Repair and Maintenance in High-Volume MBE Production

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Abstract

Molecular beam epitaxy is a challenging technology to implement in a high-volume production environment. Maintenance of the complex systems and delicate components play a major role in the overall success of the MBE organization. This paper will describe the development of a dedicated Repair and Maintenance group that has realized significant improvements in uptime and yield in the operation of a multi-system, production MBE fleet.

INTRODUCTION

The research and development legacy of molecular beam epitaxy (MBE) is one in which growth scientists took responsibility for system repair and maintenance. This model is clearly unacceptable for high-volume production of cost competitive materials. Maximizing uptime, throughput and yield on these complex systems requires specialization in personnel, tools and facilities. At RFMD we addressed these issues by establishing a dedicated Repair and Maintenance (R&M) group and providing them with specific tools and facilities to enhance their capabilities.

The R&M group is responsible for ensuring reliable operation of the MBE systems and maximizing the campaign length achieved between major maintenance cycles. These goals directly impact the cost of operation for the overall MBE organization. System stability enhances both throughput and yield. Maximizing campaign length avoids the loss of costly source materials and other consumables that cannot be carried over from one campaign to the next. Continuous improvement in these areas has been achieved by focusing on three main areas associated with the R&M group: Organization and training of personnel, development and application of specific software tools and the installation of specialized facilities for carrying out various maintenance functions.

ORGANIZATION AND TRAINING

In order to maximize the effectiveness of the R&M group, it has been organized into three distinct sections: the Equipment Maintenance group, the Component Build Team and Equipment Engineering. The Equipment Maintenance group has primary responsibility for scheduled maintenance activities, such as system turn-around, as well as unscheduled maintenance items that can occur over the course of a campaign. Given the number of MBE systems in RFMD's production fleet, this group maintains a consistent level of activity which is critical to keeping skills sharp. The Component Build Team focuses on the repair and rebuilding of various sub-assemblies of the MBE system, such as the source furnaces. Once again, specialization has allowed for a more consistent work flow so that activities remain well-practiced. The Equipment Engineering group provides engineering support to the Equipment Maintenance and Component Build groups. They are also responsible for continuous improvement activities related to equipment design and maintenance procedures. In this capacity they are tasked with identifying and pursuing projects that enhance the stability and reliability of MBE system hardware. Dividing the R&M group into different functional groups has provided several advantages. As already noted, we are able to maintain more consistent levels of activity in each work area, keeping skills sharp, enhancing expertise, and allowing for more focused training.

SOFTWARE TOOLS

As the MBE production capacity expanded, the need for accurate tracking of MBE system activities became essential. Database tools proved to be absolutely necessary for monitoring activity given the size of the MBE fleet and the wide range of R&M tasks. The data collected from these programs is now used to generate historical trends and help set goals that lead to cost reduction through continuous improvement.

To address this need we developed a custom application, ToolTrack, to provide activity tracking. This application consists of activity, failure codes and an interface that makes it easy to time stamp efforts. Monitoring over time has allowed us to determine which failure modes were most frequent and which activities were taking the longest. This allowed us to organize our efforts to tackle the most significant sources of downtime and system instability, see Figure 1. This chart shows data collected from ToolTrack for the top five major maintenance contributors identified in

2007 and the current contributions in 2011. Based on the pareto from 2007, actions were put into place to reduce the individual contributions.

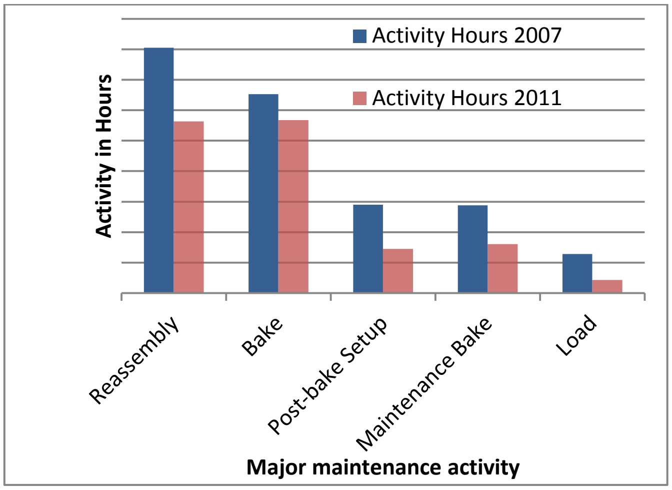

Figure 1: Major maintenance activity pareto; comparison for 2007 and 2011

For the R&M group, the recorded information from ToolTrack has proven beneficial time and again by enabling us to track and resolve issues that are directly impacting production. Dopant cell instabilities were identified by production and experimental cell modifications were tracked over multiple systems, resolving the problem, and leading to a new crucible design that eliminated the instability.

Another use of ToolTrack is in recording the effusion cell characteristics acquired from testing at the start of each campaign. Prior to the material load, the cells are mounted on the system and the chamber is evacuated to ultra high vacuum. For testing, the cell is set to a target power above standard operating conditions, and the current and voltage from the power supply, as well as the thermocouple temperature readings are recorded into ToolTrack. This information can later be used as a troubleshooting reference when diagnosing individual cell issues, and for developing expected cell operating characteristics from the historical values.

One deficiency with the ToolTrack software however was the inability to maintain the repair history, location and availability of individual system components. With the large number of system components on each MBE systems, coupled with the amount of internal rebuild work, it was realized a need for tracking component lifetime, and location. A Repairable Part Tracking program was designed for this specific purpose of addressing new demands from R&M. This new software is used for tracking the system components to provide information on location, repair history, warranty information, and all pertinent original equipment manufacturer contact information. This information is used in developing rebuild schedules that may lead to reduced component failures and increase system uptime.

MAINTENANCE FACILITIES

There are approximately 13 major maintenance cycles performed each year at the RFMD MBE facility, resulting in a large amount of hardware to be cleaned, components to be repaired, and waste generated. To handle this volume of work, the maintenance is most efficiently carried out in specialized facilities. A dedicated maintenance infrastructure was designed to support the specific requirements of the R&M group. These facilities consist of a maintenance bay, component build room and wet scrape area.

The maintenance bay is necessary for dealing with all chemical cleaning and baking of parts that need to be performed. The area is equipped with acid and base wet decks used for the cleaning of arsenic and phosphorus contaminated parts. There are various exhausted work tables for rebuilding pumps, heaters, and other contaminated components, tube furnaces for high temperature part outgassing, and vacuum ovens for high temperature vacuum outgassing. Effective chemical cleaning and vacuum baking of system components ensures minimal contaminates are introduced to the production systems that may impact cleanliness and result in added downtime.

In trying to determine the optimal procedure for cleaning large cryo-panels from the production systems, we experimented with various methods. External cleaning services were attempted, but there were multiple obstacles preventing its adoption; the cost was high, cryo-panels were out of the facility for extended periods of time, and cryo-panels were being returned damaged resulting in additional downtime and cost. Internal cryo-panel cleaning efforts started with dry scraping the deposits into the base of the chamber. To eliminate the potential flare-ups associated with the dry scrape process, a wet scrap of the cryo-panel was attempted. This method work very well, and resulted in a cleaner panel in a shorter time, but also resulted in a contamination hazard. In an effort to drive down the major maintenance cycle time, improve the quality of cryo-panel cleaning, and contain the generation of hazardous waste, the decision was made to invest in a dedicated wet scrape area.

The wet scrape area was brought online at the start of 2008, and became the standard facility used for cleaning cryo-panels, and other large contaminated components. To provide the most efficiency and hazardous material containment, the area is designed with three separate rooms, each used for a specific purpose; gowning, wet scrape, and wet bead blasting. The gowning area is an isolated “clean” area used as a dressing room for putting on all required personal protective equipment prior to entering the wet scrape room. The wet scrape room is a designated hazardous area and requires supplied breathing air at all times. This room is set up to handle large contaminated components, and has the ability to provide three technicians breathing air, pressurized water, pneumatic tool connections, electric crane hoist, and hazardous waste recovery. As this wet scrape area came online and became fully utilized, it made a noticeable impact on the decontamination activity time as illustrated in Figure 2.

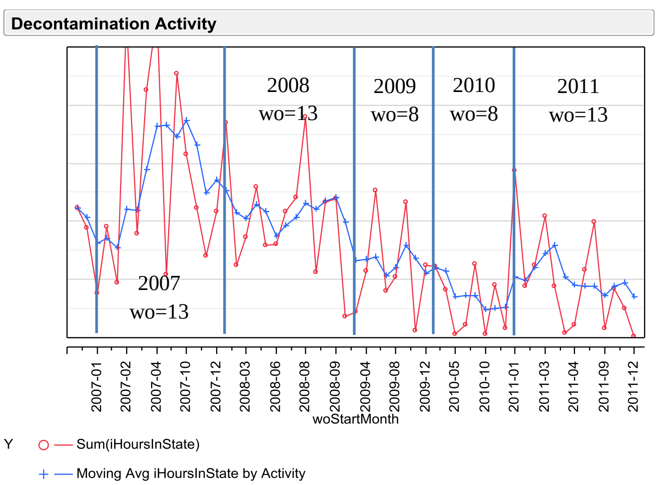

Figure 2: Downtime in hours for major maintenance decontamination activity. The number of major maintenance work orders (wo) per year is indicated.

In a separate portion of the wet scrape area is the wet bead blast system used for the cleaning of growth platens and other small molybdenum hardware. The value of the wet bead blast system is the elimination of the long chemical etch used to remove deposited material from the platen following a campaign. Eliminating the lengthy etch step has reduced chemical usage, waste generation, and most importantly the deterioration of the platens and molybdenum hardware. This has extended the platen lifetime, and reduced the frequency of replacing these costly parts.

The final dedicated maintenance facility is the component build room. This room is setup to handle the rebuild of all internal components used on the production systems, and contains the necessary cell rebuild equipment. The room is equipped with a pulsed arc welder used for making high quality tantalum welds for effusion cell components, allowing for in-house fabrication of long lead time tantalum parts. An internally designed test chamber, connected to production monitoring software, is used to test refurbished effusion cells and new cell designs in UHV conditions prior to installation on a production system. This tool allows for outgassing of cells, minimizing potential contamination and helping to expose furnace problems or unexpected failures. Finally there is a dedicated residual gas analyzer (RGA) tuning station that allows an introduction of a known test gas for calibrating peak positions on the RGA systems prior to being placed on the production tools. Accurately tuning RGA systems is vital to accurately detecting vacuum leaks prior to returning a system to the production group.

The Component Build Team has utilized the component build room to resolve the problem of keeping expensive spare components in stock vs. the long lead times and ultimate high cost to avoid keeping the part in inventory. The solution is to have internal repair and rebuild capabilities for all system components. Only materials used during a rebuild need to be stocked, and since the work is performed internally, the inventory investment is minimal, and the lead time is minimized.

CONCLUSION

A large part of making MBE a competitive production technology has been managing the repair and maintenance of the MBE systems. The complexity of the MBE systems coupled with the inherent safety hazards of the materials used presented significant challenges to the R&M group. These challenges were met through a combination of organization and training along with specialized data tools and facilities. These efforts have allowed the R&M group to make a significant contribution to the overall cost effectiveness of the MBE organization.

One way of judging the continuous improvement efforts from the R&M group is through the rate of equipment failures events. The success in reducing the equipment failure event is not related to one specific tool or group, but is an overall effort by the R&M group to minimize equipment related failures. Figure 3 illustrates the continual efforts made by the R&M group to reduce the number of equipment scrap events, through component upgrade or redesign to resolve equipment failures. These efforts have resulted in a reduction in the average rate of equipment failure events by almost 75%.

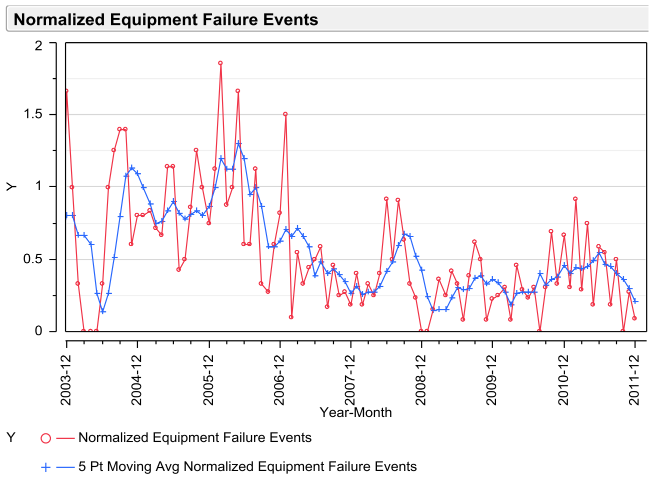

Figure 3: Normalized equipment failure events

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Acronyms

RFMD: RF Micro Devices
MBE: Molecular Beam Epitaxy
R&M: Repair and Maintenance
RGA: Residual Gas Analyzer