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PVD Process 39: Process Documentation

Documentation is the key to reproducible processing. Documentation is also important for the transfer of a process or product from research and development to manufacturing, for improving the process, and to qualify for ISO 9000 certification. There have been many instances where the lack of proper documentation has resulted in the loss of product yield, and even in the loss of the process itself.

Documentation starts with the laboratory/engineering (L/E) notebook where the experiments, trials and results of development work are recorded. Where the data are not amenable to direct entry, a summary of the findings can be entered into the L/E notebook with reference made to particular charts, graphs, memos, etc. To ensure accuracy, the L/E notebook should be hard-bound and have numbered pages, with hand-written, dated and initialed entries. If an entry is about a patentable process, product or idea, the entry should be read by another person, initialed and dated with the statement "read and understood" next to the entry. Patents are developed from L/E notebooks, and dated entries are important if questions are ever raised about when and where an idea was conceived, or a finding made. Some companies require two L/E notebooks; one for laboratory use, and another updated copy kept in a fireproof safe.

Process specifications ("specs") are essentially the "recipe" for the process and are the goal of a focused R&D process development effort. Specifications define specific functions, the critical process parameters, and process parameter limits that will produce the desired product. The specification can also define: Substrate material; materials to be used in processing; handling and storage conditions; packaging; process monitoring and control techniques; safety considerations; and any other important aspect of the process. There should be procedures allowing changes to the dated specifications. Reference should be made to the particular "issue" (date) of specifications. It is important that calibrated instrumentation be used to establish the parameter windows for the process, so that specifications are based on accurate measurements. Specifications do not usually specify equipment and non-critical process parameters. Specifications can, however, be used to define functional and stability properties of the product, and associated test methods.

Pay Attention to Details

Generating a specification entails a great deal of care to avoid missing critical details, and to allow the processing parameter window to be as large as possible (*i.e.*, a "robust" process). Writing specifications begins with the L/E notebooks from which the critical process parameters and parameter windows are extracted. In many cases, as the specifications are being written, it will be necessary to expand development work to further define critical processes and their parameter windows. Sometimes critical details are not found in the L/E notebooks, but are given by the person performing the work, or by a trained observer watching the procedures.

Manufacturing processing instructions (MPIs) are derived from specifications as they are applied to particular equipment and manufacturing procedures. MPIs often contain information not found in the specifications, but that is important to manufacturing flow, such as the type of gloves to be used with specific chemicals (*e.g.*, no vinyl gloves around alcohol; rubber gloves for acids). MPIs should be dated and updated in a controlled manner. MPIs should also include appropriate Manufacturing Safety Data Sheets (MSDSs) for the materials being used. In many cases, MPIs should be reviewed with the R&D staff involved in writing the specifications to ensure that there are no mistakes. For the same reason, the R&D staff should be included in process review meetings. In some cases, MPIs and specifications must be written from an existing process. Care must be taken to assure that operators reveal all essential steps and parameters.

Substrates are sometimes identified in a common group or lot. In such cases, it may be desirable to have a "traveler" accompany the group of substrates through the processing flow to communicate information on which specifications and MPIs were used. The travelers can then become the archival records for that particular group of products. It is important to retain samples of the product, with appropriate documentation. This procedure will assist in failure analysis, if there is a problem during further processing, or in service. Samples can be prepared periodically, or when there is a significant change in the process.

Document Information

In manufacturing, it is important to keep logs on the equipment and instruments used. Logs contain information about when and how long the equipment was used, its perfor-

mance, any modifications made, and any maintenance and service performed. The log on a vacuum deposition system, for example, should include entries such as:

- Time to crossover pressure (roughing to high-vacuum pumping).
- Time to the base pressure specified.
- Leak-up rate between specified pressure levels.
- Process being performed.
- Chamber pressure during processing.
- Fixturing used.
- Number and type of substrates being processed.
- Mass spectrometer trace at base pressure and during processing.
- Total run time.

In critical applications, the system performance can be evaluated by statistical analysis.

Logs are Useful

Equipment logs can be used to establish routine maintenance schedules, and determine the cost of ownership (COO) of specific equipment. When equipment is repaired or serviced, it is important to log the date, action, and person performing the work. Equipment logs should also contain calibration log(s) for associated instrumentation, if applicable.

Standards are accepted specifications that are issued by various organizations. "Recommended practices" are issued in cases where the "practices" have not been as rigorously tested and reviewed as the standards. Recommended practices are generally used in the same way as standards. Both may be included in specifications by name (*e.g.*, "as per Mil Spec XX"), giving specs within specs. Some organizations that develop industrial specifications and standards related to the vacuum and thin film industry are:

- U.S. Military—Military Specifications (Mil Specs) available from Document Center, 1504 Industrial Way, Unit 9, Belmont, CA 94002.
- ASTM—American Society for Testing and Materials, 1916 Race St., Philadelphia, PA 19103-1187.
- SEMI—Standards for the Semiconductor Industry, Dept. 05607, San Francisco, CA 94139.
- ANSI—American National Standards Institute, 11 West 42nd St., 13th Floor, New York, NY 10036.
- NIST—National Institute of Standards Technology (previously National Bureau of Standards), Gaithersburg, MD 20899.
- ISO—International Standards Organization, Technical Committee 112 for Vacuum Technology, available through ANSI (refer to ASTM Committee E42.94, the ANSI Technical Advisory Group).

Where to Find Specifications

Catalogs and copies of specifications and standards are available from the various organizations. Copies of patents are available from the Commissioner of Patents, U.S. Patent Office, Washington, DC 20231 (include patent number and $3 for each patent). Many government publications and publications on government-sponsored work are available from the National Technical Information Service (NTIS) (Phone: 703/487-4650). o

Bibliography:

V.S. Dharmadhikari, R.O. Lynch, W. Brennan and W. Cronin, "Physical Vapor Deposition Equipment Evaluation and Characterization Using Statistical Methods," *Journal of Vacuum Science Technology*, **A8**(3) 1603 (1990).