MECHATRONIC DEVICE FOR BIO-MEDICAL SAMPLES MICROMANIPULATION

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Abstract
This paper presents an innovative device that allows manipulation of biological or micromechanical samples in dimensional range [10 ÷ 100] µm. Accuracy of movement / positioning is submicrometer. The principle is based on a hybrid drive, a combination of the electro-magnetic and piezoelectric forming a microgripper with two arms, each of two degrees of freedom. The in-plane microgripper actuation (tightening direction) is generated in a magnetic field, the movement being governed by compliant joints. The second degree of freedom is based on the piezoelectric effect, yielding the second bending movement in a vertical, transverse direction with respect to the former, magnetically-determined, direction of movement.

Keywords: *mechatronics, biomechanics, micro-technologies.*

1. INTRODUCTION

The literature reports a variety of actuation principles for microrobotics (thermal, piezoelectric, electrostrictive, electromagnetic, electrostatic, shape memory and so on). Of these, the usual commercial technical solutions for micro pincers are based on integrated electrostatic micro actuators (MEMS) that are easily mass produced, but are mechanically fragile instead. Other less common design solutions consist in multiple-electrode piezoelectric actuators (including several pairs of electrodes), but require high complexity operations in the assembly stage [1].

MEMS (Micro Electromechanical Systems) are an important category of micro-structures with high applicability in such fields as automotive mechatronics, medical instrumentation, computer science, aerospace engineering and robotics: micro-actuators, micro-pumps, micro-motors, micro-gear transmissions, micro-grippers, micro-robot motion systems, micro sensors etc [2].

2. DEVICE DESCRIPTION

Magneto-piezoelectric actuator for micromanipulation (Figure 1) consists of a simple but ingenious system for clamping and moving brittle objects between [10 ÷ 100] µm in size, with a gripping force control ranging in the multiples and submultiples of mN.

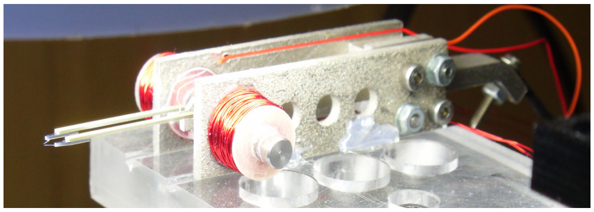

Figure 1.

Due to the fact that the device is able to manipulate objects of a much finer scale than the diameter of a human hair, its potential applications target the field of micro-technologies and advanced biomedical applications.

The device is based on a hybrid actuation principle, using a combination of electromagnetic and piezoelectric effects and consists in a micro pincer with two arms, each of them provided with two degrees of freedom [3].

Thus the actuation in the micro pincer's plane (in the tightening direction) is performed in a magnetic field, developing the movement on the arm provided with a compliant joint. The second degree of freedom is carried out by means of the piezoelectric effect (Figure 2), generating the second bending movement in a direction perpendicular to the direction of the magnetically driven movement.

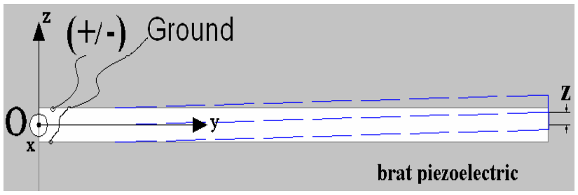

Figure 2.

The advantage of the proposed design consists in simplicity (a small number of components, an integrated structure, reliability), micrometric precision in positioning, millimeter working area and the possibility to be fitted with movement sensors for the closed loop control of the micro pincer's opening .

Figure 3 shows the CAD design of the mechatronic device assembly, where the essential components and the definition surfaces' geometry can be seen.

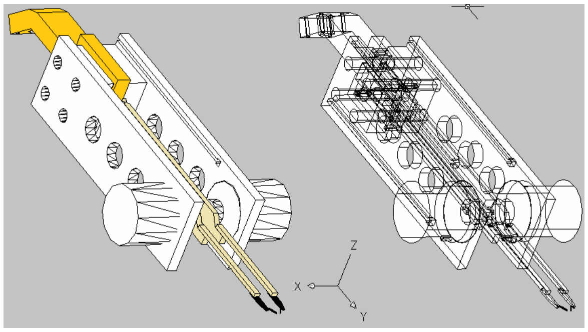

Figure 3.

The technical device comprises a metal casing, made by deposition of sintered metal powder layers. This casing positions the magnetic field generating elements relatively to the cohesive elements (compliant arm - permanent magnet). The electro-magnet or the magnetic field generating element is provided with a supporting construction by winding a sized to match copper conductor on a wire spool.

The permanent magnet or, depending on the case, the electrostrictive element reacts to the variation of the generated magnetic field by transmitting the exerted force to the compliant arm, thus producing a mechanical distortion in the compliant joint. The compliant arm produces a micrometric movement of the tip (pincer's end) in xOy plane (the micro pincer's plane) within the designed working perimeter.

The piezoelectric actuator is bilamellar (having at least one piezoelectric layer) and, when subjected to an electrostatic field, produces a distortion in the bilamellar structure in accordance with the laws of the piezoelectric effect, which consists in a bending in the Oz direction, perpendicular to the micro pincer's plane. The main role of the piezoelectric actuators is to accurately align the tips (pincer's ends) in the xOy plane (offsetting the dead loads, the static loading, the manufacturing tolerances) and to enable the objects' micro-positioning / micromanipulation by translation in the Oz direction and / or rotation in the yOz plane. A secondary role of the piezoelectric elements is to boost the mechanical advance in the Oy direction.

Further, a micrometric tip ending element is designed for the effective gripping of the object to be handled. The tips are only a few micrometers in size and are obtained by means of special micro-technologies (photolithography, ion beam etching and so on).

The system is characterized by a particular technical capacity given by the accurate alignment of the tips in the xOy plane (offsetting the dead loads, the static loading, the manufacturing tolerances) and by the possibility to micro-position/ micro manipulate objects not only by opening arms in the Oy direction, but also by translation in the Oz direction and / or rotation in the yOz plane.

Figure 4 shows an example of magneto - piezoelectric micromanipulation device, consisting of a metal casing (1) which positions the magnetic field generating elements represented by two coils (2) that interact with the two permanent magnets (3), transmitting the resulting force to the compliant arms (4) through the joint compliance (4'). The piezoelectric arms (5) have a bilamellar structure and enable the driving in the direction perpendicular to the figure's plane.

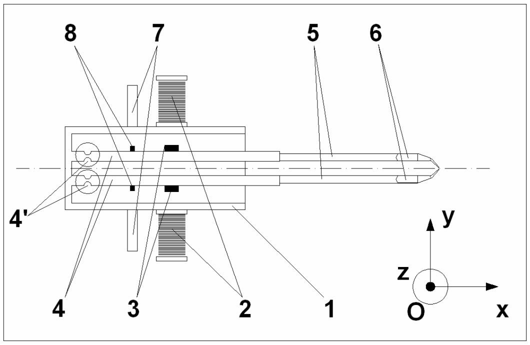

Figure 4.

The passive elements (6) take over the contact with the object to be manipulated. Optionally, the monolithic structure of the casing (1) may be fitted with magnetic field sensors (7) which, in association with the magnetic elements (8) convert the mechanical advance signals into electrical signals.

The piezoelectric effect aligns the arms horizontally, canceling the Δz error (Figure 5.a). In addition, the movement generated by the piezoelectric effect, in combination with the electromagnetic movement, will lead to a pivoting motion of the grasped object between the terminals (6), as shown in Figure 5.b.

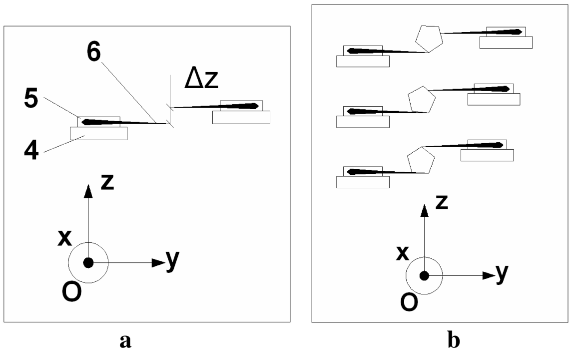

Figure 5.

Optionally, an assembly consisting of a magnet and a magnetic sensor may be attached, which will enable measuring and controlling the movement of the compliant arm.

The arms move separately and involve a console provided with joystick-type manipulators allowing the operator to handle the control signals, which are graduated in an algorithmic manner through the control unit (Figure 6).

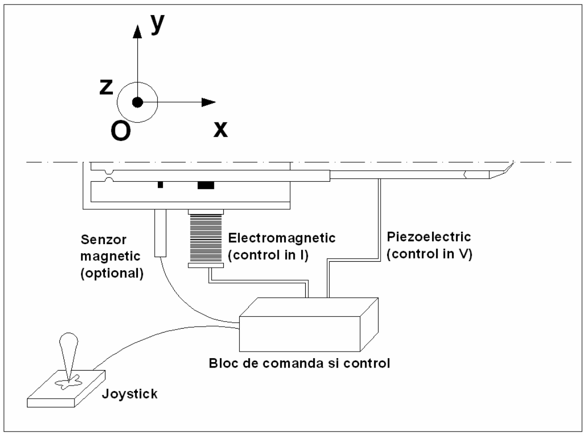

Figure 6.

Currently, this device is provided with an interface with two joysticks that enable the operator to dictate the movements of each of the two fingers of the device and with the possibility to apply different movement speeds on your desktop (Figure 7). This is the manual operation version of the device; the automatic version involves visual control by means of video cameras integrated in the optical system [4].

Figure 7.

The structure of the arms may be changed, using elements of different sizes and rigidities, as well as terminals specific to the application, so that the device can be adapted to the handling of various micrometric objects, including MEMS components and even biological samples (Figure 8).

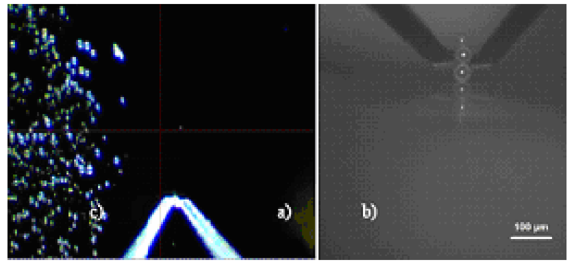

Figure 8.

3. ACHIEVEMENTS AND PERSPECTIVES

The device may be used successfully in the following directions:

• Assembling of micromechanical MEMS components and MOMS micro-systems;

• Biomedical applications: cell sampling, sample collection, minimally invasive surgery, spot electrochemistry;

• Micrometer samples description.

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