Educational Guide to Vacuum Coating Processing

Vacuum Technology:

Cryopumps, Sorption Pumps, and Cryopanels

A cryopump is a capture-type vacuum pump that operates by condensing and/or trapping gases and vapors on progressively colder surfaces. Figure 1 shows a schematic of a cryopump. The coldest surfaces are cooled by liquid helium to a temperature of 10-20 K (-263 to -253°C), which condenses gases such as N_2, O_2, and NO. Gases that do not condense at temperatures of 10-20 K, such as He, Ne, H_2, are trapped by cryosorption in charcoal (adsorption area of 500-1500 m^2/gram) panels bonded to the cold elements. Other surfaces are near the temperature of liquid nitrogen (77 K or -196°C), which will condense and cool vapors, such as water and CO_2, to a temperature such that their vapor pressure is insignificant. Cryopumps can be mounted in any position. The helium compressor/refrigeration unit for the cryopump can be sized to handle the requirements of several cryopumps.

The best vacuum range for the cryopump is 10^{-3} to 10^{-8} Torr. The pumping speed of a cryopump is very high in comparison with other pumps of comparable size. The cryopumping speed varies for different gases and vapors. For example the pumping speed may be 4,200 liters/sec for water vapor, 1,400 liters/sec for argon, 2,300 liters/sec for hydrogen, and 1,500 liters/sec for nitrogen. The pumping speed of the cryopump is proportional to the surface area and the amount of previously pumped gas on the surface. The cryopump has a specific capacity for various gases. The pumps are rated as to their gas capacity at a given pressure.

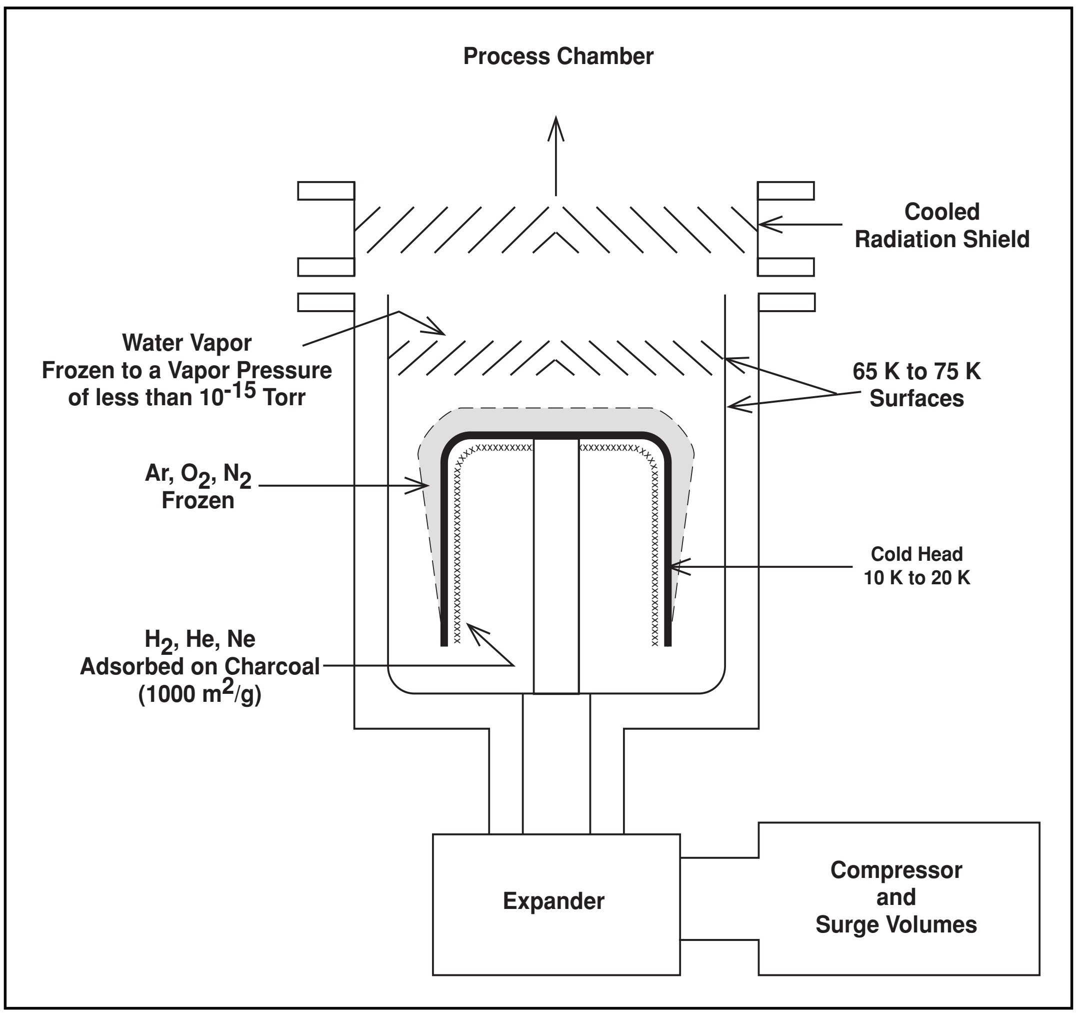

Figure 1: Cryopump with radiation shield.

Author: Donald M. Mattox, *SVC Technical Director*

For example, at 10^{-6} Torr for a 20" cryopump, the capacity might be 10,000 standard (760 Torr and 0 °C) liters of argon, 27,500 standard liters of water vapor, and 300 standard liters of hydrogen. The capacity for condensable gases is much higher than that for trapped (cryosorbed) gases, with the hydrogen capacity generally being the limiting factor. When the gas capacity for one gas is approached, the pump must be regenerated ("defrosted") in order to achieve maximum performance.

Regeneration of the whole pump can be accomplished by allowing it to warm up to room temperature, purging with a dry, heated gas, or by selectively electrically heating the cold surfaces. A typical regeneration cycle with a cryopump used in sputter deposition might be once a week, with the regeneration time requiring several hours. Recently a cryopump has been introduced that can selectively regenerate the 10-20 K surfaces and thus reduce the regeneration time to less than an hour.

The worst enemy of cryopumps are vapors, such as oils, that plug-up the pores in the cryosorption materials and do not desorb during the regeneration cycle. Cryopumps should never be used to pump explosive, corrosive, or toxic gases, since they are retained and accumulate in the system. Recently a hybrid pump has been introduced that combines a cryopumping stage, which pumps water vapor very efficiently, with a turbopump, which pumps water vapor rather poorly.

The cryopump is very desirable for non-contamination requirements such as in thin-film-deposition systems. The internal pump design determines the cool-down time, sensitivity to gas pulses, and the ability of the cryopump to be used with high-temperature processes. In processing applications, care should be taken that the pump elements are not heated by radiation or hot gases from the process chamber. For example, in thermal evaporation, the cryopumps may give a "burst of pressure" when the evaporation is started because the pump is not adequately shielded from radiant heating from the thermal vaporization source.

Sorption (adsorption) pumps are capture-type pumps in which the gases and vapors are adsorbed on activated charcoal, or zeolite surfaces in a container that is cooled directly, generally by immersion in liquid nitrogen. The adsorption of gases not only depends on the temperature and pore size of the adsorbing media but also on the gas pressure and the amount of gases already absorbed. The pump works best for pumping nitrogen, carbon dioxide, water vapor and organic vapors. Ultimate pressures of 10^{-3} Torr are easily obtained when pumping air with sorption pumps but the residual helium can interfere with helium-leak detection. These pumps are often used to pump down clean systems where the potential for contamination by a mechanical pump is to be avoided. After adsorbing gas, the pumps must be regenerated by heating to room temperature if the adsorbing medium is activated charcoal or to 200 °C if the adsorbing medium is a zeolite.

Zeolites are alkali alumino-silicate mineral materials that have a porous structure and a surface area of about 1000 m^2/g. The zeolite materials are sometimes called molecular sieves because their adsorption selectivity is based on pore size. The material can be prepared with various pore opening sizes (3Å, 5Å, 13Å, etc.) with 13Å material being mostly used in sorption pumps. The 13Å pore is about the diameter of the water vapor molecule. Smaller pores can be used to selectively absorb small-atomic-diameter gases, but not large molecules. One gram of the 13Å zeolite absorbs about 100 mTorr-liters of gas. Zeolite materials are also used in foreline traps, either cooled or at room temperature, to collect vapors.

Cryopumps and sorption pumps are very useful where very clean pumping systems are desired. If pumping water vapor or organic vapor is the concern, then an in-chamber large-area cold panel (cryopanel) cooled by refrigerants to about -150 °C may be a better answer. At that temperature the vapor pressure of water is less than 10^{-12} Torr. In the chamber the conductance to the cold panel for water vapor can be made very high. As the ice builds up in thickness on the cryopanel, the thermal transport rate is decreased and the panel must be "defrosted."

Reference:

Capture Pumping Technology: An Introduction, K.M. Welch, Pergamon Press, 1991.