

Microrobotics

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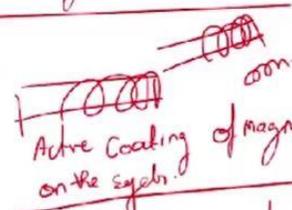
Indian Institute of Technology, Indore

Week- 04

Lecture No- 17

Micro-actuation and Micromanipulation - Module 02

In the last class, we discussed an introduction to the magnetic-based actuator and different applications of magnetic-based actuators. We also discussed the different classifications of these magnetic-based micro-robotic systems. We also discussed some of the key configurations of these magnetically based actuators and the different equations with respect to these magnetic actuators. In this lecture, we will discuss the different fabrication methods for magnetic micro and nano robots and then the incorporation of the various magnetic components. The microfabrication capability and the magnetic components are compiled in a table here. These magnetic components are classified into three categories.

micro fabrication:	magnetic comp:
<ul style="list-style-type: none"> 1) photo lithography 2) Pencil laser wash 3) Glue atom angle deposit 4) Thermal evaporation Electro de. 5) Bio template method 	 <p>Active Coating of magnet on the surface</p> <ul style="list-style-type: none"> → Creating magnetic segments → magnetic particles

magnetic film
 or. It can be in the bulk state (200nm)

- ↳ e beam evaporation
- ↳ physical vapour depositions sputter (200nm)
- Dip Coating

magnetic segments

- Electro deposits
- oblique angle deposit
- Ag / Ag Ni metal wires
- integrated

magnetic particles
 size of hydrogel robots are
 100nm → superparamagnetic

First is the coating of a magnetic structure on the system. It involves the active coating of magnets on the systems. Second is creating magnetic segments. Third is the generation of magnetic particles.

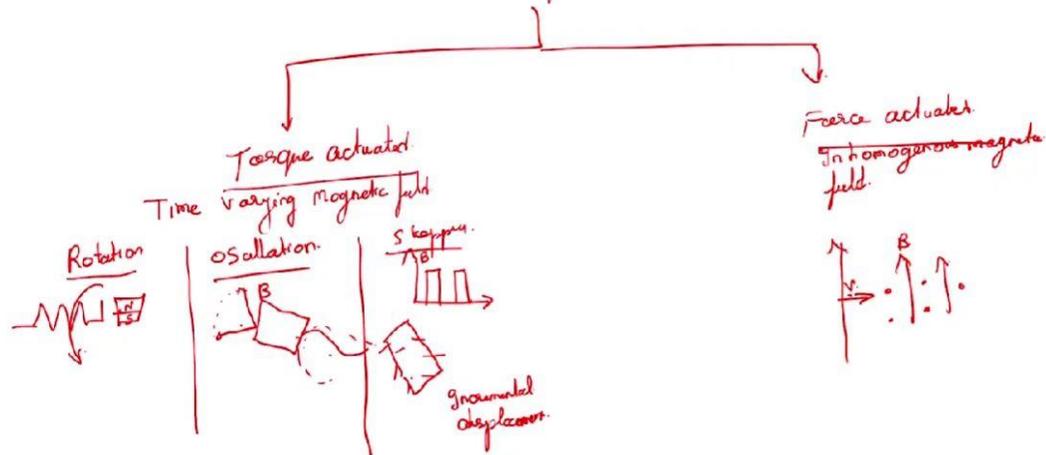
The basic architecture of an active coating of magnetic systems consists of two components: a flexible rod on which a magnetic coating is applied and biasing toward the magnetic field, which can produce the desired deflection. This magnetic coating can be either in the form of magnetic films or in the form of bulk structures on the order of a few microns. The different techniques employed for the coating process of a magnetic film are E-beam (electron beam) evaporation, sputtering, and dip coating systems. For the fabrication of magnet segments, the techniques employed are electrodeposition and oblique angle deposition. Magnetic segments refer to the parts of the magnetic structures that can be integrated into the system. For example, Ag/Ag Ni microwires are integrated with the system. These microwires can be mixed with other materials such as fibers or composite structures. Such structures are combined with composite structures and then employed or operated to create a specific number of configurations, among other things.

Next, considering the magnetic particle-based systems, they include hydrogel robots. The hydrogel robots are integrated with the magnetic particles and can be utilized for different applications. The integration of the magnetic particles can be achieved by dispersion. The dispersion of the magnetic particles can be done through a dip coating process or an emulsion process. The application of an external stimulus will actuate the magnetic particles along with the hydrogel, and a deflection will be achieved. It is also called magnetic particle impregnation.

Now we will see some case studies where magnetic particles are deployed for efficient diffusion and actuation characteristics. The microfabrication techniques employed for developing such systems include photolithography, direct laser lithography, glazing angle deposition, template-assisted deposition, electro-deposition, and the bio template method.

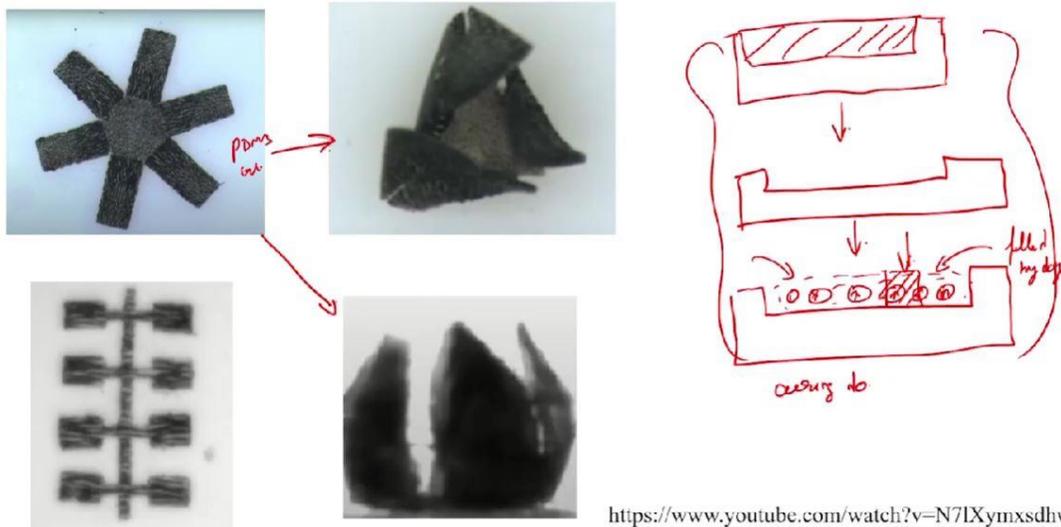
The different magnetic micromanipulation techniques that can be used for the actuation of different magnets in magnetic micro robots can be classified into two categories: one is torque actuated, and the other is force actuated. The torque-actuated micro-manipulation works on the principle of a time-varying magnetic field, and the force-actuated micro-manipulation is based on inhomogeneous magnetic fields. The rotational propulsion can be achieved by attaching the magnet to a torsion element. The application of the magnetic field will create rotation when the circular structure is being propelled.

micro-manipulation technique for actuation of different class of mag.
 magnetic micromanipulation
 for microbotic



Partial rotation can also be generated using oscillation. The magnetic actuator is subjected to a magnetic field across it, which results in oscillation, as shown in the figure. The third kind of motion is a stepping system. Here, the magnetic field is applied in steps/pulses to create incremental displacement of the actuator. Last type is field gradient-based actuation. In this configuration, a dispersed magnetic field (B) is applied to the actuator moving with velocity v . The dispersed magnetic field applies the force necessary for actuation. These four actuators have potential applications in the biomedical-related domain. So, these were some of the basic comparisons and classifications of magnetic micromanipulation for micro robotic systems, and based on the manipulation capability, they were appropriately classified as torque actuators and force actuators.

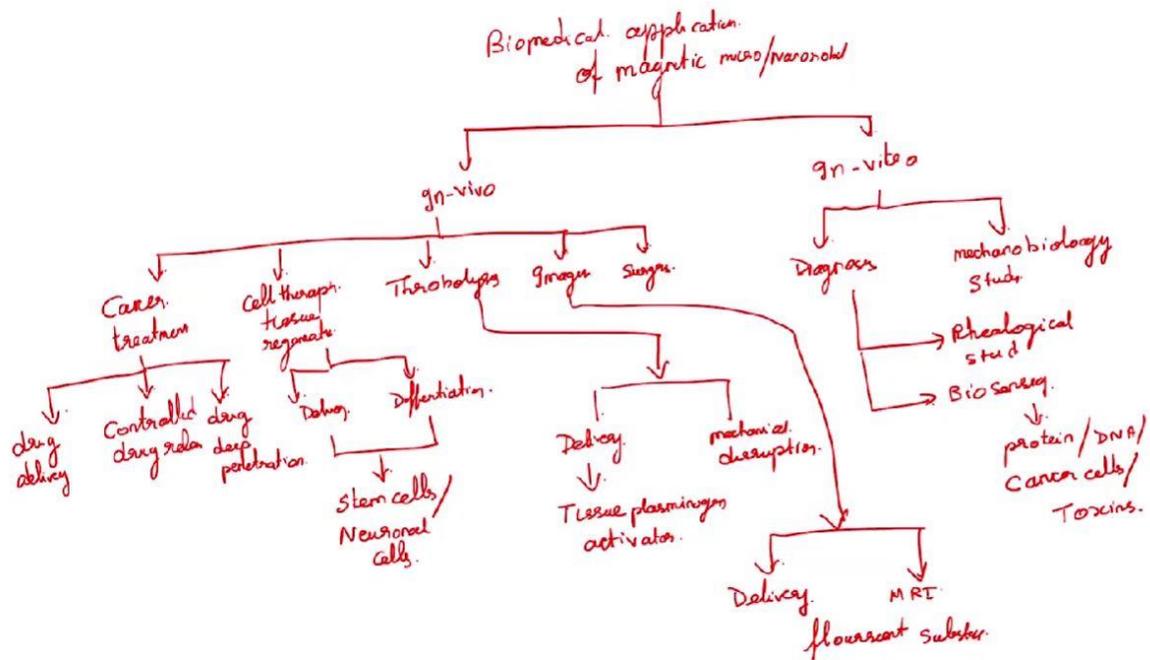
Now we will study the origami-based actuator. The actuation of this origami-based actuator is done by just dispersing the magnetic nanoparticles inside these structures. The base material is a fibrous layer. Magnetic particles are dispersed within the fibrous layer, and then the structure is encapsulated. The following steps are involved in the fabrication of this kind of actuator. The base material is a PDMS structure.



The PDMS structure is etched in a particular form as shown in the figure. Now, the nanoparticle is dispersed in the PDMS-based structures, and then it is filled with hydrogels. A layer of hydrogel fills the space in the structure. Based on the type of shape or geometry requirement, curing will be done. During curing, a laser beam will be incident on the filled region, and the motion of the laser beam is controlled to cure the region in the desired shape. This results in the alignment of the domains of magnetic particles in a particular portion. Thus, patterning or curing is done to achieve a set shape or geometry for the desired actuation. Here we have seen the structure where PDMS is coupled with the hydrogel, which can generate actuation upon the application of a magnetic field. One of the structures shown here is a lotus structure. It produces the opening and closing of the lotus structure when the actuating petals are subjected to an external magnetic field.

The programming of higher flexibility of the lotus structure can be achieved by employing origami-based petals. Further, multiple shapes can be achieved by dispersing magnetic nanoparticles in the hydrogels, which will then be coated with the PDMS layer and cured based on the type of shape or actuation. Some of the fabricated shapes are shown in the figures.

Let us see some of the applications of these nanomagnetic actuators in micro robotic applications. These micro actuators find applications in non-contact-based actuation. They have potential applications in the biomedical field for therapeutic-related applications or imaging-related applications. The magnetic micro robots can be classified into two categories according to their applications: in-vivo applications and in-vitro applications. For in-vivo applications, the Miro robot is used for cancer treatment, cell therapy and tissue regeneration, thrombolysis, imaging, and surgery. The in-vitro applications include areas such as diagnosis and mechanobiology study. For cancer treatment, micro robots are utilized for drug delivery, controlled drug release, and deep drug penetration. For cancer treatment, micro robots are utilized for drug delivery, controlled drug release, and deep drug penetration.



Cell therapy for tissue regeneration can be efficiently achieved via delivery and differentiation, especially for stem and neuronal cells. For thrombolysis, the magnetic micro robots are used in delivery and mechanical disruption. In the case of delivery, they are used in tissue plasminogen activator. For imaging applications, it is used for delivery and MRI-related applications; especially, it can be used as a fluorescent substance. The in-vitro applications are classified as diagnostics and mechanobiology studies.

The diagnostics application involves rheological studies and biosensing. Especially in the case of biosensing, it is used for detecting proteins, DNA, cancer cells, and toxins. So, these are some of the biomedical applications of these magnetic microrobots. They can be used as surface walkers, in rotational applications, and in many cases, they are used for therapeutic applications. Now, we will study the next actuator called a piezoelectric actuator.

The piezoelectric materials can transform mechanical energy into electrical energy and vice versa. The piezoelectric effect is obtained when a specific crystal structure, which must be asymmetric, means there is no symmetry center about the positive and negative ions of the unit cell. This atomic arrangement results in an inherent electric dipole moment within each unit cell. In their natural, unpoled state, these dipoles are oriented randomly, but mechanical stress can induce a macroscopic polarization and surface charge by displacing the positive and negative charge centers. The piezoelectric actuator is a kind of crystal.

When we apply a load to the crystal, we get a biasing of the domains within the crystal, and then when we apply an electrical biasing, we get an actuation. So, the interesting part of these piezoelectric structures is that they can be efficiently used as actuators as well as sensors. So, when we go back to the same magnetic-based system, in addition to simple magnetic-based structures, another structure is used called magnetostrictive-based structures. These magnetostrictive-based structures are not efficiently used for Microrobotics applications. However, there are a wide variety of applications for these structures in different devices.

Terfenol D is a standard material that is used in magnetostrictive structure-related actuators and applications. Now, considering the piezo actuator, magnetostrictive and piezoelectric devices work with almost the same functionality. However, piezoelectric has a wider application. Since these piezoelectric materials can transform mechanical energy into electrical energy and the piezoelectric effect is obtained with a specific crystal structure that must be asymmetric, it means there is no symmetry center regarding the positive and negative ions of an elementary cell. An external mechanical compression causes the positive and negative charge centers of each elementary cell to be separated, which leads to ionic polarization, and an electric charge appears on the outer surface of the crystal. Since the cause (the voltage applied) and the effect (the change in length) are strictly proportional, additional sensors are not required. The piezo actuators are also known for their quick reaction speed to the supplied stimulus, and they have reproducibility in the travel distance. Piezo actuators can exert a significant amount of high force compared to other conventionally available smart actuators. The figure shows different piezo actuators that are commercially available. So, if you closely observe these piezo actuators, they are stacks of actuators that are coupled and efficiently used for the transfer of the systems.

The piezoelectric material works on two effects. One is called the direct piezoelectric effect and the other is called the converse piezoelectric effect. The comparison between these two, the direct piezoelectric effect and the converse piezoelectric effect, will be discussed in the upcoming lecture.