Chapter 1
Using Precise Mechanisms in Modern Vacuum Technological Equipment

There are several groups of vacuum technological equipment equipped with vacuum transporting systems. These groups include: thin films coating equipment [1–4], electron and ion lithography [5], molecular epitaxy [6], surface research [7, 8], electron beam equipment for welding, melting, crystal growing; equipment for outgassing, tubeless pumping, assembling vacuum devices (in ultrahigh vacuum up to 10^{-8} Pa) [9]. It is necessary to transfer the samples, heaters, evaporators, screens, sensors into vacuum chambers of this equipment with high to very low speed and high precision. In many cases it is impossible to use any lubricants in vacuum transporting systems because of the special requirements on the residual atmosphere.

The *coating equipment for thin films* is the largest group of vacuum equipment, which uses the precise vacuum mechanisms. In this kind of equipment it is necessary to transfer the wafers or samples into the treatment area (coating, heating, cooling), to move screens of the evaporators and view-ports, to move the evaporators or sensors for measuring thickness of the film.

Every new generation of this equipment, especially equipment for optical film coating, requires a higher degree of vacuum. As it is known, the ever lower residual pressure makes worse the working conditions of the mechanisms in vacuum and decreases the reliability of the mechanisms.

In order to increase the output of the equipment makes it necessary to equip the installations with gate valves, storage devices, load-lock chambers automatic transporting systems.

The thin film coating installation (USSR design YVND-1) with electric arc evaporator and multiple working positions is shown in Figure 1.1. According to the designer's opinion the high output of the installation can be reached owing to the fact that 48 small samples, fixed to and rotating on the mandrels are coated simultaneously. The rotating mandrels fixed on the rotating carousel one by one move to the evaporation zone. To make this process possible the designer used 144 ball bearings (pos. 6, 7) which rotating at 100–300 rps at temperature 200°C in high vacuum

E.A. Deulin et al., *Mechanics and Physics of Precise Vacuum Mechanisms*,
Fluid Mechanics and Its Applications 91, DOI 10.1007/978-90-481-2520-3_1,

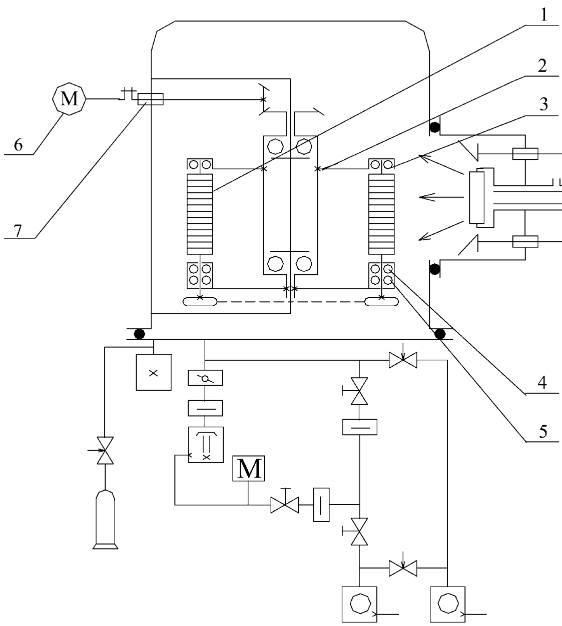
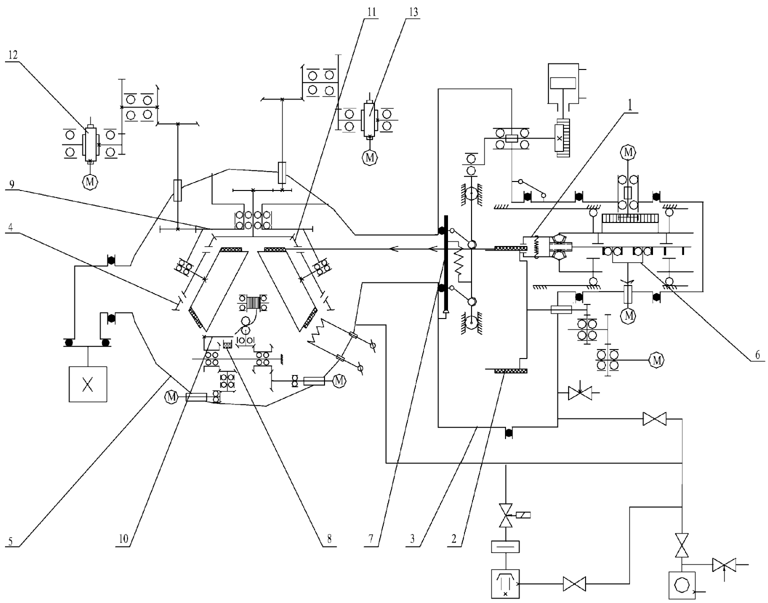


Fig. 1.1 The thin film coating installation with an electric arc evaporator: 1 – cylindrical details assembled on the mandrel; 2 – workpiece carrousel; 3, 4, 5 – ball bearings of the mandrels; 6 – motor, 7 – rotary-motion feedthrough.

(7×10^{-3} Pa). The rotating carousel and mandrels are driven through the rotary-motion with the rotating motion feedthrough (pos. 1). From experience we know that the least reliable component of the installation is a vacuum ball bearings. High output of this installation can be reached only by using a special method of maintenance. The best solution to this problem is using a diagnostic system.

The theory of technological equipment productivity [10] shows that in the case of multiple working positions installation productivity is limited by the idling duration. In the case of vacuum equipment the idling include the pumping time, which for ultrahigh vacuum (UHV) equipment can reach 10–30 hours! To decrease this waste time the designers create installations supplied with load-lock chambers.

The example of UHV installation of thin films coating (UVN-73P-2) [11] is shown in Figure 1.2. The arm of the manipulator 1 carries the samples from the storage drum 2 situated in the load-lock chamber 3 into the working drum 4 situated in the vacuum chamber 5. During the loading operation, the arm 1 has to move through the narrow slots (holes) of the gears 11 of the working drum 2. The precision of the drives 12 and 13 of the carousel and of the working drum, respectively must be quite high to ensure this loading operation. The precision of the arm positioning is about 0.2 mm at the length of its travel 700 mm.



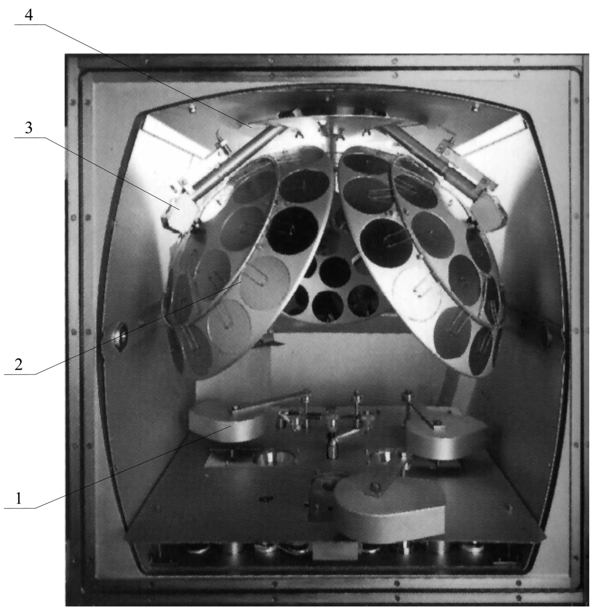


Fig. 1.2 Top: The diagram of the thin film coating installation (USSR design UVN-73P-2): 1 – the arm of the manipulator for the samples loading into vacuum chamber; 2 – storage drum; 3 – sluice chamber; 4 – working drum; 5 – vacuum chamber; 6 – drive of the arm; 7 – gate; 8 – evaporator; 9 – carrousel; 10 – evaporator screen; 11 – gear wheel of working drum; 12, 13 – the drives of the carrousel and the drum. Bottom: The view of the internal vacuum chamber mechanisms of the thin films coating installation manufactured by Balzers Company [1]: 1 – evaporators screens; 2 – working drums, 3 – drums rotation drive; 4 – carrousel.

Table 1.1 The requirements to the mechanisms of thin film coating equipment.

	Parameter	Allowable value
1	Residual working pressure	10^{-6} Pa
2	Outgassing rate of the mechanism	10^{-7} $m^3 Pa \cdot s^{-1}$
3	Temperature at the outgassing process	700 K
4	Error of linear positioning	0.1 mm
5	Error of angular positioning	0.01 radian
6	Length of the travel	2 m
7	Step of the travel	100–800 mm
8	Transporting speed	10–200 $mm \cdot s^{-1}$
9	Rotation speed	1–300 rpm
10	Time of response	0.1 s
11	Axial load	100 N
12	Torque	80 N·m
13	Number of degrees of freedom	3
14	Reliability (the probability of failure before the planned repair)	0.95

The drive of the gate 7 has to provide a normal sealing force of about 500 N. The mechanism of the evaporator 8 has to provide high smoothness of the motion of the wire during evaporation.

The intention of the designers to increase the output of this installation has lead to an increase in the number of the feedthrough mechanisms (up to 8) and ball bearings (up to 50).

Figure 1.2a shows the internal view of the vacuum chamber and the mechanisms of the coating installation for thin films manufactured by Balzers Company [1]. We can see that the internal design of the installation described above closely resembles this one. The carousel 4 with three working drums 2 should provide high productivity of the installation.

According to the theory of productivity [10], we know that as the number of the used mechanisms increases the reliability of the designed installations decreases. So, the requirements for small residual pressure and high output contradict with the requirement of high reliability of the vacuum mechanisms. Table 1.1 shows the main requirements for the mechanisms of coating equipment for thin films.

The *crystal growing equipment* requires very uniform linear motion of the growing crystal in combination with its rotation in high vacuum. Growing speed is very small (0.0001–0.002 ms^{-1}) and the time of manufacturing of one crystal can be three weeks, so the vacuum drivers, pumps and other mechanisms of these installations must be very reliable. Growing processes are usually realized at very high temperature (2000–3000°C), therefore, vacuum mechanisms must be cooled down. The designers usually use a cup-type seal in combination with different types of the drive of the monocrystal transference.

Figure 1.3 shows the kinematic and vacuum schemes of the installation of monocrystal growing with Verneuil's method. The guide screw 10 ensures the vertical transference of the monocrystal 1 being grown. The drive consisting of the motor 6, reducer 7, and coupler 9 ensures the working feed of the monocrystal 1. The mo-

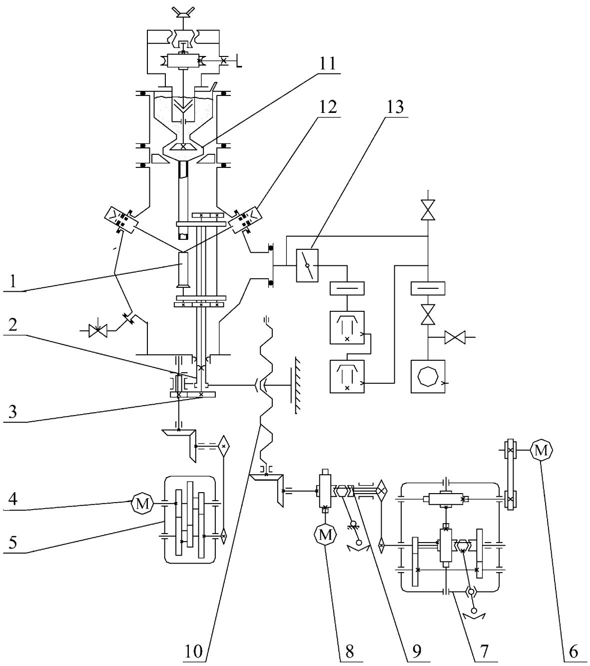


Fig. 1.3 The diagram of the installation of monocrystal growing with Verneuil's method: 1 – the monocrystal, being grown; 2 – the coupling of the vertical feeding; 3 – the drive of the monocrystal rotation; 4 – motor; 5 – reducer of the monocrystal rotation; 6 – motor; 7 – reducer of vertical transference (feeding); 8 – motor; 9 – socket of fast monocrystal transference; 10 – the guide screw of the monocrystal feeding; 11 – choker; 12 – electron gun; 13 – the gate of the vacuum system.

tor 8 ensures the fast monocrystal transference. The drive, consisting of motor 4 and reducer 5 ensures the rotation of the monocrystal 1 being grown. The linearly moving hollow spindle 2 and rotating shaft 3 are sealed with two coaxial cup-type seals. The choker 11 has to ensure the stability of the working dust feeding to the melting zone. The drive of the choker is also sealed with the cup-type seal. The melting instrument consists of two electron guns 12. The pumping system pumps the air out of the work chamber through the gate 13 till the pressure reaches 10^{-3} Pa.

The routine method of monocrystal growing, which is known as the Czochralski technique, is illustrated in Figure 1.4. This method sets high requirements on the mechanism of the touch-string monocrystal transference: speed of vertical transference is 0.0001–0.002 $mm \times s^{-1}$, length of the travel is about 500 mm, speed instability is less than 0.1%, speed of monocrystal rotation is 40 rpm. The diagram 1.4 shows that for the working (slow) monocrystal (pos. 1) vertical transference the harmonic gear reducer 2 was used in combination with nut-screw pair 3. The drive 4 is used for a fast touch-string manual transference. The drive 5 is used for the touch-string rotation.

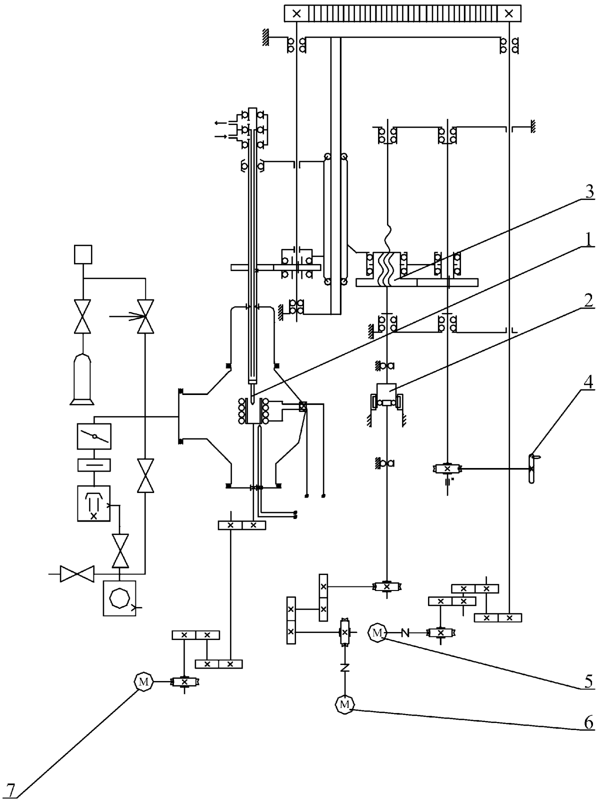


Fig. 1.4 The diagram of the monocrystal grow installation based on the Czockhralski method: 1 – touch-string of a monocrystal; 2 – harmonic drive for the monocrystal touch-string transference; 3 – nut-screw drive; 4 – drive of the fast touch-string transference; 5 – drive of the touch-string rotation; 6 – motor of the touch-string transference; 7 – motor of the touch-string rotation.

Table 1.2 The requirements to the mechanisms of crystal growing equipment.

	Parameter	Allowable value
1	Residual working pressure	10^{-5} Pa
2	Length of the travel	0.8 m
3	Transporting speed	10^{-4} mm·s^{-1}
4	Softness (uniformity) of transference	0.1%
5	Reliability (the probability of failure less work till planned repair)	0.99

So, we can see that the requirements of small residual pressure in combination with high temperatures are in conflict with the requirements of high reliability of the vacuum mechanisms. Table 1.2 shows the main requirements to the mechanisms of crystal growing equipment.

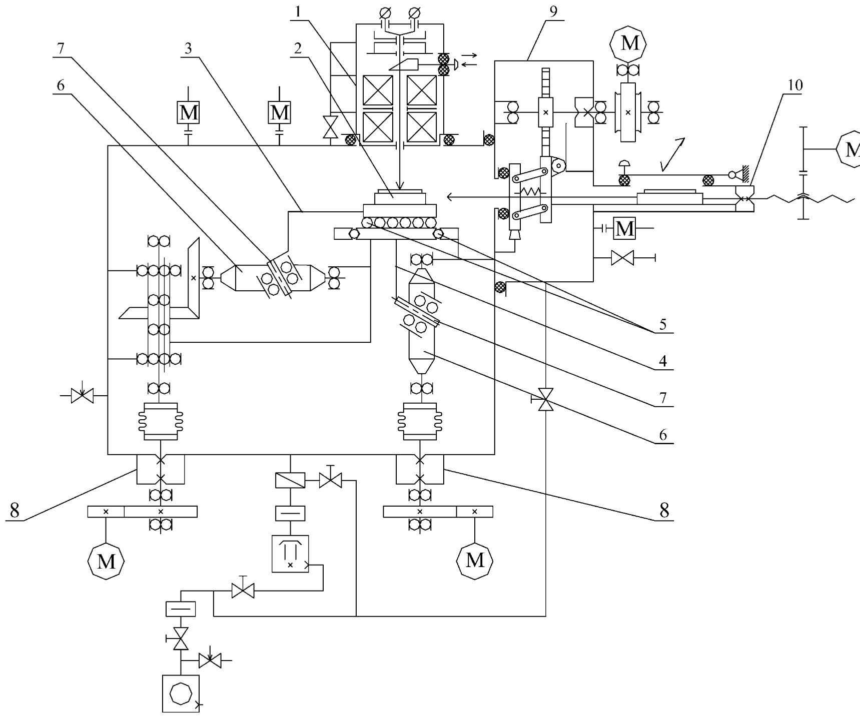


Fig. 1.5 The diagram of the electron beam lithography installation with friction drive of the table: 1 – electron beam focusing system; 2 – positioning table; 3 – drive of linear transference of the table; 4 – drive of the cross transference of the table; 5 – ball guides of the table; 6 – driving shafts of the table; 7 – inclined rolls of the table drive; 8 – rotary-motion feedthroughs; 9 – sluice; 10 – rotary-motion feedthrough of the feeder.

The *equipment of electron, X-ray and ion lithography* allows us to realize processes of direct formation of microstructures on clean surfaces in vacuum. Small range of electron or ion beam deviation (1–10 microns) and impossibility of X-ray deviation require use of precise vacuum mechanical scanning systems. Usually it is two-coordinate drives which work in indexing or continuous motion regimes in high vacuum (in case of electron or ion lithography) or in protective gas (in case of X-ray lithography). These drives must ensure high precision of positioning (error less then 0.5 micron) in the "start-stop" regime of the sample transference at high speed of the scanning (till 200 mm s^{-1}).

Figure 1.5 shows the kinematic and vacuum schemes of the electron beam lithography installation with friction drive of the worktable. The electron beam focusing system 1 forms the electron beam, which forms the required topology on the sample fixed on the positioning table 2. The positioning table is based on the ball guides 5 and is driven with two orthogonal drives 3 and 4. The original inclined rolls 7 in combination with driving shafts 6 are used for the table precise positioning. The

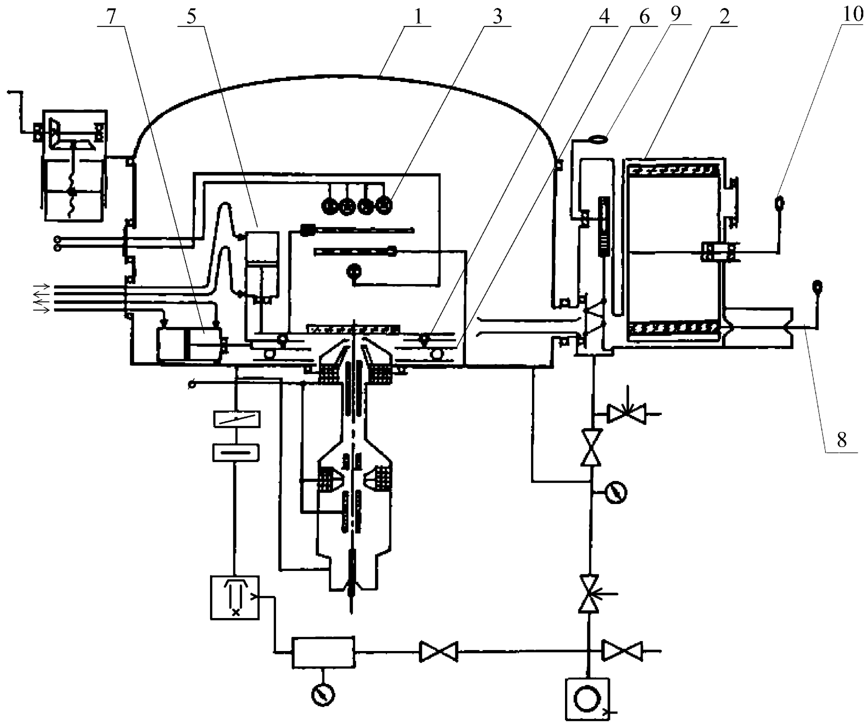


Fig. 1.6 The diagram of the electron beam lithography installation based on a hydro drive: 1 – work chamber; 2 – sluice chamber; 3 – light-emitting diodes of raster coordinate counting system; 4 – cross pilot-bearing of the coordinate table; 5 – hydro drive of cross transference; 6 – pilot-bearing of the coordinate table; 7 – hydro drive of the coordinate table transference; 8 – manual drive of the samples feeder; 9 – drive of the gate; 10 – drive of the storage drum.

precision of positioning is about 1 micron. The electron beam inclination ensures fixation the final element. The speed of the table linear transference is 50 mm s^{-1}. The load-lock chamber 9 with loading device 10 is used to shorten the pumping process and to increase the output of the installation.

Figure 1.6 shows the kinematic and vacuum schemes of another design of electron beam lithography installation. The high productivity in this case [5] is reached using the hydro-drive of a worktable situated in the work chamber 1. The load-lock chamber 2 helps to shorten the pumping time during the loading process. The positioning system includes light-emitting diodes 3, photo diodes and raster coordinate counting system. The work coordinate table is fixed on cross pilot-bearings 4 and 6 and is driven with cross hydro drives 5 and 7.

The automatic drive of the worktable must ensure the precision of the table positioning about 1 micron and fast action 0.005 sec. The requirement of high fast action contradicts in this case with the requirement of high precision in high vac-

Table 1.3 The requirements to the mechanisms of the equipment of electron, X-ray and ion lithography.

	Parameter	Allowable value
1	Residual working pressure	10^{-6} Pa
2	Length of the travel	200 mm
3	Range of the step	1–10 mm
4	Transporting speed	200 mm·s^{-1}
5	Operating speed (time of response)	0.005 s
6	Error of positioning	0.5 micron
7	Error of element stitching	0.1 micron

uum. High speeds of the drive cause oil evaporation into residual vacuum because the hydrodrive is placed inside the vacuum chamber.

Now, the designers attempt to ensure oilless UHV in the vacuum chamber and in such a way to increase the longevity of the electron-optical system. However, these attempts were not very successful because of the contradicting requirements of constant growth. Table 1.3 shows the main requirements to the mechanisms of equipment of electron and ion lithography.

The *equipment for assembling vacuum devices* exists in the form of the equipment of electron-beam welding, equipment of high frequency current soldering and equipment of assembling vacuum devices and cold welding. The *equipment of electron-beam welding* and the *equipment of high frequency current soldering* use high vacuum, about 10^{-4} Pa, because this pressure ensures enough length for traveling of the electrons in an electron beam and also sufficient cleanness of the surfaces being joined at processes of welding or soldering.

Figure 1.7 shows the kinematic and vacuum schemes of the electron beam welding installation of the carousel type. Electron gun 1 welds the components fixed to the spindle 2. Drive 3 of the spindle vertical transference takes the detail to the work zone. Rotary-motion feedthrough 4 with cup-type seal is used for spindle rotation. Cross wheel 6 is used for periodical carousel turn. The shaft of the carousel is sealed by a cup-type seal 7. The nut-screw pairs 9 and 10 are used for adjusting the electron gun. The bellow 8 plays the role of linear motion feedthrough. The ultimate residual pressure is limited because of the use of the cup-type seal.

Figure 1.8 shows the kinematic and vacuum schemes of the installation of ultra-high frequency (UHF) soldering in vacuum. The installation contains three similar drives, every one of which contains motor 1, reduction gear 2, bellows sealed rotary-motion feedthrough 3. The left one of these drives is used for the spindle 4 vertical transference on the length higher than 500 mm. The middle one is used for the periodical carousel 5 rotations. The right one is used for the periodical carousel horizontal transference by the nut-screw pair driven by gear 8. The carousel is shown in its left position. After the carousel transference has reached its right position, the spindle 4 rises about 50 mm upwards and its gear 7 comes into coupling with gear 5 of the carousel. Then the middle drive turns the carousel in the next position and

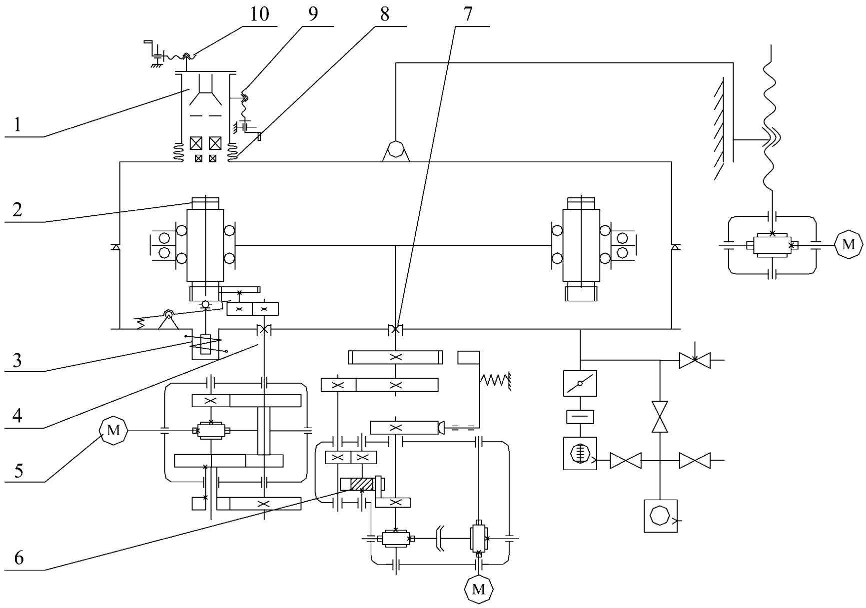


Fig. 1.7 The diagram of the electron beam welding carousel installation: 1 – electron gun; 2 – spindle with the detail being worked; 3 – drive of the spindle vertical transference; 4 – rotary-motion feedthrough; 5 – motor of the spindle rotation; 6 – cross wheel for periodical carousel turning (rotation); 7 – rotary-motion feedthrough.

the left drive raises the component being soldered to the upper position (inside UHF coil 6).

The large number of different kinematic pairs reduces the reliability of this installation. The bellows sealed rotary-motion feedthrough 3 ensure precision at small angles (0.01–0.02 radian) and is more suitable for use in an oilless ultrahigh vacuum applications.

The *equipment for assembling vacuum devices and cold welding* use the ultrahigh vacuum which ensures good emission ability for welded vacuum gauges. In case of night vision 3 assembling the working pressure in vacuum chamber must be about 5×10^{-9} Pa.

The length of the travel of the transporting mechanisms must allow the transference of a welded component (cold cathode in case of night vision gauge) from one vacuum chamber to another one through the vacuum gate. This distance can reach 1 meter. The precision of transporting mechanisms must ensure precise positioning of the component being welded in ultrahigh vacuum.

The kinematic and vacuum scheme of the simplest installation of photoelectron gauge assembling in vacuum is shown in Figure 1.9. The photo-cathode is activated by the radiation passing through the window 12 into the work chamber 1 at work pressure 5×10^{-9} Pa. The linear motion feedthrough 4 transfers the activated cath-

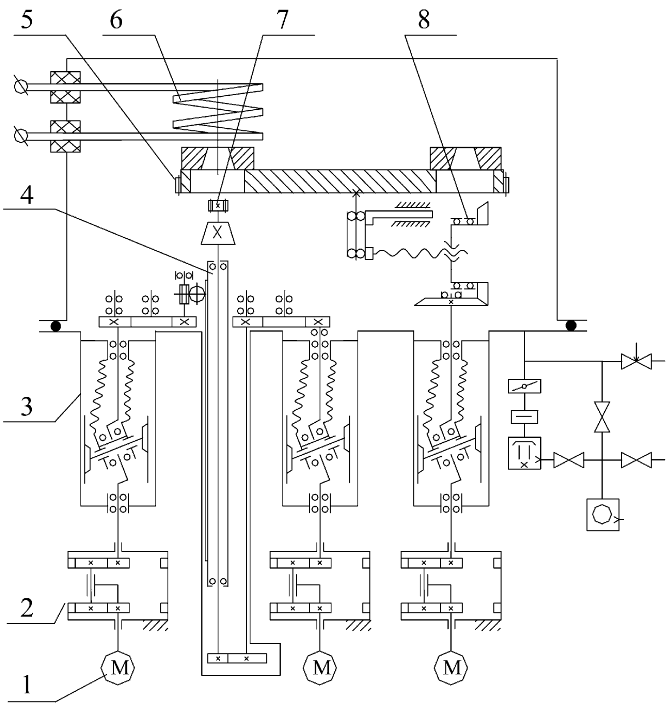


Fig. 1.8 The diagram of the installation of ultrahigh frequency (UHF) soldering in vacuum: 1 – motor of the rotary-motion feedthrough; 2 – reduction gear; 3 – bellow sealed rotary-motion feedthrough; 4 – spindle for the detail being worked vertical transference and rotation; 5 – gear for the carousel rotation (now carousel is shown in its left position); 6 – the coil of UHF inductor; 7 – spindle gear (coupling with gear 5 at carousel rotation in the right position of the carousel); 8 – drive of the carousel transference (left–right).

ode into the photoelectron gauge 2 being assembled through stem 3 of the gauge. To ensure a good quality of the photo-cathode, the spectrum of the residual gases should not contain any carbohydrates, oxygen, water vapors and methane. The resulting outgassing rate has to be lower than 10^{-8} m^3 Pa s^{-1}. The maximum temperature of outgassing is 400°C. The final pumping is done with vacuum pumps 7, 8 and cryogenic adsorption pumps 9, 10. The rough pumping is done with rough-vacuum pump 11 and adsorption pumps 9, 10.

The requirements to the linear-motion feedthrough are the following: photo-cathode positioning against the window 12 with precision 0.1 mm; the stock of the feedthrough 8 deviation below 0.2 mm; the axial load on the stock of the feed-through higher than 400 N at the gauge assembling.

Table 1.4 shows the main requirements to the mechanisms of the equipment of vacuum devices assembling and cold welding.

The *equipment of molecular beam epitaxy* is designed for the growing of thin monocrystal films with the use of a set of molecular or atomic beam sources. The

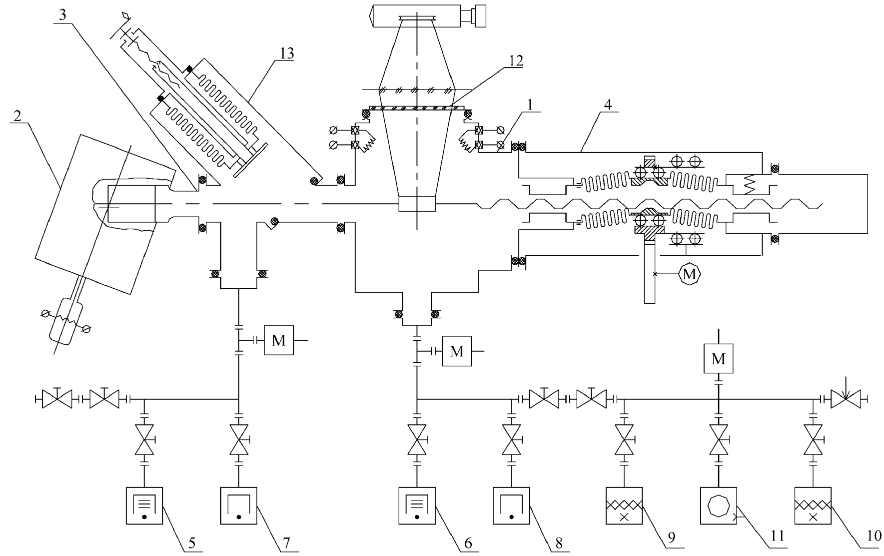


Fig. 1.9 The diagram of the installation of photoelectron gauge assembling in vacuum: 1 – work chamber for photo-cathode forming; 2 – the photoelectron gauge being assembled; 3 – stem of the photoelectron gauge; 4 – linear motion feedthrough; 5, 6 – cryogenic sorption pumps; 7, 8 – vacion pumps; 9, 10 – adsorption pumps; 11 – rough-vacuum pump.

Table 1.4 The requirements to the mechanisms of the equipment of vacuum devices assembling and cold welding.

	Parameter	Allowable value
1	Residual working pressure	$5 * 10^{-9}$ Pa
2	Outgassing flow from the mechanism	10^{-9} $m^3 \cdot Pa \cdot s^{-1}$
3	Length of the travel	1 m
4	Error of positioning	0.2 mm
5	Axial load in welding mechanism	100–1000 N
6	Reliability (the probability of failure less work till planned repair)	0.99

main condition of thin monocrystal films growth is the cleanness of the wafer surface during the coating process which could last 10–30 hours. To ensure such cleanness, the gas pressure in installation must be about 10^{-9} to 10^{-10} Pa. The time to reach such ultrahigh vacuum could be from several days to 1–2 weeks. It means that the reliability of this equipment including the vacuum mechanisms must be very high.

The temperature of outgassing heating can be up to 450°C. Ultrahigh vacuum in combination with high temperature reduces the reliability of the mechanisms and it contradicts with the requirement of high reliability of the equipment.

Figure 1.10 shows kinematic and vacuum scheme of the simplest installation of molecular beam epitaxy. The chambers of the evaporators 1, 2, 3 contain the certain

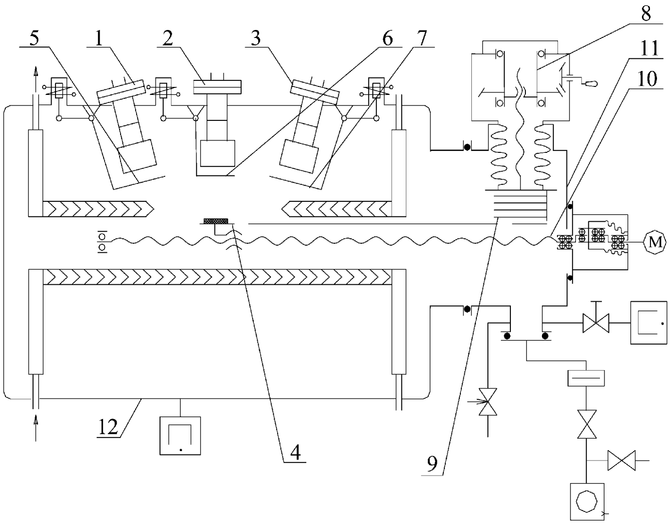


Fig. 1.10 The diagram of the installation of molecular beam epitaxy: 1, 2, 3 – evaporators; 4 – the carrier with the sample; 5, 6, 7 – the screens of the evaporators; 8 – linear motion feedthrough for the carrier transference; 9 – the samples magazine; 10 – the carrier drive; 11 – sluice chamber.

Table 1.5 The requirements to the mechanisms of the equipment of molecular beam epitaxy.

	Parameter	Allowable value
1	Residual working pressure	$5 * 10^{-10}$ Pa
2	Outgassing flow from the mechanism	10^{-10} $m^3 \cdot Pa \cdot s^{-1}$
3	Outgassing temperature	450°C
4	Error of positioning	0.2 mm
5	Number of degrees of freedom of transporting mechanism	3–4
6	Reliability (the probability of failure less work till planned repair)	0.999

materials coated on the sample 4. The screens 5, 6, 7 are used for control of the flows of the materials being evaporated. The linear motion drive 7 transfers the container 9 with the stored samples in vertical direction. Linear-motion feedthrough 10 transfers the carrier with the sample 4 from the container 9, situated in the load-lock chamber 11 to the work chamber 12. The total outgassing rate has to be below $10^{-9}m^3$ Pa s^{-1}. The vacuum chamber is pumped by vacuum pumps and cryogenic sorption pumps during 1–2 weeks. This installation has to work without repair during 0.5–1.5 years and the requirement of its reliability are unusually high.

Table 1.5 shows the main requirements to the mechanisms of the equipment of molecular beam epitaxy.

It is obvious that the way to eliminate these contradictions is to design new mechanisms based on new principles. These mechanisms must be of high reliability. The

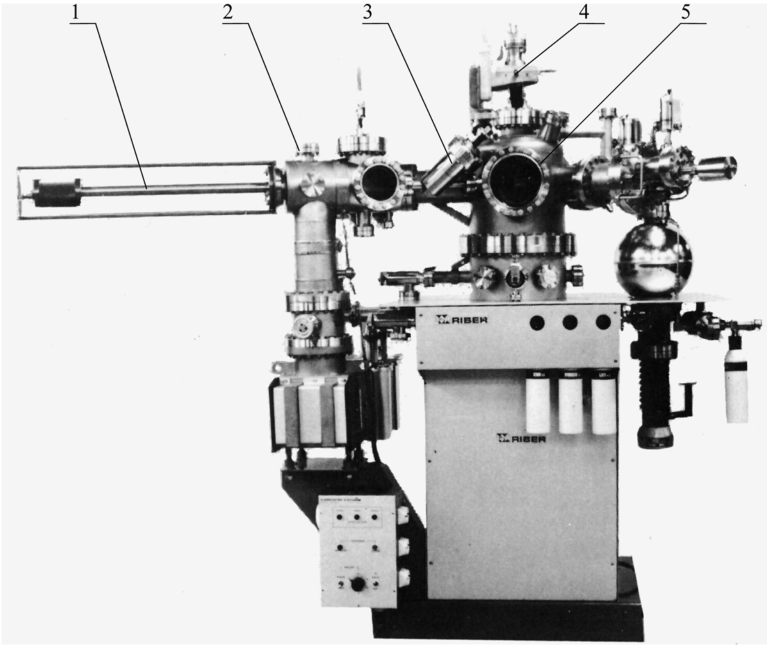


Fig. 1.11 The general view of the analytical installation of Riber Co. [8]: 1 – two degrees of freedom magnet vacuum manipulator; 2 – sluice chamber; 3 – inlet vacuum gate valve (inclined design); 4 – positioning vacuum manipulator; 5 – work chamber.

other way is the developing of better diagnostic methods as well as the rules of maintenance and repair.

The *surface research equipment* enables a number of processes which can protect the effective electronics devices appearance/scanning.

These processes include:

- the uniformity of surface analysis;
- the impurity or doped level analysis;
- the impurity or doped level distribution analysis;
- the surface structure analysis.

Most methods work by analysis of the secondary particles which appear as a result of the bombardment of the surface by primary particles. For the practical realization of this principle, it is necessary to use a drive which realizes the sample positioning with standard error of positioning the characteristic dimensions of the working primary beam. Usually these dimensions: d – diameter of the primary beam crossover and h – definition in depth are ranged betwen 10 and 1 microns.

All methods of surface analysis are very sensitive to the cleanness of the surface which directly depends on vacuum degree. It is known that the time of clean surface conservation: $T_a = 4 \times 10^{-4} \times p^{-1}$ s, where p is the residual pressure, Pa. So, at

Fig. 1.12 The scheme of the research and technology instruments positioning [7] in vacuum about the searched wafer: 1 – searched wafer; 2 – detector of the secondary ions; 3 – secondary ions mass-spectrometer; 4 – electron gun for Auger analysis; 5 – X-ray source; 6 – energy analyzer; 7 – ion gun; 8 – ultraviolet source; 9 – micro focus electron gun; 10 – electron gun; 11 – Faraday cup.

pressure 10^{-7} Pa this time is only about 1 hour, which is too short for the analysis. Usually, the surface research equipment requires a working pressure of 10^{-8} Pa.

The general view of the analytical installation of Riber Co. [8] for LEED, AUGER, ESCA, SIMS analysis is shown in Figure 1.11. The analyzed samples are transferred by the manipulator 1 from the load-lock chamber 2 through the inlet vacuum valve 3 to the work (analytical) chamber 5, which is pumped with UHV pumping system.

Different analytical instruments include SIMS analyzer, AES electron gun, X-RAY gun, energy analyzer, ION gun, ultraviolet source, SAM Microfocus electron gun, flood gun, Faraday cup, and others. These instruments work properly if the analyzed surface is kept in certain positions at high precision in respect to the instrument.

The scheme of the research and technology instruments positioning [7] in vacuum above the analyzed wafer 1 is shown in Figure 1.12. We can see that differ-

Table 1.6 The requirements for the mechanisms of the surface research equipment.

	Parameter	Allowable value
1	Residual working pressure	10^{-9} Pa
2	Number of degrees of freedom of transporting mechanism	6
3	Length of the travel along X, Y axes,	40 mm
	along Z axis	20 mm
4	Error of linear positioning	1 micron
5	Range of angular rotation of a sample around X axis;	360°
	around Y axis;	100°
	around Z axis	360°
6	The accuracy of angular readout	1 angular sec
7	The angular drive accuracy	10–50 microns
	The axial drive accuracy	0.5–1 microns

ent instruments like the detector of the secondary ions 2, secondary ions mass-spectrometer 3, electron gun for Auger analysis 4, X-ray source 5, energy analyzer 6, ion gun 7, ultraviolet source 8, micro-focus electron gun 9, electron gun 10, Faraday cup 11 require the certain and precise orientation in UHV conditions.

Table 1.6 shows the main requirements for the mechanisms of the surface research equipment.

The *equipment of vacuum scanning microscopy* enables observing surface morphology with atomic resolution, measuring atomic forces and energy, analyzing the structure, topology and chemical variations in the composition without distortions caused by the adsorbed gases. The general view of high vacuum scanning microscope is shown in Figure 1.13a. The internal mechanisms of the microscope are mounted on a vacuum flange as shown in Figure 1.13b. The principle of operation of a scanning microscope is shown in Figure 1.14. The piezo drive 7 (piezo tube) ensures scanning motion of the sample 6 in the range 3–5 microns along the X, Y coordinate axes. The probe 5 deflection which corresponds to the profile of the sample 6 variation is measured using the input receiver 3 and is then sent to computer 1 through the converter 2. It is clear that the adsorbed gas film of one monolayer (0.3 nanometer) is able to distort the results of the measurement. All methods of scanning vacuum microscopy are very sensitive to the cleanness of the surface. That is the reason for using ultrahigh vacuum instruments.

Usually, different instruments of vacuum scanning microscopy, for example Scanning Tunneling Microscopy (STM), Atomic Force Microscopy (AFM) among others, are joined in one ultrahigh vacuum installation.

To ensure the required cleanness, the working vacuum in the equipment of vacuum scanning microscopy must be about 10^{-9} to 10^{-10} Pa.

The required accuracy and the minimal scanning resolution of the scanning mechanisms must correspond to the dimensions of one atom. The existing piezo mechanisms ensure scanning areas about 4×4 microns^2 with a resolution of 0.1 nanometer. This scanning area is too small for the solution of the modern tasks of nanotechnology and it must be increased to the size about 1×1 mm. This task can

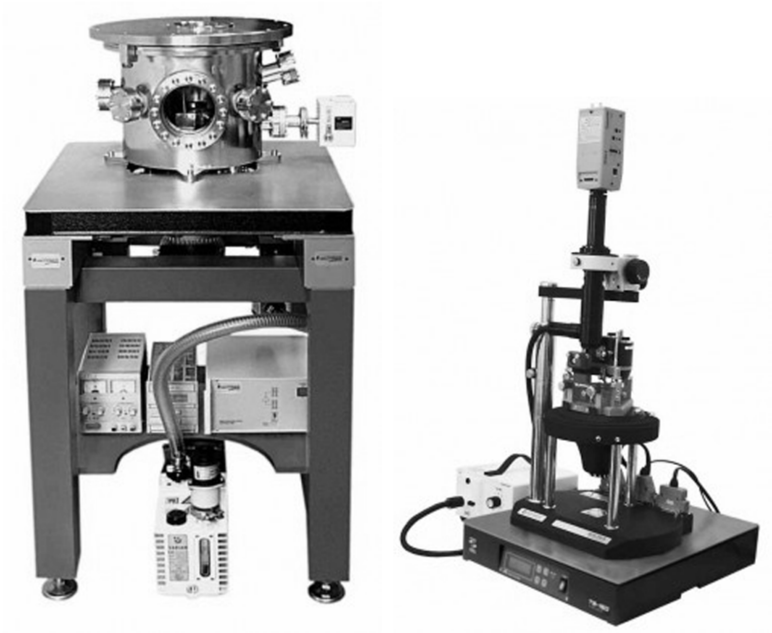


Fig. 1.13 The general view of high vacuum scanning microscope (a) and view of its internal vacuum mechanisms (b) mounted on a flange.

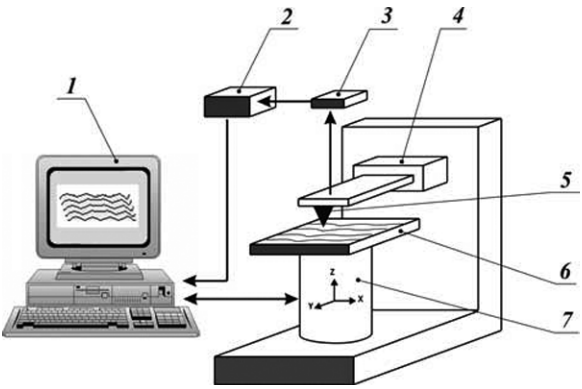


Fig. 1.14 The general scheme of scanning tunneling microscope (a): 1 – computer, 2 – converter, 3 – input receiver (of tunneling current or cantilever deflection), 4 – probe holder, 5 – probe, 6 – researched sample, 7 – piezo ceramic drive; and the scheme of tunneling microscopy (b): 1 – probe (W filament), 2 – the researched surface.

be solved using a secondary drive. The linear resolution of this secondary drive must be about 0.3 nm.

Table 1.7 shows the main requirements for the mechanisms of vacuum scanning microscopy equipment.

Table 1.7 The requirements for the mechanisms of vacuum scanning microscopy equipment.

	Parameter	Allowable value
1	Residual working pressure	10^{-9} Pa
2	Number of degrees of freedom of transporting mechanism	3
3	Length of the travel along X, Y axes,	1 mm
	along Z axis	1 micron
4	Error of linear positioning along X, Y axes	0.3 nm

Table 1.8 The main requirements for the mechanisms of vacuum technological equipment.

	Parameter	Allowable value
1	Residual working pressure	10^{-9} Pa
2	Outgassing flow of the mechanism	10^{-10} $m^3Pa{\cdot}s^{-1}$
3	Temperature at the outgassing process	750 K
4	Error of linear positioning	0.3 nm–0.1 micron
5	Error of angular positioning	30 angular sec
6	Length of the travel	2 m
7	Step of the travel	0.8–10 mm
8	Transporting speed	0.0004–300 $mm{\cdot}s^{-1}$
9	Rotation speed	0.1–300 rpm
10	Time of response	0.05 s
11	Axial load	100–1000N
12	Torque	80 N·m
13	Number of degrees of freedom	6
14	Reliability (the probability of failure less work till planned repair)	0.8–0.999

We have considered the different groups of vacuum equipment in order to decrease the tolerances of the different vacuum mechanisms.

Table 1.8 shows the main requirements to the mechanisms of vacuum equipment.

References

1. Booklet of “VAT Valves Product Line”, BPRL91E1, 1991, 12 pp.
2. Booklet of “Balzers”, The Balzers Group, BA800074PE (8801), Liechtenstein, 1987, 16 pp.
3. Booklet of “Leybold”: Linear and/or Circular Coating System, 012.8.60.52.037.02, Hanau (Germany), 1988, 4 pp.
4. Booklet of “ULVAC”: High Vacuum Equipment and System, E0203-1, 90101000ADP, Tokyo, 20 pp.
5. Pancratov I.V., Satarov G.K., Deulin E.A., et al., *Analysis of Productivity of Electron/Ion-Lithography Equipement*, Electronika, Moscow, 1986, 44 pp. [in Russian].
6. Booklet of “Riber”, MBE 608.15H82.710, 1988, 16 pp.
7. Booklet of “Leybold–Heraeus”: Leybold–Heraeus in Surface Analysis and Laser Mass-Spectrometry. A Short Portrait, 190-1000.2/2494, Köln, 1985, 8 pp.
8. Booklet of “Riber”: 608.40j595, Ruel, Malmaison (France), 1988, 803 pp.
9. Kostin A.B., Filimonova G.A., Technological installations for photoelectron tubes manufacturing with usage of transference method, *Electronica* **15**, 1983, pp. 217–255 [in Russian].

10. Shaumian G.A., *The Complex Automation of the Technological Process*, Mashinostroenie, Moscow, 1973, 640 pp.
11. Deulin E.A., *Mechanics and Physics of Precise Vacuum Mechanisms*, Vol. 1, Vladimir State University, 2001, 176 pp. [in Russian].