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HABILITATION THESIS

SUMMARY

Electromagnetic actuators made by microfabrication technologies

Qualification field: MECHANICAL ENGINEERING

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SUMMARY

The manuscript, developed as a habilitation thesis in the fundamental field of Engineering Sciences, presents the main activities of scientific research, technological and professional development carried out after obtaining the title of "Doctor of Engineering" in 2014.

The habilitation thesis is structured in accordance with the legislation in force and with the Regulation on obtaining the habilitation certificate in the "Valahia" University of Târgoviște (approved by Senate Decision no. 32 of 02/06/2015).

The habilitation thesis presents aspects from the author's activity carried out after defending the doctoral thesis. Thus, it focuses on the presentation of microfabrication technologies, used here in processing of some electromagnetic microactuators.

It is well known the magnitude of microelectromechanical systems (MEMS), that are invading our lifes in more and more sectors of it; contributes to the exercise of new functions for sensing phenomena, collecting signals and processing them, low-power commands and drives in increasingly important areas: the automotive industry (airbags, safety systems), robotics, aerospace and security, medicine (medical optics, administration and monitoring of drug administration and endoscopy), uses in industry (process control), applications in biology (cell separation, blood analysis, catheters), information technology (scanning), etc.

MEMS systems operating on magnetic principles, proposed to be presented in this thesis, can generate greater forces than other systems and operate at greater distances than those based on electrostatic principles, as the energy densities provided are much higher. In addition, the lack of contact between the parts reduces the influence of frictional forces and increases the dynamic performance.

Moreover, they are less susceptible to malfunctions when subjected to adverse environments - such dust and moisture - and can be operated with low-cost voltage controllers.

Several such microelectromechanical systems are presented in this thesis.

The development of electromagnetic micro-actuators was stimulated by the development of LIGA technology and the SU8 family of photoresist, which allowed the development of MEMS applications with thick layers, of the order of hundreds of micrometers. This technology involves several operations, described during the thesis.

Chapter I of the thesis presents the main achievements, regarding education and training, as well as the professional experience gained throughout the activity so far.

After graduating the Faculty of Mechanics from the Polytechnic University of Bucharest in 1985, specializing in Fine Mechanics, I was employed at the Titu Electrical Equipment Company, and since 1987 at the Research and Design Institute for Electrical Engineering, ICPE, in Bucharest. Since 2001, due to the split of the institute, I moved to the newly established National Research and Development Institute for Electrical Engineering, ICPE-CA

During 2010-2014 I attended doctoral courses at the Polytechnic University of Bucharest, Faculty of Mechanical Engineering, with the thesis "Contributions on determining dynamic imbalances for precision mechanical systems with rotational motion, on balancing machines driven by magnetic field."

Between 2015 and 2017 I attended the master courses "Maintenance Engineering for ELI-NP", within the Polytechnic University of Bucharest.

Within the ICPE-CA institute I was the head of the Microprocessing Laboratory, a laboratory developed by me since 2007 and I am currently the head of the Electromechanical Systems and Technologies department of ICPE-CA.

Chapter II presents the general structure of developed microactuators, their advantages compared to other types of microactuators.

The principle of operation is based on maintaining the balance between an electromagnetic force and a mechanical force. The mechanical force is given by a cantilever that bends and the electromagnetic force is given by the interaction between a flat coil and a system of permanent micromagnets.

Chapter III presents the implementation of micromagnet networks in matrix organization, using LIGA technology. The manufacturing technology of the support plates is presented in a technology that not depends on silicon, the realisation of the conception and the execution project of the microelectromagnets, as well as their processing.

It presents the optimization of the process parameters for lithography that uses as resistance a photoresist milk that allows relatively large thicknesses of components, SU8. In the templates obtained in SU8, the galvanic deposition of the permanent magnet alloy, CoNiPMn, will take place in a matrix structure.

The practical results obtained in the end are presented, after the optimization of all process parameters.

Chapter IV presents the measurements made on the demonstration structures to determine their mechanical properties.

It presents test structures made by microprocessing on specialized machine tools, by wire EDM and by LIGA technology.

The analytical and numerical calculation of the test structures and the experimental modal analysis for several structures are presented.

Conclusions are drawn regarding the choice of the most suitable material for the realization of the cantilever elastic element.

Chapter V presents the method and results of checking the assembly of test structures.

Several categories of coupling elements (intended for the assembly of the final product) and the technology for their realization at the microassembly level are presented.

The practical results obtained are presented

Chapter VI presents some contributions to the standardization of some elements made by LIGA technology, used to make microactuators.

The need for standardization is recognized by all those working in the field, signalising efforts to standardize the elements underlying the development of microsystems, even if this field - due to its complexity and constructive features of MEMS devices (optical, magnetic, electrostatic, giro, etc.) - is constantly changing.

The elements of the microactuator that can be standardized have been identified: the cantilever, the permanent magnets and the flat coil, those that require primarily a typing and standardization due to the fact that they can be used on a wider range of devices. In parallel, there was a need for a standardization in terms of optical, electrical, mechanical or climatic measurements.

Chapter VII presents the integrated manufacture of a microactuator with a degree of freedom, using microfabrication technologies.

It is presented the realization of a microactuator with coils in multiple layers, the way of their manufacture in two constructive variants: flat spiral coil or parallel current paths.

It is also presented the variant of realization, both of the flat spiral coils and of the permanent magnet networks, using microfabrication technologies, on specialized machine tools (compared to their manufacture first LIGA technology).

Two distinct technologies for the integrated realization of the same microactuator are compared and analyzed.

Chapter VIII presents the magnetization mode of permanent micromagnets and the assembly of final structures.

It presents the testing of several motor constructive variants of microactuators: with a central cantilever, with two parallel cantilevers, with a flat spiral coil, with parallel current paths.

In order to improve the performance, they were added, in series with flat spiral microboils, classic spiral microboils, with and without ferromagnetic core.

The assistive devices in carrying out the tests are also presented.

Both static and dynamic testing of micro-actuators was performed.

Chapter IX presents the plans for the development of my professional career, having as main points of interest the development of systems and products suitable to be transferred to the interested economic agents.

Also, an important point in the development of my future activity will be the transfer of knowledge accumulated so far to my younger colleagues.