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Intelligent Automation of Electron Beam Physical Vapor Deposition Using LabVIEW

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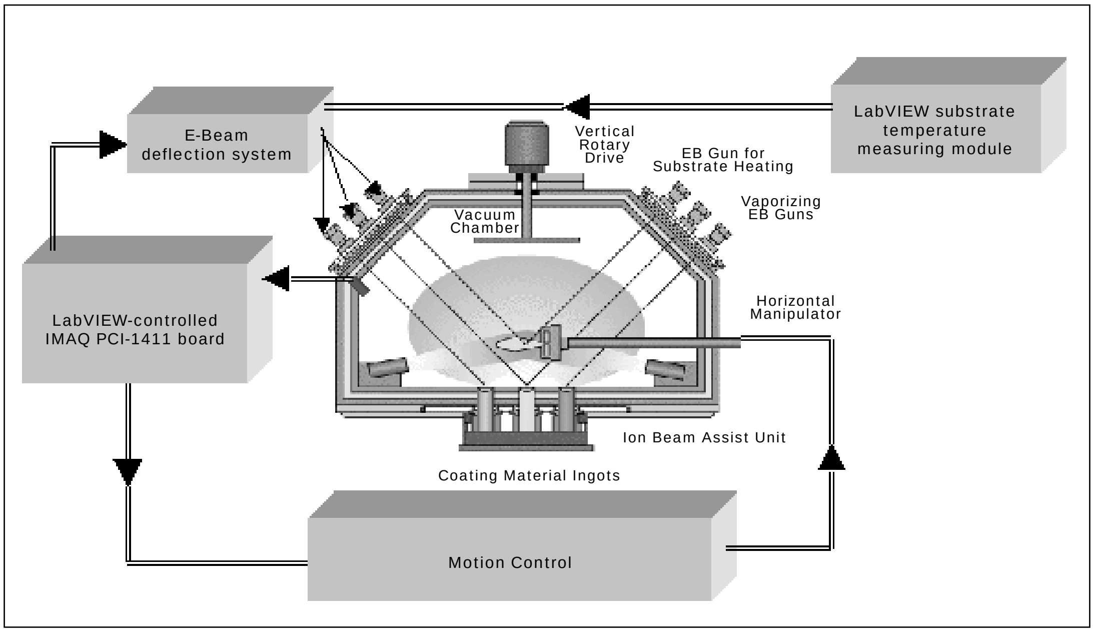
The Challenge:
Automating various operations of Electron Beam Physical Vapor Deposition (EBPVD), a coating process used in the semiconductor industry.

The Solution:
Developing a PC-based system using LabVIEW, DAQ, SCXI, and IMAQ hardware and software for real-time monitoring and control.



Schematic Diagram for EBPVD Chamber with Control Blocks Shown

Introduction
Electron Beam Physical Vapor Deposition (EBPVD) is a material coating technology where a coating (metal, alloy, or ceramic) is melted, vaporized in a vacuum, and then deposited on a component or workpiece.

A strong mechanical bond, uniform microstructure, and relatively high deposition rate make EBPVD an attractive and versatile coating process. Because the process is performed in a vacuum, it is an environmentally friendly technology, suitable as a replacement for other coating processes in many applications. This technique is capable of producing coatings for a wide range of industrial applications. However, at present the process is dependent on highly trained users and is not equipped with the automatic control capabilities to make it attractive and cost-effective in manufacturing. The ultimate goal is to have the capability to autonomously control the thickness of the coating and the rate of deposition in a real-time environment. It is necessary to integrate different aspects of process control and human-machine interface to ensure good overall performance.

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System Requirements
The three main parameters that we control in this project are the temperature of the substrate, the melt pool conditions, and effective workpiece manipulation inside the vapor plume. The figure above shows a schematic diagram of the complete process.

The workpiece is maintained at a specific temperature to ensure good adhesion of the evaporated particles. Out of the six electron beams, two are directed at graphite plates adjacent to the workpiece, which is indirectly heated through the graphite plates. The thermocouples are mounted on the graphite plates in a 5 x 5 matrix. We continuously monitor these thermocouples. This data acts as a feedback to the system that deflects the electron beam to the underheated part of the graphite plate. This arrangement guarantees that the component is uniformly heated to a correct temperature, shown in the above diagram.

The remaining four electron beams are for evaporation. The CCD camera captures the images of melt pools of these ingots. The image is acquired in the PC via an IMAQ board. Using the IMAQ Vision software with LabVIEW, this image is compared with a known good image of a melt pool. The underheated areas in the melt pool are identified in the image on the top right of the next page. The data is fed to the electron beam deflection system and the motion controller, which makes adjustments of the workpiece motion in the vapor plume based on the shape and intensity of the evaporated plume and the melt pool conditions in real time.

System Design
The system was based on a Pentium II 400 MHz PC running Windows NT 4.0. It was equipped with a PCI-MIO-16E-4 DAQ board and a PCI-1411 IMAQ color image acquisition board. An SCXI-1102 module conditioned the thermocouple signals en route to the DAQ board. We

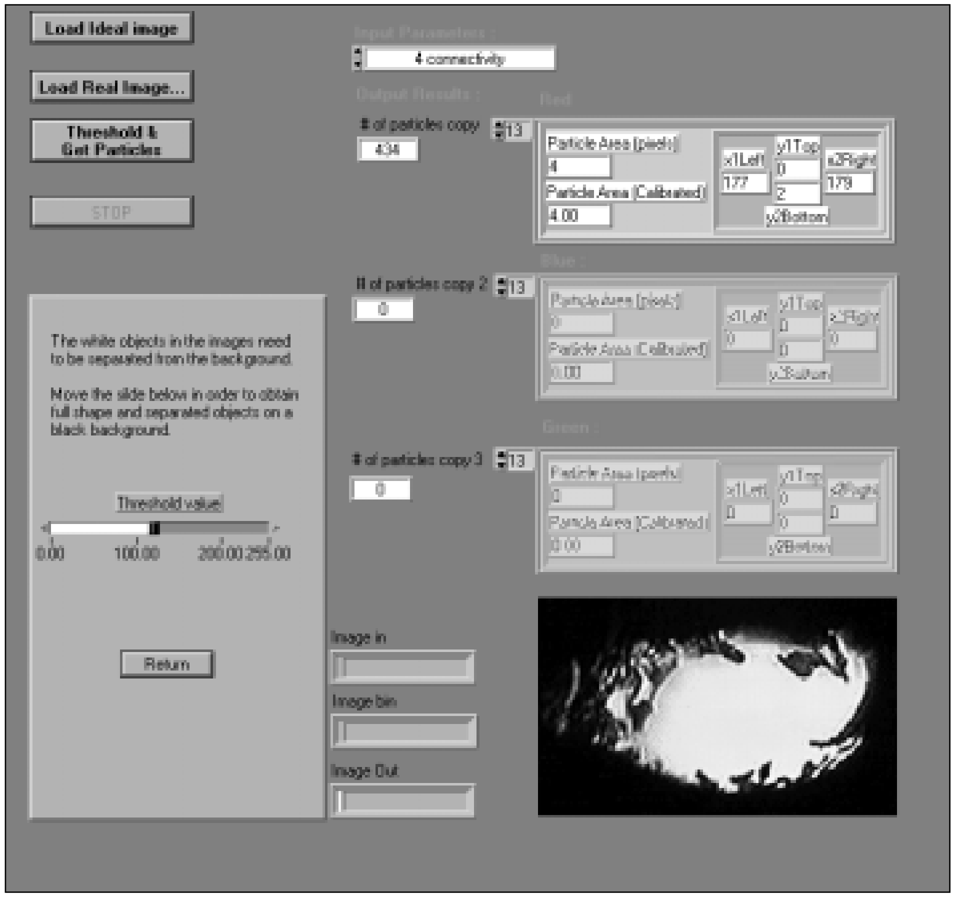
used LabVIEW to program these components and to process, display, and store the data.

There is continuous monitoring of these thermocouples using LabVIEW and the SCXI thermocouple module.

Conclusion

EBPVD is a relatively new material coating method that produces good results. It is particularly useful in thermal barrier coatings in aircraft turbine blades and in protective coatings on cutting tools. The increased deposition rates and variety of materials and techniques of the EBPVD process provide an opportunity to broaden the application of this technology into the U.S. marketplace and to expand its impact on military and commercial systems. EBPVD is also a member of a family of coating technologies that can replace the environmentally incompatible coating processes used today. EBPVD has the advantage of working with a wide variety of materials and techniques to improve performance and increase the service life of coated components.

The semiconductor industry independently estimated the domestic economic potential of EBPVD technology during the next decade to be more than $10 billion along with the creation of an additional 10,000 skilled jobs. However, a major hindrance in the process integration and control of EBPVD is that accurate comprehensive *in situ* measurements of the process parameters are often difficult and sometimes impossible because of the complexity of the process. In most cases, specially trained workers with experience need to control the operation. This work in process control is expected to make important contributions toward EBPVD process automation. ı



MeltPool Analysis Screen

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