THIN-FILM DEPOSITION

PRINCIPLES & PRACTICE

DONALD L. SMITH

GlobalFoundries 1017

Thin-Film Deposition

Principles and Practice

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Cover photo: A thin film of the high-temperature superconductor $YBa_2Cu_3O_7$ is being deposited from a pulsed-laser vaporization source onto a ~750°C MgO substrate shown glowing orange at the top of the picture. Pulses from a UV (248 nm) KrF excimer laser enter the vacuum chamber from the right and impinge at 45° upon a sintered pellet of $YBa_2Cu_3O_7$ situated near the bottom where the white glow originates. Energy from the pulses electronically excites and partially ionizes both the vaporizing material and the 4 Pa of O_2 ambient gas, resulting in a spectacular plume of glowing plasma. The pulsed-laser deposition process is discussed in Sec. 8.4. This photo of Douglas Chrisey's apparatus was taken by M.A. Savell at the U.S. Naval Research Laboratories, Washington, D.C., and appeared on the cover of the *MRS Bulletin,* February 1992. (Used by permission of MRS and NRL.)

ration." In *Handbook of Thin Film Technology,*
York: McGraw-Hill.
rmodynamics, the Kinetic Theory of Gases, and
mbridge, Mass.: Addison-Wesley.

Chapter

3

Vacuum Technology

Most of the film deposition processes to be discussed in this book operate under some degree of vacuum. Only atmospheric-pressure CVD does not, but the same vacuum techniques of contamination reduction and process control still apply to it. Vacuum technology is a large topic which is well treated in textbooks such as those in the recommended readings list at the end of this chapter. Our purposes here are more specific: first, to become oriented to the general topic and, second, to examine certain aspects of vacuum technology that are particularly relevant to film deposition and deserve special emphasis. As we know, "Nature abhors a vacuum," so good equipment and techniques are needed to create one.

Figure 3.1 is a schematic diagram of a typical vacuum system for thin-film deposition. The purpose and functioning of the components shown will be elaborated upon in the subheadings below. Sometimes not all of these components will be required for a particular process. As shown, the substrate is introduced through a "load-lock" chamber to allow the main process chamber to remain under vacuum, because this reduces contamination and shortens substrate turnaround time. The roughing pump evacuates the load-lock chamber from atmospheric pressure after the substrate has been loaded into it and before the valve is opened into the process chamber. Once the substrate is in the process chamber, it is heated and controlled at the film deposition temperature. Process gases and vapors are metered into the chamber through mass flow-controlled supply lines, which are discussed more in Sec. 7.1.2. Process pressure is measured by a vacuum gauge that can be coupled to a motor-driven throttle valve in the pump throat for

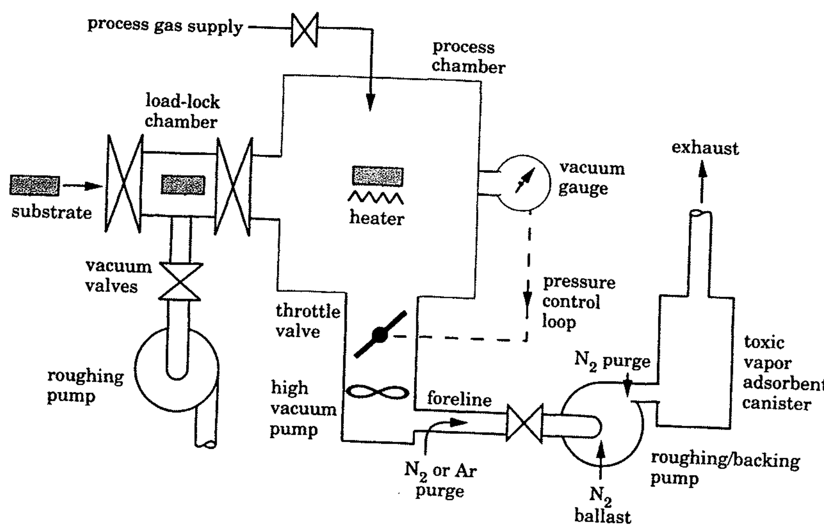

Figure 3.1 Typical vacuum-system components for thin-film deposition.

pling the vacuum gauge to the gas-supply metering valve, but that technique does not allow independent control of gas flow rate and pressure. Finally, process and impurity gases are evacuated through a high-vacuum pump followed by a "backing" pump which often serves to rough out the process chamber from atmosphere as well. For process vacuums above 10 Pa, only one stage of pumping is needed. The foreline and "ballast" nitrogen/argon purges which are shown are often required for reducing process and pump contamination, respectively. The exhaust nitrogen purge and the vapor-adsorbent canister provide safe disposal of flammable and toxic process vapors, respectively.

3.1 Pump Selection and Exhaust Handling

The principal types of vacuum pumps are listed in Table 3.1, along with their key characteristics. The choice of pumps will depend on the process vacuum level and on the properties of the vapors to be handled. Pumps fall into two categories by pumping principle: those that *displace* gas from the vacuum chamber and exhaust it to atmosphere, and those that *trap* it within the pump itself. Displacement pumps are often oil lubricated, which means that great care must be taken to avoid contaminating the process chamber with oil. On the other hand, they can pump large gas flows continuously without becoming saturated like trapping-type pumps do. Trapping pumps of the cryogenic variety are not recommended when pumping flammable vapors,

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