Micromechanisms for Laser Phonosurgery : A Review of Actuators and Compliants Parts.

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I. INTRODUCTION

Phonosurgery has to do with a surgical procedure, performed with an aim to enhance the voice. Common anomalies of the vocal fold includes a wide variety of pathologies such as nodules, polyps, cysts, and cancer. The method most commonly used of phonosurgery is done using a laser beam. The laser beam source is located approximately fourty centimeters away from the vocal cords. With this long distance, a small accuracy error would strongly impact the quality of the intervention.

Recent advances in the area of micromechanisms used in medicine have increased the potential for an early detection and a better treatment against vocal folds diseases Using microdevices, micromechanisms can be designed to guide the laser beam nearest to the vocal fold, for an accurate treatment and for minimizing the risk of detriment of the delicate vocal fold structures.

Micromechanisms are designed in accordance with the constraints of the microworld and with the requirements of the task. These include the limited space, biocompatibility and severe accuracy (micrometric or submicrometric). To build micromechanisms, there are often tasks of microassembly and micromanipulation of the small components that compose them. However at the sizes of the components (micrometric), new phenomena, identified as scale effects, appear. They include the adhesion forces composed of Van Der Walls forces, the capillary force and the electrostatic force. In order to account all these scale effects, the constraints of the microworld and te required accuracy, smart materials combined with compliant structures are often used as principal components of micromechanisms. [1].

In this review, we describe and discuss the most used smart material used for actuation in micromechanisms: thermomechanical actuators (shape memory alloy, thermal dilatation of solids, thermal expansion of gas), magnetomechanical actuators (Magnetostriction, magnetic fluids, shape memory alloy magnetic), electromechanical actuators (piezoelectric, electroactive polymers, fluid electric, electrostatic), fluid mechanical actuators, and also those that use multiple principles at the same instant. Their advantages and drawbacks will be discussed with particular regard to biocompatibility.

This review also present compliant parts that can be used in combination with the smart materials to make micromechanisms. Compliant mechanisms are commonly made of flexure hinges. This review gives a brief presentation of different flexure hinges for microscale applications. A flexure hinge is a thin member that provides a rotation between two adjacent rigid members. Flexure hinges can be made in a monolithic way making them very interesting for micromechanisms ; less expensive manufacturing methods for complex geometries can be achieved, little or no assembly required (so easy to manufacture), the monolithic nature eliminates the backlash and does of the hysteresis a variable predictable, practically no maintenance needed and it is availble for used in microscale. Also compliant parts for applications in two dimensions are axposed. Flexure parts in two dimentions are supposed to be compliant only around one axis called sensitive axis.

II. ACTUATORS

In the construction of micromechanisms, actuators are often active materials. Indeed, these last ones, allow sensing and acting, when there is a change of state, like a force, a magnetic field ,an electrical field or temperature level. Active material has remarkable features such as high resolution and high bandwidth. However, the active materials are very sensitive to environmental conditions and have non-linear behavior and a strong hysteresis which are compensated by the suitable control system.

The selection of a microactuator is made to meet certain criteria such as:

- input energy;
- power consumption;
- amplitude of deformation;
- microactuator dimensions;
- technological facility;
- repeatability and passband;
- force and torque to be developed;
- rigidity;
- cost;
- biocompatibility;

A microactuator has an identical definition to that of a traditional macroactuator, which is a system that transforms any type of energy (electric, thermal, magnetic, chemical, etc.) into mechanical work (displacement and force) [2], [3]. In micromechanisms, the term microactuator implies that the transducer that generates the displacement typify micrometric of submicrometric resolutions. The dimensions of a microactuator are generally lower than those of a cube of 10mm. of edge.

According to the input energy there are a list of technologies that are typically used, as shown the figure 1 shows[4].

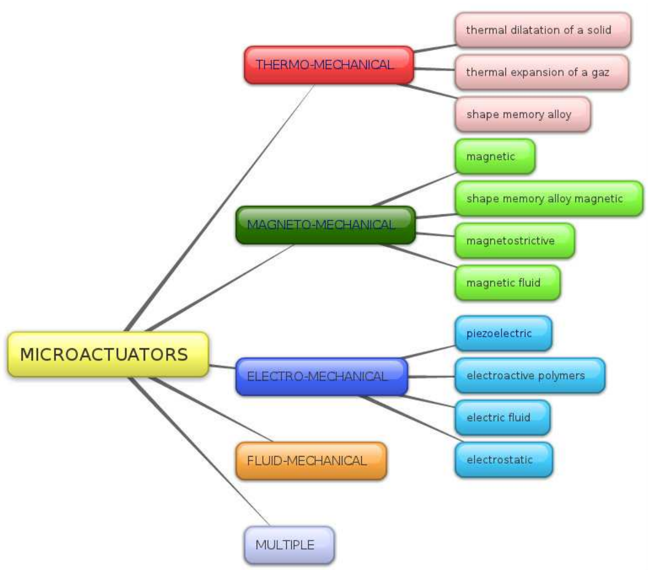

Fig. 1. Actuators Clasification [4]

A. Thermomechanical Conversion

Here the type of power at the input is thermal. They have the disadvantage of being slow and heat dissipation problems.

1) Shape Memory Alloy Microactuators (SMA): A shape-memory alloy is an alloy that remembers its original, cold-forged shape: Returning the pre-deformed shape by heating.

2) Microactuators Obtained with Thermal Dilatation of a solid: Here is exploited the thermal dilatation of a solid, as shown in the micromirror of [5]

3) Microactuator to Thermal Expansion of a Gas: As Gay Lussac's law describes, the volumetric expansion of a gas can be used to create a displacement.

B. Magnetomechanical Conversion

Here the type of input energy is magnetic, this has the advantage of having a remote control, but the repeatability and response time are weak.

1) Magnetic Microactuator: Here the type of input energy used is made of the force of attraction produced by a magnetic eld (if it is generated by permanent magnets) or an electromagnetic eld (if generated by a coil on a core ferromagnetic) on ferromagnetic materials.

2) Magnetostrictive Microactuator: The magnetostriction is a property that causes, in ferromagnetic materials, change of shape or dimensions during their process of magnetization

3) Magnetic Fluid Microactuator: It uses fluids that respond to magnetic fields such as magnetorheological fluids and ferrofluids.

4) Magnetic Shape Memory Alloy Microactuator: Here it was found that the deformation of the original state is made by means of a magnetic field.

C. Electromechanical Conversion

The electromechanical conversion process use a transducer for receiving energy from an electric system and delivering energy to a mechanical system.

1) Piezoelectric Microactuator: The piezoelectricity is a phenomenon which makes electric charges appear on the surfaces of a material when it is exposed to a mechanical load, this is the direct piezoelectric effect. In the inverse effect, deformation is obtained when an electrical eld is applied. Although piezoelectric material are sensitive to thermal variation, they offer a high resolution (up yo some nanometers), a high bandwith (up to tens of kiloherz) and a hig force density wich make them well recognized in microactuator design.

2) Electroactive Polymers based Microactuator: They are polymers which exhibit a deformation when they are exposed to an electric eld. The deformation can be large but he generated forces are often weak. They are classified to be biocompatible. In addition, the input voltages used to supply them are low. However, electroactive polymers typify low bandwidth making them not suitable for applications with high speed tasks.

3) Electric Fluid Microactuator: They are fluids that react to an electric eld. They often require high input energy.

4) Electrostatic Microactuator: The principle of operation is based on the Coulomb attraction between two electrically charged bodies. The force generated depends on the distance between the surfaces, the levels of electric charges and the type of material between the two surfaces. The operating volage for this kind of microactuators are between 40 and 200V.

D. Fluid Mechanic Conversion

When the pressure or the flow of a hydraulic or pneumatic fluid is used to obtain a linear or angular motion or a bending, we have a fluid mechanic microactuator. Currently, few numbers of fluid mechanic microactuators exist

E. Multiple Conversion

When several energu conversions are used in the same microactuator, we have the multiple conversion principle. The commonly used of this kind is the electrothermal microactuators that combines electrical and thermal energies to provide a mechanical work.

III. COMPLIANT MECHANISMS

Among the essential wishes to construct micromechanisms is to have fewer small pieces and components to assemble. Compliant mechanisms, also called flexure hinges, are suitable to that spirit since they can be fabricated with only one bulk (monolithical) instead of several components like in classical mechanical hinges A definition given by [6] of a flexure hinge is a thin member that provides the relative rotation between two adjacent rigid members through flexing.

Some of the advantages of flexure hinges are:

- No friction, then increase of accuracy
- No lubrication required
- No Backlash due to mechanical clearances, therefore hysteresis is predictable
- Capacity to be utilized in microscale structures
- Easy to manufacture
- Practically no maintenance needed

Also flexure hinges do have limitations:

- Relatively low levels of rotations
- Complex deformation (torsion combined with flexure/bending)
- Non-fixed rotation center during the deformation of the flexure hinge
- High local divergence of stress around the deformed part of the flexure hinge
- Around the rotation there are different spring rates
- Sensitive to temperature variations

Flexure hinges in two dimensions are supposed to be compliant only along the axis which has the relative rotation between the two rigid parts. It is usually symmetric about the longitudinal and middle transverse axes. Mostly in micro-fabrication, they are fabricated by removing material from the wafer. Processes that are utilized for this purpose are: end-milling, electrical discharge machining, photolithographic and others.

Micromechanisms are almost entirely based on microdevices that generate their motion by means of flexure-like component as shown in the figure 2.

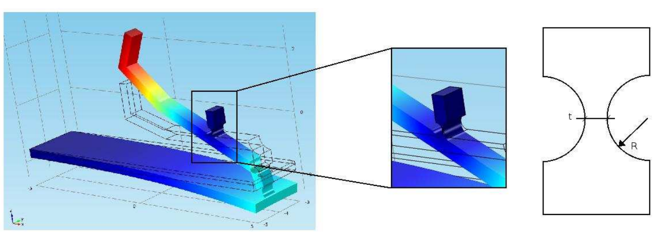

Fig. 2. Compliant Structure and Flexure Hinge

IV. ACKNOWLEDGMENTS

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