XHV INTEGRATED PROCESS WITH MAGNETIC LEVITATION TRANSPORTS

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SUMMARY

Extreme high vacuum (XHV), below 10^{-10} Pa, can result in no surface contamination by adsorption of gases and offer an ideal ultraclean environment which lasts long enough to artificially synthesize advanced materials with atomic manipulation. An XHV integrated process with magnetic levitation transports has been developed in order to transfer substrates long distances from one instrumented vacuum chamber to another without any contamination on the ultraclean substrate surface. The process consists of vacuum chambers, pumps, gauges, gate valves, transports for the main line and sidetrack line and so on. The integrated process has five main line chambers and six sidetrack line chambers with connections to six chambers with instruments. A main line has a connection-chamber to join a main line chamber and a sidetrack line chamber which can attach chambers with such instruments as surface analyzers, film preparation and so on. Magnetic levitation transports are installed into the line chambers because they have no sliding parts to generate dust particles and outgassing which may extensively damage ultraclean substrate surfaces and environments. One transport for the main line electromagnetically levitates a carrier and transfers it by linear motor drive. The other transport for the sidetrack line levitates a carrier by $YBa_2Cu_3O_{7-x}$ superconducting magnet discs and mechanically transfers it by means of pinning effect. The levitation transports can transfer a substrate from one connected chamber to another with a pressure change of less than 10^{-10} Pa.

INTRODUCTION

Extreme high vacuum (XHV) below 10^{-10} Pa which contains few gas molecules and atoms can cause almost no surface contamination by absorption. An excellent laboratory to study and develop advanced materials on an atomic scale can be established in an XHV environment because it can offer and maintain an ideal ultra clean environment for a long enough time to artificially synthesize advanced materials with manipulation of atoms. The study and development of materials on an atomic scale requires many operations such as sample cleaning, deposition, etching, surface analysis, performance testing and so on as well as an XHV environment, but it is impossible to carry out all operations in the same vacuum chamber because the chamber becomes so large due to the installation of all material operation components and instruments into one chamber. It takes a long time to acquire the XHV environment once the chamber is exposed to atmosphere for change of instruments or replacement of the components.

The XHV integrated process, therefore, consists of lots of continuous operations in XHV joined by a transfer system because it is more practical and efficient to carry out each operation in individual connected chambers.

We have successfully developed the extreme high vacuum integrated process with two types of magnetic levitation transports using no sliding mechanism and could transfer a sample in the pressure change of less than 10^{-10} Pa (ref.1). The problem of the first developed XHV integrated process is the limitation that the process can not share more than three connected chambers and requires large space for the installation due to a 2 stage transfer system with sliding magnetic transports to deliver the sample from sidetrack to connected chambers.

The purpose of this work as a second step is to downsize the XHV process to increase the number of the connected chambers by means of simplifying the electromagnetic levitation transport for the main track line and introducing direct sample delivery between the carrier of the side track line and the sample stage of connected chambers.

EXTREME HIGH VACUUM INTEGRATED PROCESS

Figure 1 shows the schematic diagram of the developed XHV integrated process with magnetic levitation transports and Figure 2 shows the whole photograph of the process. The process consists of four main track vacuum chambers connected in series, five sidetrack chambers standing in a row, five coupling chambers, six connected instrument chambers, vacuum pumps, pressure gauges, and valves. The connected instruments with the process are three film preparation chamber (MBE & two RfmsVD) and three surface analysis chambers (SAM, ESCA & AFM). Production of the XHV environment requires a very low outgassing chamber, high sensitivity gauge system, high performance vacuum pumps and so on. Type 316L stainless steel employed as chamber material has no ferritic structure which causes magnetization and little intergranular corrosion at welds because of low carbon content. The surface of the inside wall of the chambers was electrolytically polished in phosphoric-sulfuric acid solution and the chambers were annealed at 823 K in a high vacuum for sufficient outgassing. Metal gate valves are installed between the main track and coupling chambers in order to keep the XHV environment of the track chambers from the ultra high vacuum environment of the connected chambers. Each track chamber is evacuated by a titanium getter pump (pump speed:1.6 $m^3 \cdot s^{-1}$) and an ion pump (pump speed:0.2 $m^3 \cdot s^{-1}$). Figure 3 shows the schematic vacuum pumping system of a unit of a main track vacuum chamber, a sidetrack chamber and a coupling chamber. The properties of extreme high vacuum is evaluated with an extractor gauge and a quadrupole mass spectrometer with the separation of an ion source and a quardrupole analyzer. The chambers were evacuated with ion pumps after the whole system was baked out with a mantle heater system at the temperature of 423 K keeping the turbo pump system in operation.

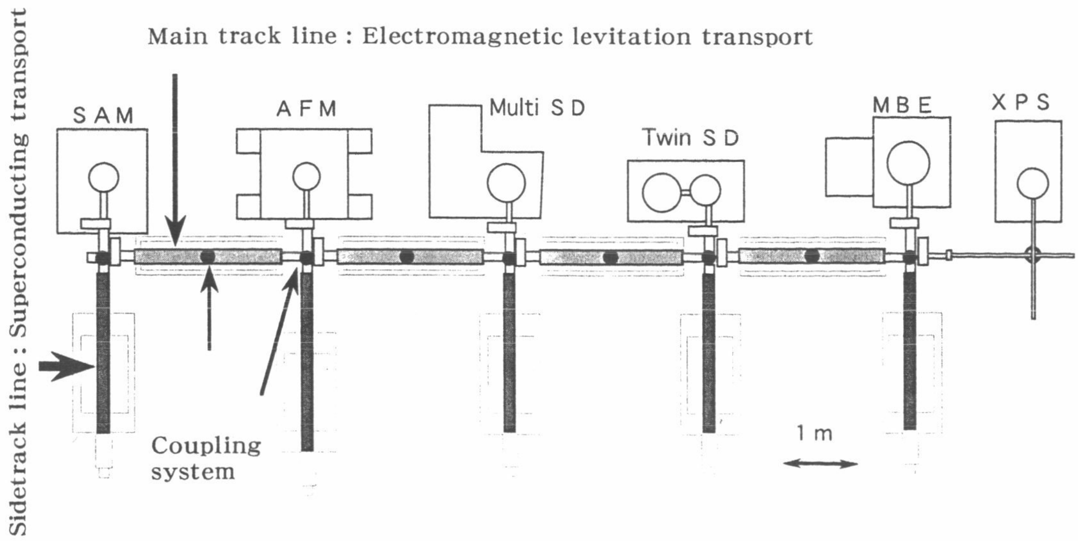

Figure 1 Schematic diagram of the developed XHV integrated process

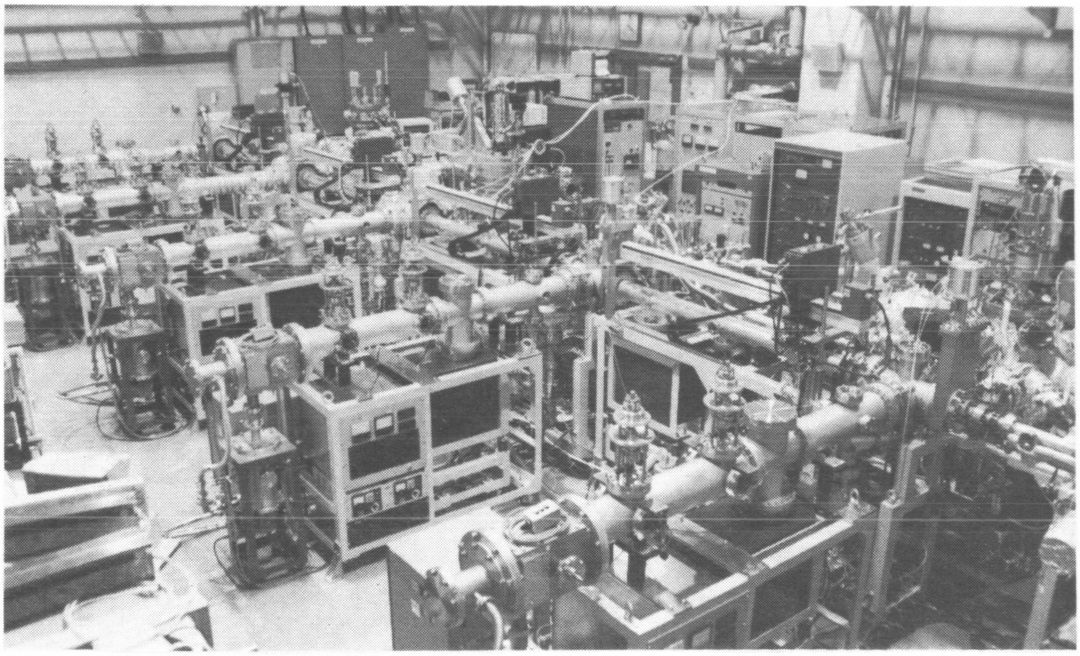

Figure 2 Whole photograph of the XHV integrated process

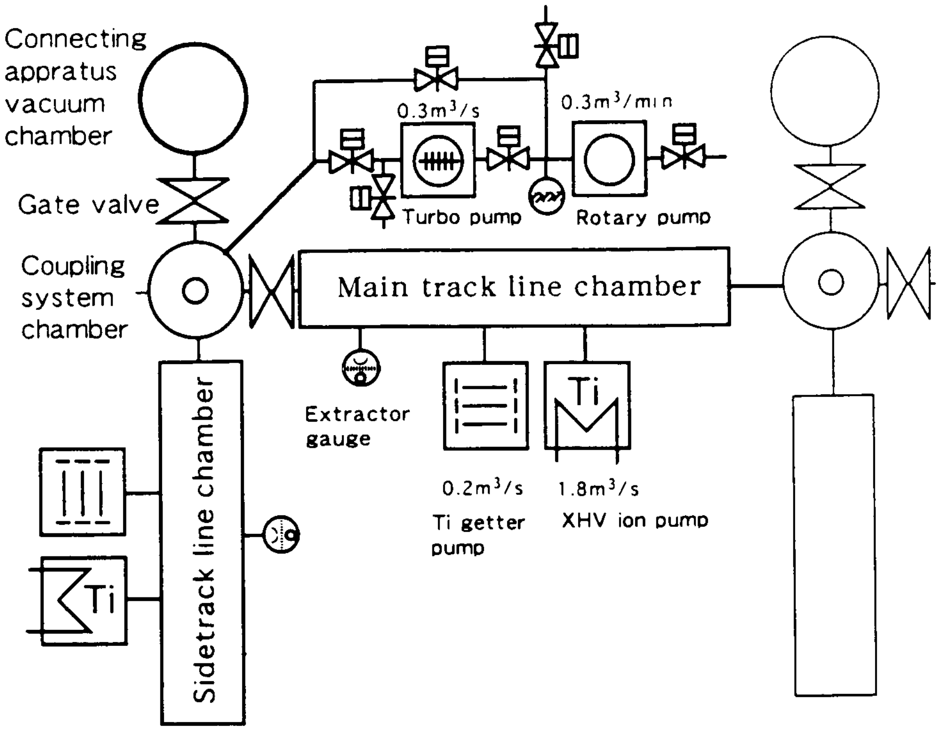

Figure 3 Schematic vacuum pumping system of a unit of a main track vacuum chambers, a sidetrack chamber and a coupling chamber.

LEVITATION TRANSPORT SYSTEM

A transport system to be used in XHV should generate no particles because particles are sources of outgassing as well as contamination. It is necessary to use no sliding components to keep the process XHV. A magnetic levitation transport system can meet the demand as it employs no sliding motion so that XHV may be kept during transport. We adopted two types of magnetic levitation transports, one is an electromagnetic levitation transport and the other is a superconducting levitation transport.

The electromagnetic levitation transport is introduced to each main track vacuum chamber for long-distance transfer and quick start operation. The superconducting magnetic levitation transport is introduced to each sidetrack vacuum chamber for short-distance transfer and stability against mechanical shock. An up and down hoist system by an air cylinder mechanism is introduced to each coupling chamber for the sample delivery among carriers of main track and sidetrack.

Figure 4 shows the schematic of a superconducting levitation transport used for the sidetrack because of the space saving and robust stability against mechanical shock. The transport consists of a sidetrack chamber, a cooler filled with helium gas coolant cooled by a freezer at the back of the chamber and a carrier rod with a sample holder at the head. Three discs of high-Tc $YBa_2Cu_3O_{7-x}$ (YBCO) superconductor driven by a rotating long bolt shaft in the cooler is cooled down below Tc and cause the effect of pinning and the diamagnetism on the three discs of samarium cobalt attached to the bottom of the carrier. The effect is strong enough to levitate the carrier with a certain gap through the cooler wall and to drag the carrier accurately without any stabilizer. The carrier can transport a sample at the speed of 3 cm•s^{-1}.

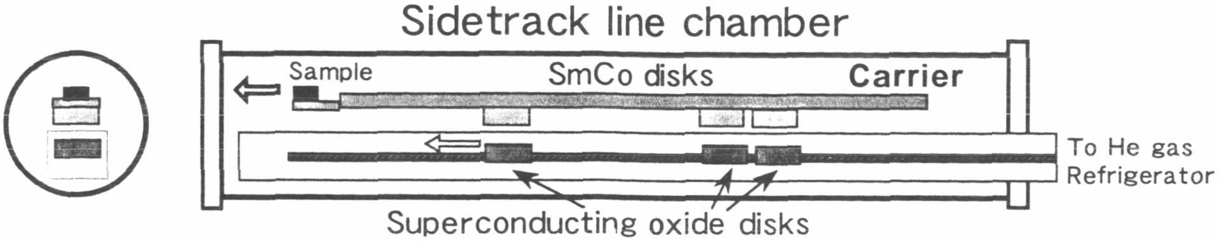

Figure 4 Schematic of a superconducting levitation transport used for the sidetrack

Figure 5 shows the schematic of an electromagnetic transport used for the main track because of easy extension and quick startup. A stator on the track chamber has electromagnets to levitate a carrier in the chamber, a linear synchronous motor above the stator to drive and position sensors as well as gap sensors with electromagnets to stabilize levitating carrier. The electromagnets in the stator control the levitation gap of the carrier about 1 mm between the carrier and chamber wall. The running carrier can stop within the error of 0.5 mm after transporting a sample holder at the top speed of 5 cm•s^{-1}.

A sample transfer direction is changed by the hoist system in the order as shown in Figure 6 and the sample is also delivered from the carrier of the sidetrack to the carrier of the main track in the same way by the hoist system.

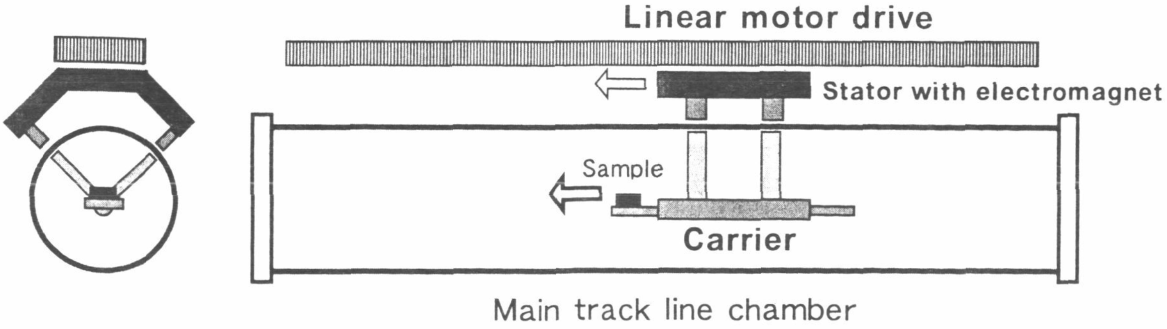

Figure 5 Schematic of an electromagnetic transport used for the main track

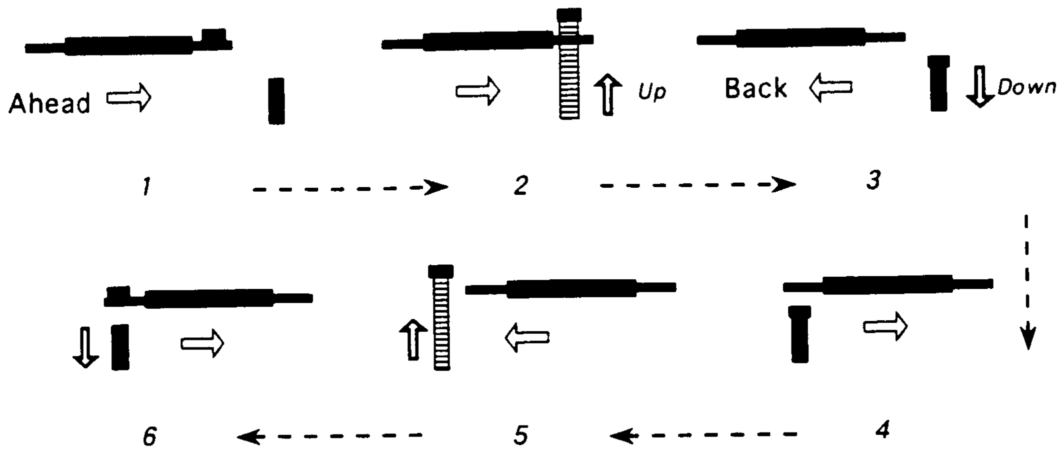

Figure 6 Schematic of change in a sample transfer direction by the hoist system

SAMPLE TRANSPORT CHECK

Operation of sample transport from the sidetrack for SAM to the sidetrack for AFM by way of a main track was carried out and the pressure change during the transport is shown in Figure 7. A change of pressure less than 2.0 x 10^{-10} Pa was obtained during the levitation transports of sidetrack and main track but the hoist up and down motion caused a large pressure increase of 2 x 10^{-9} Pa. More perfect outgassing operation of the bellows wall is required because mechanical vibration still releases gas from the wall surface. This indicates that the current system is successful in the transport in an ultra high vacuum though additional improvement of the system is required for the stable transport in XHV.

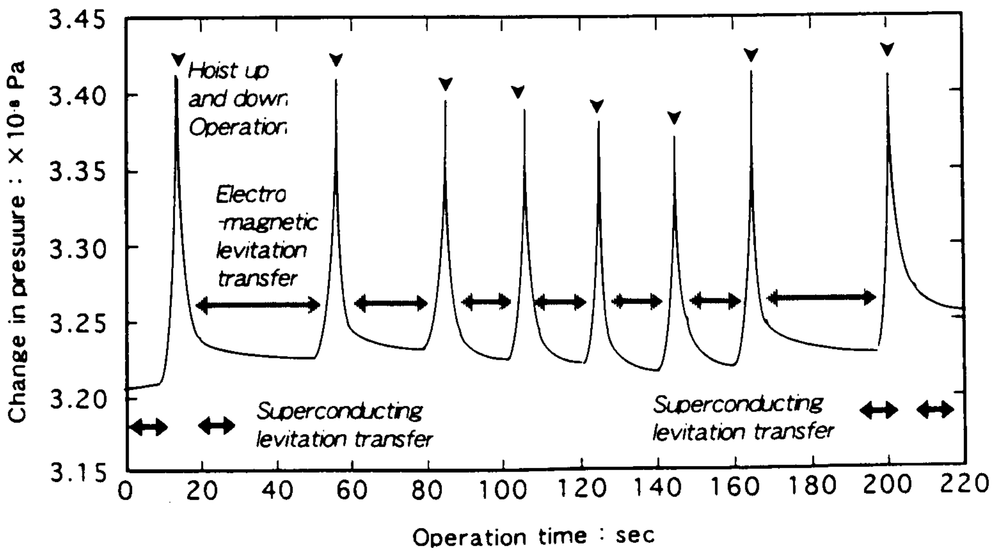

Figure 7 The pressure change during the transport from a sidetrack to another sidetrack by way of a main rack

CONCLUSIONS

We have successfully downsized the XHV integrated process with two types of magnetic levitation transports by direct sample delivery to a connected chamber from a sidetrack, can connect six vacuum instruments, and the pressure change less than 2.0×10^{-10} Pa was obtained when a sample was transported from one sidetrack to another sidetrack by way of a main track.

ACKNOWLEDGMENT

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REFERENCE

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