Module 10 : Futuristic topics in robots

Lecture 38 : MEMS- II

Objectives

Introduction

In last lecture we saw what are MEMS, its importance ,use of MEMS in robotic systems, material used for MEMS & conventional fabrication processes for MEMS.

In this lecture we will have look on other nonsilicon based MEMS fabrication (non-conventional) processes such as:

In this course you will learn the following

- **Microstereolithography.**
- **LASER based micromachining etc.**

The motivation behind using these non conventional processes is limitations of traditional processes which we will see in coming part of lecture. Also we will see application of MEMS in Robotic systems. Also we will see some types of micromanipulators which are widely used in practice especially dealing with bio-cells.

Microstereolithography:

This process is evolved from rapid prototyping process called stereolithography.The principle behind this process is whenever a photopolymer is exposed to light, it turns into solid. So selective exposure of liquid layer (photopolymer) to light is done.Using this complex 3-D structure is built layer by layer with one layer built on another. basically motivation behind using this are the limitations of traditional processes which are explained as below.

Limitations of traditional processes:

- Inability to manufacture high aspect ratio and complex 3D microstructures. Conventional fabrication processes has capability to manufacture 2-D parts or planar components.
- Limitation on materials processed in conventional processes.using Microstereolithgraphy there is wider choice of materials such as Ceramics, Polymers, metal powder etc.
- Types of Microstereolithographic Process :
- Scanning Type :
- After dividing 3-D structure into planar layers, each layer/section is scanned by Light (LASER) line by line. Figure 38.1 here the entire section is not exposed to light at a time..
- Dynamic Mask Type :

After dividing 3-D structure into planar layers, each layer/section is exposed to light at a time. Here is a mask which changes its shape dynamically. So after exposing one entire layer to light, mask changes its size & next entire section is exposed to light. To explain how the shape of mask changes, we will go in detail but later on.

Microstereolithography (Scan Type) :

Figure 38.1

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Set-up :

A LASER curable photopolyner liquid is kept in a tank.There is a Lens used to focus LASER on photopolymer.There is elevator which can be moved in vertical direction. This motion is used to expose new layer after exposing one layer to light.There is mirror used by rotating which we can achieve movement of LASER beam in one direction. Typically two mirrors are used so that scanning in two directions (perpendicular to each other) can be done. For sake of simplicity we have shown only one mirror.

Figure 38.2 Vector Scan

Procedure:

LASER curable photopolymer is taken into a tank. Elevator which is initially above liquid level in tank is dipped into tank to certain depth & agin brought up so that liquid of suitable thikness is on the top of it. Then it is exposed to LASER. Here we are scanning the section line by line (Vector scan).For detain understanding of scanning see animation. One thing to mention is that as scanning is line by line, the actual section will be slightly different from desired one. There is slight error as the scanning is done line by line.(generally accuracy is 5-10% which can be tolerated in case of large sections but in case of submicron components it can not be tolerated.This is the limitation of this type of process. This is used to build components having dimensions above 30 micron size.we can use this process for compnents having dimensions less that 30 micron, but it will be costly & also it may persist accuracy problem. Once the section is built, the elevator is dipped again so that surface tension effects will gone & once again it is brought up so that suitable thickness of liquid is on top.Then same procedure is repeated for next section which will be built on previous section.

Factors affecting resolution of components:

- Laser intensity.
- Motion of the beam.
- Photopolymer/ monomer used.
- Focusing.
- Exposure time.

In case of ceramic materials we use ceramic powder & also use process of laser sintering.

Some Variations:

In the set-up discussed above we have fixed tank & moving optics(i.e. Rotating mirrors) The problem with the set-up discussed above is that focal point of LASER beam is not fixed which changes as mirrors are rotated. So the focal point may not be exactly on the liquid surface. It may be slightly above or below the liquid surface. To avoid it we can used Fixed optics, & movement will be given to liquid tank for xy scanning.Also we can have variation in scanning method. In the set-up above described the mirrors used are Rotating galvano scanning mirrors but we can also have linearly moving mirrors. Advantage of using this is we can have focal point at fixed level. Another variation is use of Raster scan instead of vector scan. In case of Raster scan beam is moved in rectangular fashion irrespective of desired section. The only thing done is that it is kept off beyond section limits.it will be on only within section limits.Unnecessarily idle movements are there with this type of scan. Hence it will take more time. So it is not used in practice.

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Microstereolithography (Dynamic Mask type) :

In this there is Mask which is changing its shape dynamically. Mask is just like LCD in which as per section required area is kept bright & remaining is kept dark. Inherent disadvantage of this process is that we can not have higher power of LASER because it will damage mask.In this process entire section is exposed to light at a time. The remaining set-up is just like the one used in case of Scaning type. There is reasonable accuracy with this type of process than the scanning type.

Dynamic mask

Limitations :

- Smooth 3D surfaces are difficult to produce with this as stepping effects will always be present.
- Mass production of several components is another challenge.
- Extremely small features(submicron components) are difficult to produce.

Now we will see LASER based micromachining.

Laser Micromachining

Mechanism:

Pulsed Laser beam with focusing optics are focussed on surface to be machined with focal point kept on the surface. High energy is delivered in pulsed fashion to remove material (micro/nano second pulses, recently femtosecond pulses).Lesser is the period of pulse higher will be the accuracy as we are giving energy in a shorter time material doesn't get chance to spread that energy. This results into localised effect. Here we use High precision XY movement of the substrate to achieve the desired cut.

Advantages:

- Microcuts on complicated 2D shapes possible.
- This is Maskless process. hence it will bring down the cost of process.
- Minimal heat input.
- Minimal damage to microcomponents fabricated as the area getting affected around the cut is very short.
- Variety of materials can be processed.Nd-YAG LASER with high power (150-200W) and wavelength (1064nm) facilitates fabrication of non-metals (ceramics) and metals (sheets of thickness 50-200 m m or even more). We cannot use Nd-YAG LASER for polymer material as these are high power which will affect accuracy. So we will use Excimer LASER for for processing polymer materials to very fine dimensional accuracy.

Now we see use of these fabrication techniques to fabricate micro-robots.

- Microgrippers and micromanipulators

- Several microactuators which can be used in future micro-robots.We will see actuators which are not currently in use but have a potential for their use.

- Novel mobile micro-robots(Scratuator).

Micro-grippers, Micromanipulators :

Figure 38.3

Principle is based on electrostatic actuation using comb drives. Comb drives are actually comb like structures whose teeths on either side are in mesh with teeths of another structures. When the voltage is applied across gold contact pad, due to electrostatic force of attaraction, teeths there is movement at gripper end.This is basic principle.From fabrication point of view these structures are freely moving structures which are anchored at base. These are just like Cantilever the only difference is that comb like structures are protruding out along the length. As gold is having better electrical conductivity use of it as a contact pad is done.

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Micro-actuators :

In case of Conventional Robots Actuators are either Electrical or Hydraulic/Pneumatic actuators.But in case of Micro-Robots following types of actuators are used.

Several types

- Thermal based on principle of Bi-Metallic strip.

- Piezoelectric.

- Electrostatic motors but based on Electrostatic Principle.

- Magnetic

Thermal Micro- Actuators:

Principle is based on Bi-Metalic strip effect. It is basically cantilever micro-actuator.it is very easy to fabricate multilayered structure with MEMS technology.We can have cantilever by any of conventional process & we can add layer of another material to this cantilever. This Bi-Metallic structure is heated by many ways either by passing hot fluid or by resistive heating . Because of different coefficients of thermal expansions we will get differential expansion of Bi-metalic strip which can be used for actuation.

Piezoelectric Micro-actuators:

When voltage is applied across some materials, strain will be produced. These materials are compatible with MEMS based fabrication processes.One of the material is SiO_2.Suppose the patch of such material is formed over a cantilever & if voltage is applied across that piezo patch it will bend. This kind of Actuators are popular in Atomic Force microscopy (AFM).

Cantilever beam magnetic Micro-Actuator:

Here the Magnetic bead is placed on the top of Cantilever.Copper coil is used lower side of Epoxy substrate through which electric current is passed. Magnetic field formed because of this will attract the magnetic bead due to which we will get desired movement.

Now we will see fabrication process for Cantilever beam magnetic Micro-Actuator.

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Now we will see one microrobot.

There is a cantilever structure which is not attached to substrate.When the voltage is applied between free end of cantilever & substrate because of electrostatic charges in the gap there will be electrostatic force of attaraction due to which it will bend down.(II) If voltage is further increased it will further bend & will scratch on substrate.(III) Now if voltage is removed because of springback effect it will slide in left direction.This procedure is repeated in pulsed fashion to get movement of Robot.This is the basic idea.

Other Futuristic Topics in Robotics :

Apart from micro robotics

- Underactuated manipulator systems: ex. 3-R manipulator with 2 actuating motors i.e. no. of degrees of freedom more than no. of actuators.

Legged robots: running, hopping

Underwater robots

Flying robots: autonomous

Recap

In this course you have learnt the following

- Microstereolithography,
- LASER based micromachining etc.

Congratulations, you have finished Lecture 38. To view the next lecture select it from the left hand side menu of the page