result in in-line diagnostics for bulk resistivity measurement and automated monitoring of module making machines.

PHASE III - Third Year

During Phase III, EVERGREEN shall continue to perform R&D needed to affect improvements in ribbon growth and cell and module manufacture. Evergreen's Phase III efforts shall address the demonstration of improved starting lifetime of as-grown string ribbon from a production-capable system, continued improvements on wrap-around cells leading to 14% efficiency, continued testing and fine tuning to demonstrate manufacturing line worthiness for a decal application machine. Evergreen shall also design and develop an improved small high voltage module, debug, test, and fine-tune module manufacturing equipment used for frameless, monolithic modules, debug, test, and fine-tune a robotic pick and place machine for automated monolithic module layout, and continue improved automation of their manufacturing line with design, development, and testing of a network for collection of all data at a central point for advanced in-line diagnostics. And finally Evergreen shall demonstrate their state of the art manufacturing capability to make monolithic modules. EVERGREEN shall report all progress from this Phase III task-oriented research through reporting requirements detailed in Sections 4, 5, and 6.

3.20 Task 20 Demonstrate Improved Starting Lifetime On Production-Capable System

EVERGREEN shall demonstrate the results of the work on impurity reduction (Task 3) and dislocation reduction (Task 10) on a production crystal growth system so as to produce a higher average and tighter distribution of starting lifetime. Presently the lifetimes vary from <1 to >10 microseconds. The goal here will to eliminate the lower end of the distribution. This task is expected to result in starting lifetimes of 5 to >10 microseconds.

3.21 Task 21 14% Efficient Wrap-around Contact Cells

EVERGREEN shall combine advances made in Tasks 12 and 20 to routinely make 14% cells. To accomplish this task, Evergreen shall make cells utilizing the advances developed during Phase II to produce cells on production-worthy equipment developed for performing tasks 12 and 20. This task is expected to result in 14% wrap-around contact cells.

3.22 Task 22 Fine-Tune And Test Wrap-around Decal Application Machine

EVERGREEN shall demonstrate, fine-tune, and test a production worthy wrap-around decal application machine with a goal of achieving throughput of 1000 cells/hr at > 95% yield. To accomplish this task, Evergreen shall execute an iterative process of fine-tuning and testing their wrap-around decal application machine at high volume. This task is expected to result in a complete debugging of their wrap-around decal application machine and a demonstration of production-worthiness.

3.23 Task 23 Design And Develop An Improved Small, High Voltage Module

EVERGREEN shall design and develop a high voltage small monolithic module suitable for automated production. To accomplish this task, Evergreen shall demonstrate the viability of laser cutting large wrap-around cells into smaller wrap-around cells, demonstrate adequate reliability for