

Georgia Tech's Photovoltaic Manufacturing Initiative

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Abstract

The Manufacturing Research Center at Georgia Tech is addressing both fundamental and practical issues related to handling, transport and inspection of thin polycrystalline silicon wafers used in the manufacture of photovoltaic (PV) cells and modules. The current focus is on developing a demonstration test bed consisting of a prototype Polariscope-based wafer residual/applied stress measurement system integrated with the handling and transport functions. In addition, the research program also includes the development of factory information software for near real-time monitoring and control of processes and machines at different manufacturing stations.

1. Introduction

The Manufacturing Research Center (MARC) at Georgia Tech is currently addressing photovoltaic manufacturing as a part of an NREL grant. Part of the Initiative deals with the creation of a laboratory that will address fundamental and practical issues related to handling and transport of thin silicon wafers used in solar cells, automated inspection of residual and/or applied stresses in the wafer due to processing and/or handling steps, and the development of factory information software tools for near real-time monitoring of the processes and machines used in cell manufacturing. The purpose of the lab will be to research and develop new and improved manufacturing techniques in order to both improve the quality and yield, and lower the cost of photovoltaic devices. A focal point of the laboratory will be an industrial scale manufacturing pilot line which will be used to investigate the handling and fracture of thin polycrystalline silicon wafers such as those produced by RWE Schott Solar, BP Solar, and Evergreen Solar. This work was initiated in May 2005 and this paper describes the layout of the laboratory, the software architecture, and the research issues being addressed.

2. Pilot Line Description

The envisioned PV cell manufacturing pilot line will contain several stations that are connected by conveyors or other material transfer mechanisms, as shown schematically in Figure 1.

The first station will be used to study forces, deformation, stresses and breakage of thin (<100~200 μ m) silicon wafers due to robotic handling. A 4-axis SCARA robot equipped with either Bernoulli, vacuum or mechanical grippers will be used to pick up wafers using precisely-controlled grip forces and

position them in a near-Infrared Polariscope (a stress measuring system based on near Infrared Photoelasticity technique) so that residual stresses can be measured. After a wafer has been inspected, it will be moved to a conveyor by the robot and transferred to the back metallization station. Figure 2 shows a picture of robot with an instrumented gripper. Sensors used include an air flow rate and pressure sensor, thin film force sensors to measure the dynamic wafer gripping forces and a laser-based wafer deformation measurement system. The polariscope-based residual stress measurement system and a typical measurement are shown in Figure 3.

Upon arriving at the back metallization station, a material handling system will place the wafer on a platform, and a stencil will be placed on top of the wafer. Solder paste will be applied to the wafer through the stencil either by using a squeegee or a sponge. Upon completion, the stencil will be removed and the wafer will be moved to a second conveyor for transfer to the third station. The metallization station will be used to study the printing process and recommend potential process improvements.

Monitoring and control of the pilot line stations will be accomplished through an XML-based factory information system. CAMX (Computer Aided Manufacturing using XML) makes use of a virtual message broker, which exchanges XML messages amongst assets in an enterprise across the internet. An application server will be used to collect, store, and present manufacturing data through a web interface such as wafer stress histories, handling forces, wafer yield, work-in-process, and other sensor output. Figure 4 provides an overview of the proposed information system design for the first manufacturing station. A sample view of the CAMX web-based interface is also shown.

3. Research Agenda

The laboratory test bed will be used to study both fundamental and practical issues related to handling, inspection and factory information systems for PV manufacturing. In particular, research issues being addressed include: 1) quantitative understanding of the impact of wafer processing and handling on wafer residual stresses and yield, 2) modeling and optimization of existing wafer handling devices, 3) development of new wafer handling methods, especially for thin ($\leq 100 \mu\text{m}$) and large ($> 150 \text{ mm}$) silicon wafer, 4) development of new cell metallization techniques, and 5) design and development of a factory information system for PV manufacturing.

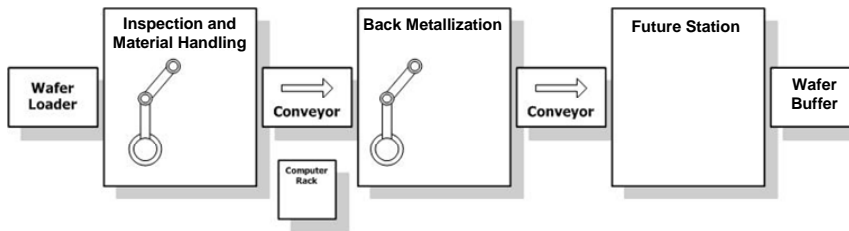


Figure 1. Laboratory Equipment Layout and Process Flow

4. Conclusions

This research program addresses the handling, transport and inspection of polycrystalline silicon wafers used in PV manufacturing. The program also addresses the development of a factory information system for PV manufacturing. Ultimately, the program aims to improve the quality and yield of thin silicon wafers. The research results will be made available to the PV manufacturers.

5. Acknowledgements

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Figure 2. 4-axis wafer handling robot equipped with sensors.

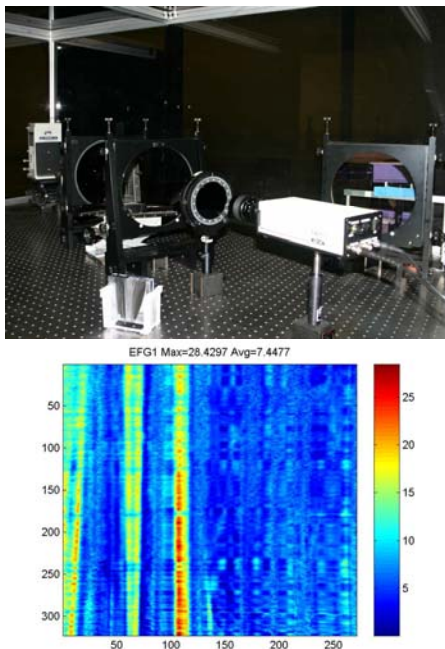


Figure 3. (a) Polariscope-based residual stress inspection system, (b) Residual stress distribution in EFG wafer.

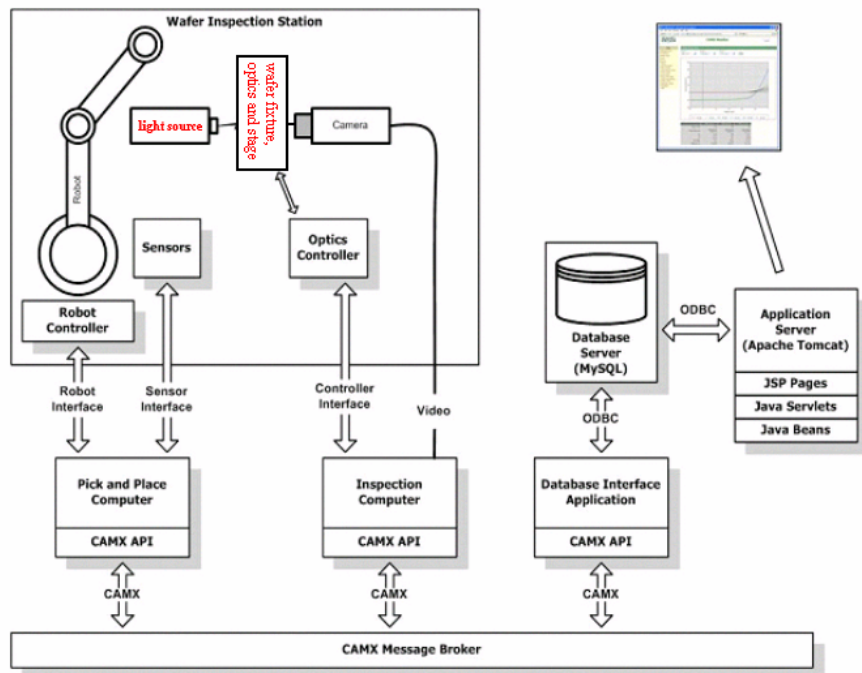


Figure 4. Software Architecture for Factory Information System