EECS 143
Microfabrication
Technology

Description of a Basic Vacuum System

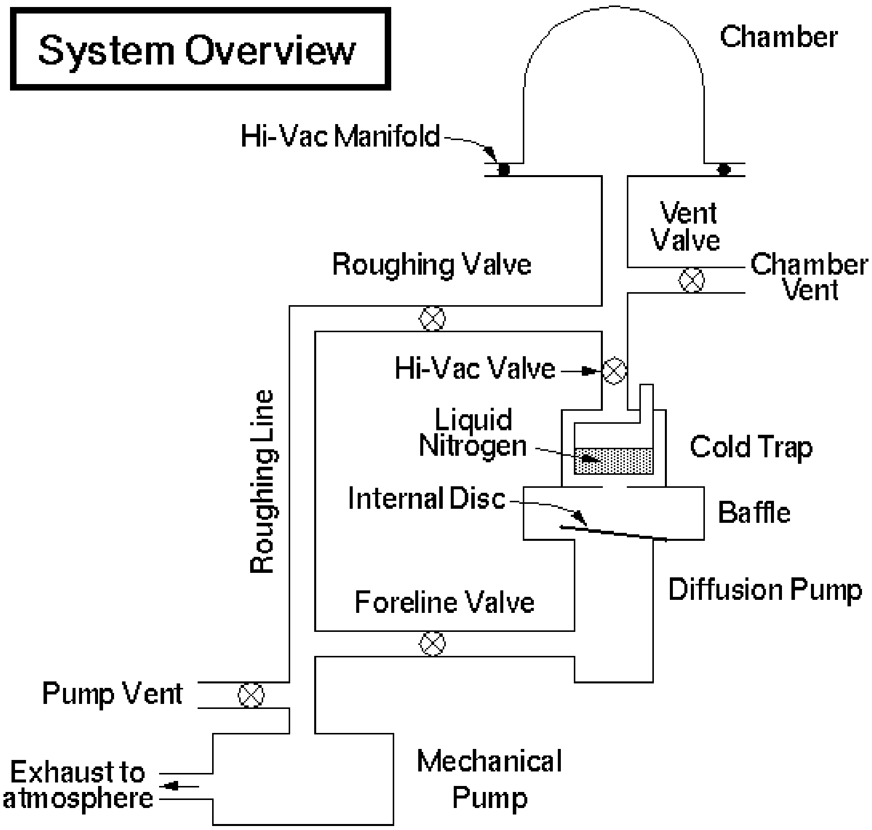

Figure 1: Configuration of a basic vacuum system.

The system, illustrated in Figure 1, contains the essential elements typically required to obtain high vacuum. The most common and reliable systems utilize three pumping devices: The rotating mechanical pump, the diffusion pump, and the cold trap. Other system components, such as valves and baffles, aid or control the action of these pumps. A graphic display of the pumping process is given below in Figure 4 (venting), Figure 5 (roughing), and Figure 6 (hi-vac).

1. Mechanical Pump

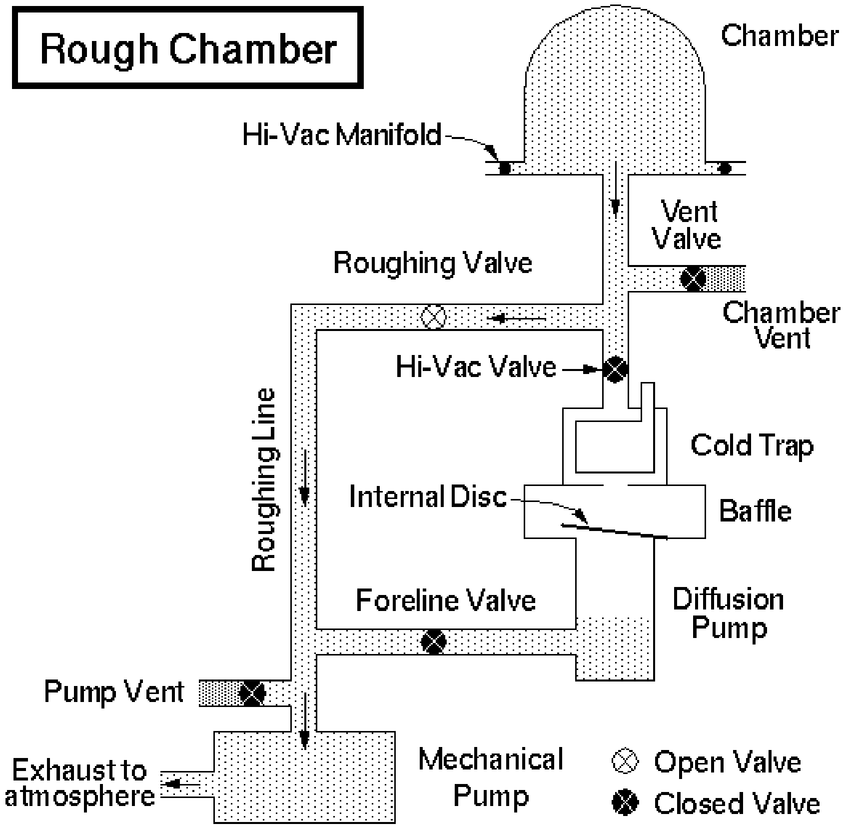

Figure 2: Mechanical Pump

(Capable of reducing pressure to about 10 millitorr.) A typical mechanical pump is shown schematically in Figure 2. Mechanical pumps physically "sweep" the air from the system, usually with a rotary device as shown. The rotor is eccentric to the pump cavity. The rotating vane (or sweep) is kept in contact with the walls of the pump cavity by means of a compression spring. Rotating vane, positive displacement pumps have large gas handling capacities, but cannot achieve high vacuum. They are used for two purposes: to remove ("rough") the bulk of the air from a system which is initially at atmospheric pressure, and, once this is accomplished, to "back" the diffusion pump, (see below), since a diffusion pump cannot exhaust against atmospheric pressure. Hence, mechanical pumps are often called roughing pumps, backing pumps or forepumps. In our illustration (Figure 1) a single pump serves for both roughing and backing. In some applications, two pumps may be used.

2. Diffusion Pump

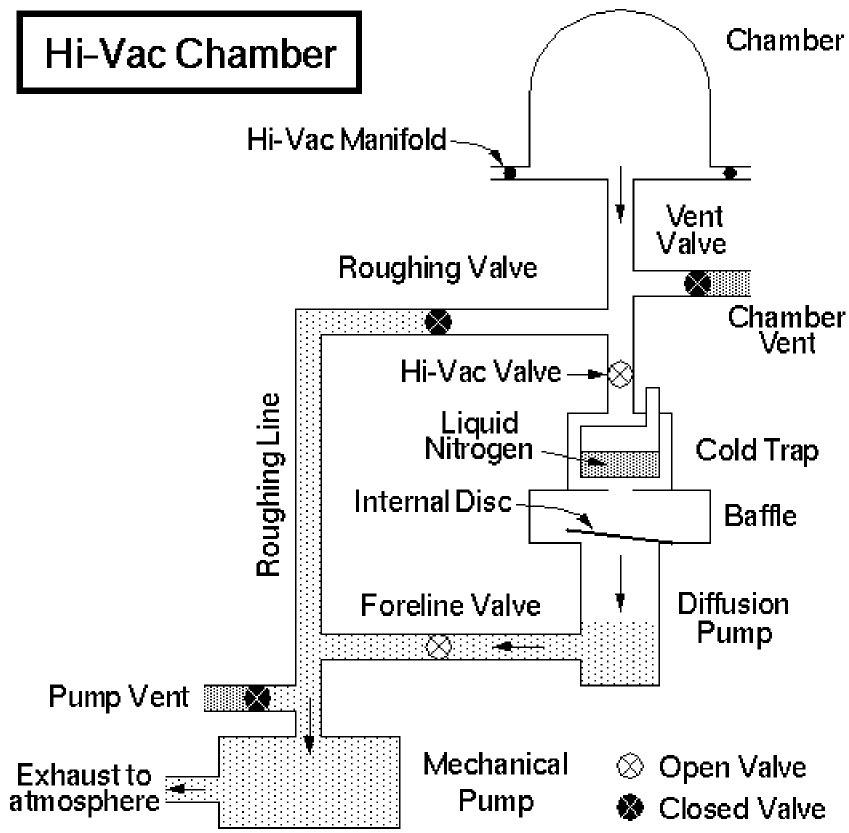

Figure 3: Diffusion Pump

(Capable of reducing system pressure to the region of 10^{-7} torr[1]). A diffusion pump has a maximum pressure against which it can exhaust; this is usually in the mtorr region. (The maximum exhaust pressure is also known as the "tolerable forepressure".) The mechanical pump noted above provides and maintains this exhaust pressure for the diffusion pump. Fast pumping action is achieved through the use of high speed jets of oil vapor which collide with gas molecules and compress them in the direction of the mechanical pump (see Figure 3). (The term "jet"is used to refer to both the vapor stream and to the nozzles from which the vapor issues.) The oil pool at the bottom of the pump is heated, causing oil vapor to be forced up the jet stack. The vapor strikes the umbrellas, and is projected downward and outward through the nozzles of the jet stack. In passing through the narrow jets, the oil vapor flows at a velocity near that of sound. The high speed vapor jet collides with gas molecules giving them a downward direction toward the foreline. The oil molecules condense on the walls of the pump which are cooled either by an air stream or by water, and flow back to the bottom pool. Thus, a continuous cycle of vaporization, condensation and revaporization takes place. Oil of very low vapor pressure is used in these pumps.

[1]1 torr = 1 mm Hg

It will be noted that the jet streams are in series; the illustrated pump is a "three-stage" type.

3. Baffle (water cooled)

Not all oil is contained and condensed by the diffusion pump. A small amount can escape toward the HiVac area of the system. This "backstreamed" oil is detrimental to the system. To contain it, a water-cooled baffle, shown in Figure 6 , is located between the diffusion pump and the cold trap. Most back-streamed diffusion pump oil molecules are condensed on the internal water-cooled baffle disc and returned to the diffusion pump in the form of liquid oil. The baffle helps keep the refrigerated surface of the cold trap operating at maximum efficiency.

4. Cold Trap

(Shown with liquid nitrogen as refrigerant in Figure 6). This device reduces pressure by condensing, or freezing out, onto its cold surfaces, condensable vapors that may exist in the system. It also prevents oil vapor from the diffusion pump from diffusing back, or "backstreaming", into the system. By removing "condensables" such as water vapor, a trap actually serves as a pump. The trap is filled after the system has been evacuated to a pressure of less than one mtorr, when most of the condensable vapors have been pumped out of the system by the mechanical and diffusion pumps.

5. Roughing Line and Valve

Exposure to atmosphere when at operating temperature will result in decomposition of diffusion pump oil. It is therefore necessary to employ a bypass line around a heated diffusion pump when evacuating a chamber from atmospheric pressure to a "rough" vacuum prior to connecting the chamber to the diffusion pump; hence, the terms "roughing line" and "roughing valve". The foreline valve and the hi-vac valve (Figure 1) serve to isolate the diffusion pump, the baffle and cold trap from the object being roughed. During roughing the roughing valve is open. When roughing has been completed (at ~20 mtorr), the roughing valve is closed before the foreline valve and the hi-vac valve are opened. The manifold vent valve admits air to the port manifold to "break" the vacuum and make possible the removal of objects after they have undergone vacuum processing. The roughing valve and the hi-vac valve must be closed during this operation if the pumps on the vacuum system are still in operation. The mechanical pump vent valve serves to admit atmosphere to the roughing line, thus bringing the mechanical pump to atmospheric pressure. It is used when shutting down the system; the diffusion pump is turned off and allowed to cool, and then the mechanical pump is turned off. Bringing the stopped mechanical pump to atmospheric pressure prevents mechanical pump oil from being drawn back into the foreline. The hi-vac valve and the foreline are usually closed during the operation, thus maintaining the diffusion pump, cold trap and baffle under high vacuum. This assures a clean system when starting up at some later date.

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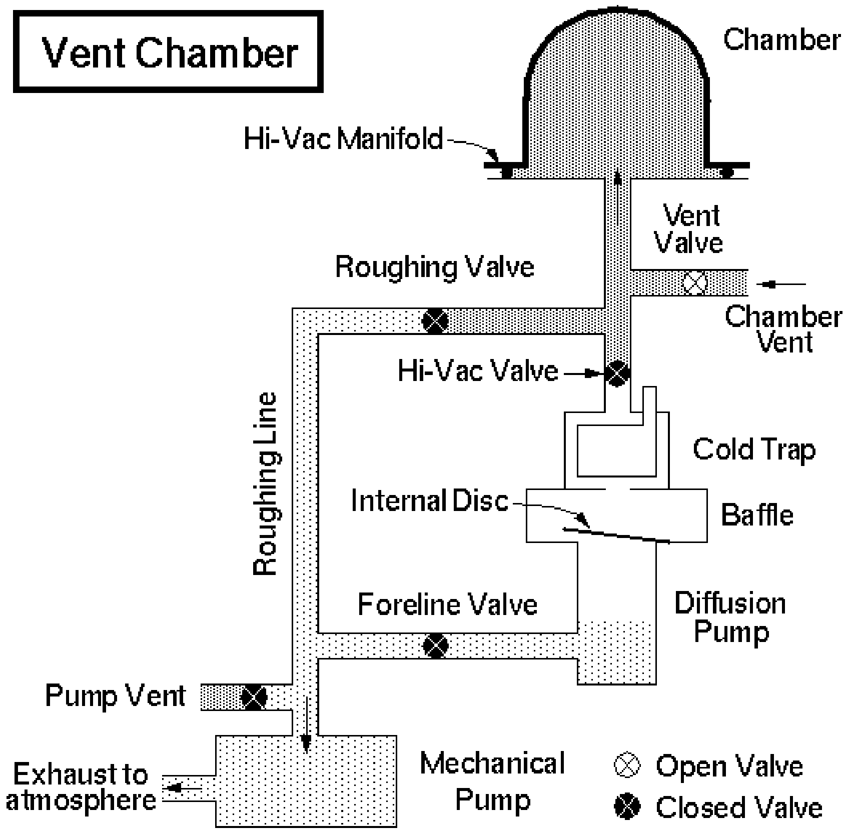

Figure 4: Configuration when the system is venting the chamber. This occurs when you place new wafers into the system. Notice that the valves that are CLOSED are dark and the valves that are OPEN are light. The regions with a darker shade are at a higher *pressure*.

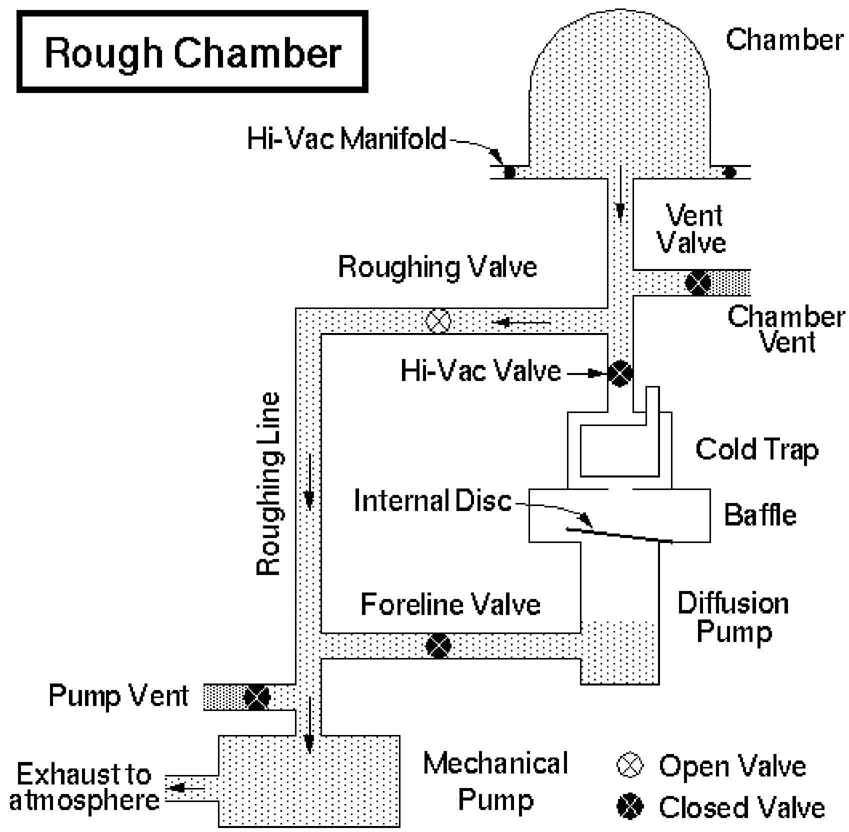

Figure 5: Configuration when the chamber is being initially pumped down or "roughed". First the vent valve is closed and then the roughing valve is opened so that the air in the chamber can be pumped out the mechanical pump.

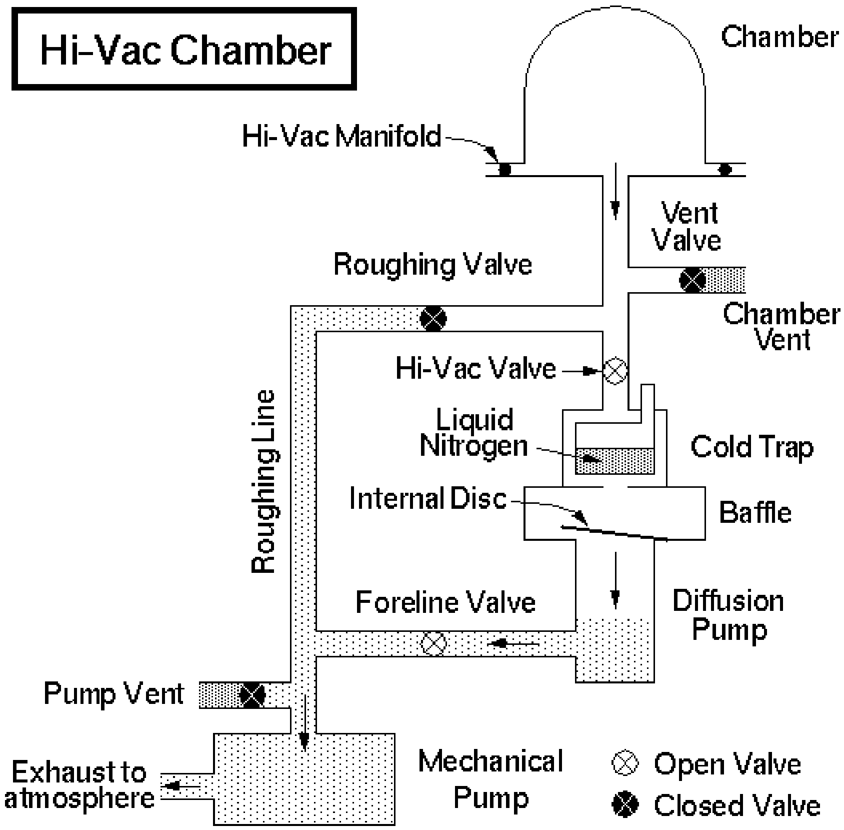

Figure 6: Configuration when the chamber is being pumped down to a high vacuum. First, the roughing valve is closed. Second, the foreline valve is opened so that back of the diffusion pump and be pumped down. Third, the cold trap is filled with liquid nitrogen. Fourth, the high-vacuum valve is opened and the chamber is pumped to a high vacuum.