

Rare Earth Magnets Provide an Effective Means to Transfer Motion into a Vacuum System

Much of scientific research, IC chip manufacturing and other industries use vacuum systems or other sealed chambers for measurement processes that need to take place. A vacuum system is an aluminum or stainless steel chamber that is evacuated of all air and other gases using pumps. In some cases, the system is totally evacuated and left that way and in other instances, different types of gases other than air are introduced into these chambers. This must be done because the elements in air can have a detrimental effect on measurements, which can only occur under vacuum or having an effect that essentially contaminates devices which are fabricated within the vacuum system.

End users of vacuum systems are much broader than the general public might understand. Users are in government, university and private research environments, as well as the integrated circuit industry (much of Silicon Valley high-tech) and even more industrial applications such as the coating of windshields for the automotive industry or decorative coatings on consumer products.



Fig. 1: An example of a vacuum system

Since vacuum or process chambers are effectively isolated from the outside world and limited types of materials can be used within these systems without contaminat-

ing them (most contamination is due to outgassing), having motion translated from the outside world to the inside of the vacuum system can be a challenging task, especially if the motion is to be well controlled or complex. There are several means by which this motion can be fed into the system.

1. Sliding seals - a rod slides through o-ring types seals from the outside in - this is a "leaky" motion into the vacuum system and can allow air to slip by the seal or gas within the system to slip out (which in many cases can be very dangerous).
2. Edge welded bellows - these bellows compress and expand, but due to the force of atmospheric pressure, great forces might need to be overcome to provide the motion through the wall of the vacuum system. Support structures are often bulky to handle these stresses. These devices also tend to be expensive and relatively delicate.
3. Magnetic manipulators - the use of powerful rare earth magnets (either NdFeB or SmCo materials) reside close to the wall of the vacuum system and magnetically couple through the wall of the vacuum system to magnetic material inside the system. The materials on each side of the vacuum wall are in close proximity to the wall and guided for free movement. As the magnet(s) on the outside of the system are moved, the magnetic material inside the vacuum system stays within the magnetic circuit formed by the materials and stays there, moving with the external magnet.

Applications

Magnetic coupling can be used to provide motion into a vacuum system in a variety of ways. The most commonplace method among vacuum system users is with the use of a "magnetic translator" or "magnetic transfer rod" for delivering sample holders (surface science research) or other substrates (often silicon wafers)

between adjacent vacuum systems, often separated by gate valves. These would also be referred to as linear, or linear/rotary magnetic transfer rods.

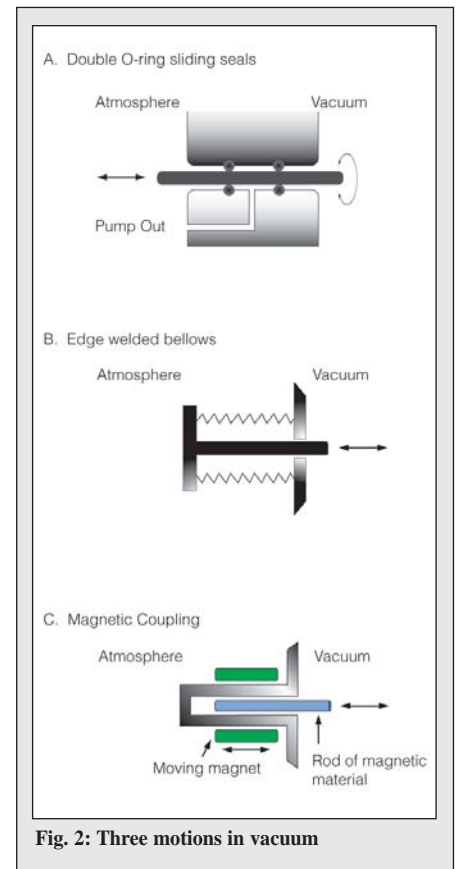


Fig. 2: Three motions in vacuum

Typical versions of the magnetic translators that make this delivery of an item between two chambers consist of a 1.5 inch relatively thin walled tube with a flange welded on one end that seals against the chamber, and a cap at the opposite end. The inside of this tube is under vacuum and the outside at atmosphere. The magnets that provide the motion are in a "magnet case" that rides on bushings or bearings with little clearance between the magnets and tube wall. Inside, the "follower" magnets are also in close proximity to the wall and are centered within the ID of the tube by bearings or bushings of the appropriate materials.

Typical linear translators then allow the movement of a single shaft, which can move linearly and also rotationally, depending on the orientation of the magnets.

One non-typical magnetic translator uses independent sets of magnets and concentric tubes and shafts to get multiple motions from a single translator.

The separated independent motions allow for different mechanical devices that include locks and devices that allow motion perpendicular to the main axis of the translator.

Rotary-only magnetic manipulators are also in common use due to the high reliability and simplicity. These are often used in applications where rotating a substrate in front of a heating source, a deposition source, or both for even coating of substrates. Other uses include shutters that rotate in front of sources or samples, or as stirrers.

A third, less common use of the magnetic coupling technology allows for a "trolley" system that can hold multiple substrate or substrate holders to be transferred between several chambers lined up end to end. In one particular application, a trolley full of sample holders is loaded into a vacuum system, then resides there for an extended period of time as substrate holders are delivered to one process chamber, then another, then another, without ever leaving vacuum.

How it Works

The coupling that occurs between the external magnets and internal magnetic material (often soft steel, but sometimes also magnets) is inherently a spring force with resistance from one side or the other allowing the magnetic circuit to be broken and therefore decouple. This coupling force is a function of the mass and strength of magnetic material and the proximity between the internal and external magnet poles.

Typically in the past, magnetic decoupling forces would occur at about 5 to 8 lbs. This loose coupling also had a detrimental effect on the accuracy by which the internal mechanism could "follow" the external mechanism. Repeatable positioning of devices might not be better than ± 1 mm for small loads, or more for larger loads. In worst case scenarios, friction within the translator might cause the decoupling of the external and internal magnet poles at very inopportune times, during the middle or critical experiments or process development.

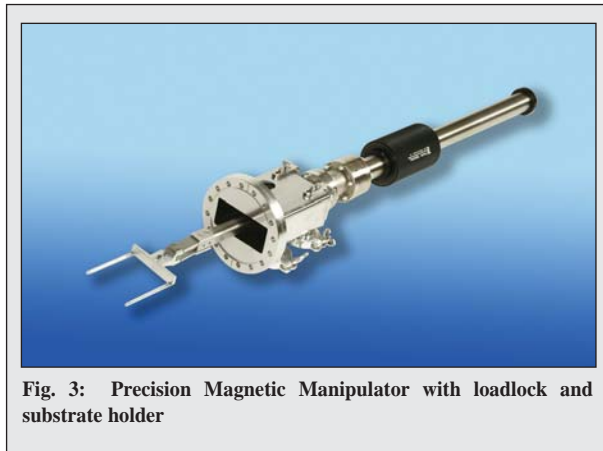


Fig. 3: Precision Magnetic Manipulator with loadlock and substrate holder

Current magnetic material available, as well the lowering in cost associated with unique shapes of magnets, much of this due to the influx of magnets from China, have allowed for much stronger, more reliable magnetic coupling in current magnetic transfer rods. Coupling on the order of 30 lbs., which gives positional repeatability better than 0.001 inch is typical, and certain applications require coupling forces on the order of 200 to 300 lbs. Although these stronger manipulators can have failures and do, these higher force manipulators can often overcome bearing failures and other problems like that to continue the important work at hand until a more opportune time is available for repairing the problem.

In other applications, a lower decoupling force or tuning the coupling force is a useful tool to prevent damage due to

overexcessive forces. In one example, magnetic translators are used to open and close large valves (doors) between multiple chambers. If the substrate being passed through this opening accidentally has the door closed on it, damage could occur that would force the shut down of a very costly piece of manufacturing equipment and damage the product being produced. In this application, we tuned the magnetic coupling force to allow the valve to close and seal one chamber from another, yet if there was some problem moving the substrate between the chambers and the door was accidentally closed, the magnet decoupling would take place preventing damage to the door, substrate holder and products.

Into the Future

As scientific measurements become more sensitive and refined, and new technologies are developed (smaller, faster computer chips) and cleaner vacuum systems are required. Magnetic manipulators are one of the cleanest means by which to translate motion into a vacuum system and older technologies will become obsolete more often.

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