I - FINAL SCIENTIFIC/TECHNICAL REPORT

1 – Project Description:

Project Title:	Recovery Act: Novel Kerf-Free PV Wafering that provides a low –cost approach to generate wafers from 150um to 50um in thickness.
Covering Period:	August 1, 2009 to July 31, 2011
Date of Report:	May 6, 2013
Recipient:	Silicon Genesis Corporation
Award Number:	DE-EE0000594
Working Partners:	
Cost-Sharing Partners:	n/a

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DOE Project Team:
DOE Field Contracting Officer - Leon Fabick
DOE Field Project Officer - Diana Martinez

2 – Distribution Limitations: none

3 – Executive Summary:

The PolyMax™ technology is a two-step process involving the implantation of light ions into the surface of a silicon brick, followed by a cleaving step that causes the top layer of silicon to separate from the brick, forming a thin silicon wafer. These two steps are repeated in order to produce wafer slices from the silicon brick. The free-standing PV wafers can have a thickness from about 20 microns to 120 microns. Detailed cost modeling suggests that the value of the eliminating the kerf waste, and a transition to thinner wafers is quite substantial and will enable the solar industry to achieve the SAI grid-parity cost targets of under $0.10 per kW-hr at the module level.

First, the research conducted by Silicon Genesis ("SiGen") added to the understanding that the SiGen PolyMax™ technology was able to demonstrate the ability to make novel Kerf-Free silicon wafers. These wafers have the potential for replacing the mono-crystalline wafers that are made today using the industry standard wire sawing method. It was also demonstrated through customer testing of the wafers, that the material was capable of producing PV cells with equivalent or better conversion efficiency as the

standard mono-crystalline silicon PV wafers. Second, the DOE project funding enabled SiGen to develop the technology to the level of a first alpha-prototype production system. A commercial system was not completed with the funding and resources provided through the DOE cost sharing grant. However, to the degree the technology, equipment and processes were developed, SiGen was able to determine the capability of the technology, the equipment development roadmap, and the wafer specifications required to enable this technology to become commercially viable. The development roadmap included being able to specify the manufacturing productivity, yield and quality metrics that would be needed for commercial deployment. Third, the project was a benefit to the public because it provided a glimpse to the PV solar industry of how the PolyMax™ technology may become a viable alternative to wire saws as the predominant method for making mono-crystalline silicon PV wafers. In addition, besides the potential for material savings from Kerf-Free wafering, the potential for a lower cost wafering method may be a compelling reason to complete the technology development to the level of commercial viability.

4 – Comparison of Actual Accomplishments versus Goals:

The overall goal of the project was to drive SiGen's PolyMax™ Kerf-Free solar wafering technology toward widespread commercialization. SiGen planned to implement this by developing an improved direct film transfer (DFT) process by 1) improving the implant and cleave equipment hardware, 2) developing processes suitable for manufacturing, and 3) developing production-grade equipment to implement this process.

SiGen planned to complete the design and test the first (alpha) production-grade ion implantation tool and then integrate both alpha implant and cleave tools into a single process cycle via semi-automated material handling. The intention of the integrated system was to refine the process, begin low volume pilot wafering and collect production yield data to support a transition to full-scale manufacturing.

In terms of equipment, SiGen was able to complete the development and testing of an alpha implant system. This system included three sub-system modules 1) linear accelerator, 2) beam line transport system and 3) end station for implanting silicon bricks. SiGen initiated the development of a mechanical cleave system and continued process development on the thermal cleave system, but was unable during the time frame of the project to complete the mechanical prototype system. SiGen was not able to develop automated integration between the implant and cleave system nor develop the beta versions of production-grade equipment.

Due to the technical challenges of the project, completion of the entire planned scope of the project was beyond the funding and resources made available through the DOE project grant.

5 – Summary of Project Activities:

Task 1.0 – Develop improved low-dose cleave process & prototype cleave tool: This task was 60% completed. Two alternative cleaving approaches, thermal and mechanical "SP" cleaving were used to determine the best approach for commercial application. Although a 40% dose reduction was achieved, the target reduction of 70% was not achieved. While the mechanical approach is interesting, at this point the thermal cleaving approach seems to be the most direct route to first commercial production tools. The mechanical method, which is believed to have the capability for the lowest dose requirement would need further R&D to develop a working alpha prototype.

Task 2.0 – Develop production-grade alpha cleave tool: This task was 20% completed. Due to the partial completion of the low-dose cleave development only preliminary work on the cleave concept design was completed.

Task 3.0 – Complete design and test alpha implanter: This task was 95% completed. A working alpha implanter was completed that enabled the testing of the Kerf-Less wafering technology on a tool that enabled the development of a roadmap for scaling to the level of commercial manufacturing. The level of productivity, yield and quality required for commercial viability were determined and this would lead to the roadmap for completing a commercial tool set.

Task 4.0 – Integrate implant and cleave tools into single process cycle. Refine process and start low-volume pilot manufacturing: This task was not started. This task could not be started due to the partial completion of Tasks 1.0 and 2.0. Without a cleave prototype tool, there was no practical way to integrate the implant and cleave equipment into a single process cycle.

Task 5.0 – Gather equipment cost and pilot performance data: This task was completed 50%. During the term of this project, SiGen was able to run more than 1,000 wafer samples using the alpha implant tool and an R&D thermal cleave tool (not for production). A significant level of data for the productivity (implant throughput), cleave yields and wafer quality were gathered. This enabled SiGen to determine the cost structure of making Kerf-Free wafers and to establish the manufacturing parameters required for commercial viability.

Task 6.0 – Design factory plan and improvements to equipment: This task was 50% completed. The three basic components of factory layout included the implant, cleave and integrated automation components of a Kerf-Free wafer manufacturing facility. During the project duration, SiGen was able to work with development partners on the layout concept. A significant portion of the concept design was completed. The portion that could not be completed was how to integrate the cleave tool set. Because the alpha cleave system was not developed, this aspect of the factory plan could not be completed. In terms of the improvements to equipment, SiGen was able to determine a clear path for the improvements required for the alpha implant system to be ready for commercial deployment. In terms of the cleave tool system, only initial concepts were developed and any alpha level equipment could not be started until the cleave methodology was completed.

Task 7.0 – Develop and test beta tools: This task was not started. Due to the challenges of completing the earlier tasks in this project, except for some conceptual designs, no other efforts were spent to complete this project task.

6 – Products Developed Under the Award and Technology Transfer Activities:

Publications: n/a

Conference Papers:

Cleaving vs. Sawing – Gaining Production Efficiency in c-Si wafering – 24th PV Solar European Conference, Valencia, Spain, September 2009

Kerf-Free 20-150um c-Si Wafering for Thin PV manufacturing – 24th PV Solar European Conference, Hanburg, Germany, September 2009

First Demonstration of High Volume Manufacturing of Kerf-Free Polymax™ Wafers - 25th PV Solar European Conference, Hamburg, Germany, September 2010

Networks or collaborations fostered:

Continued parallel development efforts with SiGen partners including REC, SunPower, Sanyo, and Shin-Etsu Chemical in development and testing of wafers made from the PolyMax™ technology.

Technologies/Techniques:

Novel implant and cleave technology applied to the manufacture of Kerf-Free mono-crystalline silicon PV wafers ranging in thickness from 20um to 120um thickness.

Inventions/Patent applications/licensing agreements:

Inventions: see patent applications below

Patent Applications:
1 – Free-Standing Thickness of Single Crystal Material and Method Having Carrier Lifetimes – Application number: 12/460899
2 – Layer Transfer of Films Utilizing Controlled Propagation – Application number: 12/460898
3 – Race Track Configuration and Method for Wafering Silicon Solar Substrates – Application Number: 12/462210
4 – Method and Structure for Fabricating Solar Cells Using a Thick Layer Transfer Process – Application Number: 12/730113
5 – Apparatus and Method of Temperature Control During Cleaving Processes of Thick Film Materials – Application Number: 13/246717

Licensing Agreements: none

7 – Computer Modeling: none

II - FINANCIAL REPORTING

See the attached Final Report status report spreadsheet and cost summary.

Silicon Genesis Corporation
DE-EE0000594

Significant Accomplishments during this Project:

1. Numerous key components of the proton accelerator were retrofit with upgraded hardware in preparation for achieving higher beam currents and energies. The maximum beam current on the alpha-implanter achieved during this project was 15mAmps.
2. Production of 120 um thick wafers (156 mm square form) in small quantities using the alpha tool and thermal cleaving. This is the thickest produced by the alpha implanter during this project.
3. Initial tests of the MP cleaving concept were made and showed mixed results: a 60mm x 60mm cleave was achieved, however it required relatively large ion dose and was a somewhat unstable process.
4. Another new cleaving concept ('SP') was developed and simulated. While this approach was be simpler than the MP appproach the cleaving results were non-conclusive.
5. Prototype hardware to test the SP approach was completed.
6. During the project the maximum energy achieved was 3.5MeV.

Plans for Next Quarter:

1 - No further plans as the project was ended with the completion of project funding at 9/30/2011

Major Task Schedule

SOPOTask #	Item: Task = T Milestone = M Deliverable = D	Task Title or Milestone/Deliverable Description	Performer (if different from recipient)	Task Completion Date Original Planned	Revised Planned	Actual	% Com-plete	Progress Notes
1	**T**	**Task 1.0 - Develop improved low-dose cleave process & prototype cleave head**		**< 8/2010**		**n/a**	**60%**	**Partially Completed**
1	T	Subtask 1.1 - Perform rapid, low cost feasibility tests of multiple cleave approaches		< 8/2010		n/a	65%	Partially Completed
1	M	Subtask 1.2 - Select best approach(s) for benchtop prototype cleave head capable of full brick cleave		< 8/2010		n/a	80%	Partially Completed
1	T	Subtask 1.3 - Design, build, test & refine prototypes(s). Demonstrate repeated full brick cleaves and clear path to a manufacturable process.		< 8/2010		n/a	50%	Partially Completed
2	**T**	**Task 2.0 - Develop production-grade alpha cleave tool**		**< 8/2010**		**n/a**	**20%**	**Partially Completed**
2	T	Subtask 2.1 - Develop initial tool architecture concepts and alternatives		< 8/2010		n/a	50%	Partially Completed
2	T	Subtask 2.2 - Determine inspection and metrology requirements and identify possible suppliers		< 8/2010		n/a	40%	Partially Completed
2	T	Subtask 2.3 - Determine wafer and brick handling requirements and interface to customer factory		< 8/2010		n/a	10%	Partially Completed
2	T	Subtask 2.4 - Select alpha tool architecture and concept. Kickoff alpha tool design.		< 8/2010		n/a	0%	Not completed by end of contract
2	T	Subtask 2.5 - Validate thin-wafer handling technique		< 8/2010		n/a	0%	Not completed by end of contract
2	T	Subtask 2.6 - Design, build and module-test alpha cleave head		< 8/2010		n/a	0%	Not completed by end of contract
2	T	Subtask 2.7 - Design and build alpha cleave tool automation		< 8/2010		n/a	0%	Not completed by end of contract
2	T	Subtask 2.8 - Integrate cleave head with cleave automation and test. Confirm brick and wafer handling reliability, failure modes & yields		< 8/2010		n/a	0%	Not completed by end of contract
3	**T**	**Task 3.0 Complete design and test of alpha implanter**		**< 8/2010**		**n/a**	**95%**	**Partially Completed**
3	T	Subtask 3.1 - Complete implanter design and assembly		< 8/2010		n/a	100%	Installed
3	T	Subtask 3.2 - Facilitize, integrate, debug & test. Achieve first beam. Testing to validate dose control, dose patterning, accelerator stablity, mechanical functionality, heat transfer coefficients.		< 8/2010		n/a	100%	First beam
3	T	Subtask 3.3 - Qualify first implants using BKM cleave process. Initial samples are one of deliverables.		< 8/2010		n/a	100%	First cleaves
3	T	Subtask 3.4 - Develop and implement automation, cooling and buffering modules and support tooling		< 8/2010		n/a	20%	Automation preliminary concept design done, vendor selected, but further work on hold pending progress on task 1 and funds availability
3	M	Subtask 3.5 - Release part of alpha tool time for pilot implant manufacturing		< 8/2010		n/a	20%	Some time has been available for wafer sampling
4	**T**	**Task 4.0 - Integrate implant and cleave tools into single process cycle. Refine process and start low-volume pilot manufacturing.**		< 7/2011		**n/a**	**0%**	**This task was not started**
4	T	Subtask 4.1 - Integrate implant and cleave tools into single process. Simulate factory using manual material transfer between tools.		< 7/2011		n/a	0%	abandoned
4	T	Subtask 4.2 - Optimize implant & cleave processes together to achieve minimum possible implant dose while maintaining specs. Finalize the BKM process recipes.		< 7/2011		n/a	0%	abandoned
5	**T**	**Task 5:0 - Gather equipment cost and pilot performance data.**		**< 7/2011**		**n/a**	**50%**	**Partially Completed**
5	T	Subtask 5:1 - Yields. Identify and quantify all sources of yield loss and develop mitigation strategies.		< 7/2011		n/a	80%	Partially Completed
5	T	Subtask 5:2 - Equipment Costs. Gather and quantify capital and operating costs and identify opportunities for cost reduction.		< 7/2011		n/a	80%	Partially Completed

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Plans for Next Quarter:

1 - No further plans as the project was ended with the completion of project funding at 9/30/2011

5	T	Subtask 5:3 - Throughput. Assess throughput and identify opportunities for improvement.		< 7/2011		n/a	80%	Partially Completed
5	T	Subtask 5:4 - Uptime. Gather data on uptime metrics based on semiconductor equipment standards.		< 7/2011		n/a	30%	Partially Completed
5	T	Subtask 5:5 - Develop a refined cost-of ownership analysis and compare vs. targets		< 7/2011		n/a	30%	Partially Completed
5	T	Subtask 5:6 - Materials qualification. Confirm minority carrier lifetime, strength, roughness, WIW and WTW thickness variation, edge and surface defects. If cells are fabricated, characterize the I-V curve & efficiency. Determine if hardware changes are needed.		< 7/2011		n/a	50%	Partially Completed
6	**T**	**Task 6:0 - Design factory and plan improvements to equipment.**		**< 7/2011**		**n/a**	**50%**	**Partially Completed**
6	T	Subtask 6:1 - Develop draft factory concept architecture in cooperation with partners and customers.		< 7/2011		n/a	90%	Partially Completed
6	T	Subtask 6:2 - Simulate/validate full scale manufacturing flow.		< 7/2011		n/a	5%	Partially Completed
6	T	Subtask 6:3 - Incorporate results of Task 5.0 into comprehensive equipment improvement plan for beta tools and beta requirements analysis.		< 7/2011		n/a	25%	Partially Completed
7	**T**	**Task 7.0 - Develop and test beta tools**		**< 7/2011**		**n/a**	**0%**	**Will not be started during this contract**
7	T	Subtask 7:1 - finalize all beta requirements and validate plan with customer/partners.		< 7/2011		n/a	0%	abandoned
7	T	Subtask 7:2 - Develop plan to increase accelerator current and assess impact on throughput and COO.		< 7/2011		n/a	0%	abandoned
7	T	Subtask 7:3 - Kickoff design, build and test beta tools.		< 7/2011		n/a	0%	abandoned
7	T	Subtask 7:4 - Deliver beta system to customer and obtain customer signoff.		< 7/2011		n/a	0%	abandoned
7	T	Subtask 7:5 - Gather & assess data & results from customer beta testing. Determine requirement engineering improvements for production equipment. Begin design of pilot production line.		< 7/2011		n/a	0%	abandoned
8	**T**	**Task 8.0 - Project Management & Reporting**		**n/a**		**5/6/2013**	**100%**	**Final Report Submitted**

Recipient:	Silicon Genesis Corporation
DOE Award #:	DE-EE0000954

Spending Summary for SF 424A Budget Forms

Object Class Categories	**Approved Budget**	**Project Expenditures**	
Per SF 424a		**This Quarter**	**Cumulative to Date**
a. Personnel	$2,346,566	$66,127	$2,451,240
b. Fringe Benefits	$563,176	$15,870	$592,620
c. Travel	$0	$0	$0.00
d. Equipment	$700,000	$0	$236,117
e. Supplies	$336,000	$81,929	$802,025
f. Contractual	$1,230,000	$191,986	$1,074,050
g. Construction	$0	$0	$0.00
h. Other	$0	$0	$0.00
i. Total Direct Charges (sum of a to h)	$5,175,742	$355,912	$5,156,052
j. Indirect Charges	$2,691,386	$178,900	$6,631,585
k. Totals (sum of i and j)	**$7,867,128**	**$534,812**	**$11,787,637.12**
DOE Share	$3,000,000	$0	$3,000,000.00
Cost Share	$4,867,128	$534,812	$8,787,637.12
Calculated Cost Share Percentage	61.9%	100.0%	74.5%

Recipient: #REF!
DOE Award #: #REF!

Spending Summary for SF 424R&R Budget Forms

Object Class Categories Per SF 424 R&R	Approved Budget	Project Expenditures	
		This Quarter	Cumulative to Date
Section A, Senior/Key Person	$ 952,688.00	$ 21,985.34	$ 516,415.76
Section B, Other Personnel	$ 1,957,054.00	$ 60,011.66	$ 2,527,444.68
Total Salary, Wages & Fringe Benefits (A+B)	$ 2,909,742.00	$ 81,997.00	$ 3,043,860.44
Section C, Equipment	$ 700,000.00	$ -	$ 236,117.42
Section D, Travel		$ -	$ -
Section E, Participant/Trainee Support Costs		$ -	$ -
Section F, Other Direct Costs	$ 1,566,000.00	$ 273,915.00	$ 1,876,074.56
1. Materials and Supplies	$ 336,000.00	$ 81,929.00	$ 802,024.77
2. Publication Costs	$ -	$ -	$ -
3. Consultant Services	$ -	$ -	$ -
4. ADP/Computer Services	$ -	$ -	$ -
5. Subawards/Consortium/Contractual Costs	$ 1,230,000.00	$ 191,986.00	$ 1,074,049.79
6. Equipment or Facility Rental/User Fees		$ -	$ -
7. Alterations and Renovations		$ -	$ -
8. Other 1			
Total Direct Charges (sum of A to F1)	$ 5,175,742.00	$ 355,912.00	$ 5,156,052.42
H. Indirect Charges	$ 2,691,386.00	$ 178,899.99	$ 6,631,584.70
Totals	**$ 7,867,128.00**	**$ 534,811.99**	**$ 11,787,637.12**
DOE Share	$ 3,000,000.00	$ -	$ 3,000,000.00
Cost Share	$ 4,867,128.00	$ 534,811.99	$ 8,787,637.12
Calculated Cost Share Percentage	61.9%	100.0%	74.5%

Recipient: Silicon Genesis Corporation
DOE Award #: DE-EE0000594

Reporting period: 7/1/2011 to 9/30/2011
Click Here ▲

Project Spend Plan (for entire Project Period)

Instructions:

1) Initial Spend Plan: Enter the initial Spend Plan for the entire project in Columns A and C (gray columns).
Once entered, these amounts will NOT be changed for the entire period of the award.
2) Reporting Period: Select the reporting period (the past quarter) by clicking on the PINK cell above.
Cells below will turn green for selected reporting period.
3) Fill in **actual outlays** for **past** quarters in the columns B. and D (green cells). (should match SF269 or SF425 Financial Status Report)
4) Adjust **projected outlays** for **present and all future** quarters columns B and D (blue cells).

Calendar Quarter	Year	From	To	A. Federal Share Initial Plan	B. Federal Share Updated Actuals & Plan	Cumulative Federal Share	C. Recipient Share Initial Plan	D. Recipient Share Updated Actuals & Plan	Cumulative Recipient Share
Q1	2008	1/1/2008	3/31/2008	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Q2	2008	4/1/2008	6/30/2008	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Q3	2008	7/1/2008	9/30/2008	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Q4	2008	10/1/2008	12/31/2008	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Q1	2009	1/1/2009	3/31/2009	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Q2	2009	4/1/2009	6/30/2009	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Q3	2009	7/1/2009	9/30/2009	$375,000.00	$1,436,767.00	$1,436,767.00	$534,661.00	$0.00	$0.00
Q4	2009	10/1/2009	12/31/2009	$375,000.00	$0.00	$1,436,767.00	$534,661.00	$1,357,381.00	$1,357,381.00
Q1	2010	1/1/2010	3/31/2010	$375,000.00	$0.00	$1,436,767.00	$534,661.00	$776,197.00	$2,133,578.00
Q2	2010	4/1/2010	6/30/2010	$375,000.00	$1,563,233.00	$3,000,000.00	$534,661.00	-$957,220.00	$1,176,358.00
Q3	2010	7/1/2010	9/30/2010	$375,000.00	$0.00	$3,000,000.00	$682,121.00	$843,227.00	$2,019,585.00
Q4	2010	10/1/2010	12/31/2010	$375,000.00	$0.00	$3,000,000.00	$682,121.00	$863,959.30	$2,883,544.30
Q1	2011	1/1/2011	3/31/2011	$375,000.00	$0.00	$3,000,000.00	$682,121.00	$395,329.89	$3,278,874.19
Q2	2011	4/1/2011	6/30/2011	$375,000.00	$0.00	$3,000,000.00	$682,121.00	$601,389.00	$3,880,263.19
Q3	2011	7/1/2011	9/30/2011	$0.00	$0.00	$3,000,000.00	$0.00	$4,907,373.93	$8,787,637.12
Q4	2011	10/1/2011	12/31/2011	$0.00	$0.00	$3,000,000.00	$0.00	$0.00	$8,787,637.12
Q1	2012	1/1/2012	3/31/2012	$0.00	$0.00	$3,000,000.00	$0.00	$0.00	$8,787,637.12
Q2	2012	4/1/2012	6/30/2012	$0.00	$0.00	$3,000,000.00	$0.00	$0.00	$8,787,637.12
Q3	2012	7/1/2012	9/30/2012	$0.00	$0.00	$3,000,000.00	$0.00	$0.00	$8,787,637.12
Q4	2012	10/1/2012	12/31/2012	$0.00	$0.00	$3,000,000.00	$0.00	$0.00	$8,787,637.12
Totals				**$3,000,000.00**	**$3,000,000.00**	**$3,000,000.00**	**$4,867,128.00**	**$8,787,637.12**	**$8,787,637.12**
				This is the initial plan. These numbers do NOT change	Total above should always equal the total Federal project amount of $X		This is the initial plan. These numbers do NOT change	Total above should always equal the total project Cost Share amount of $Y	

III **– Closeout Reports (none)**