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PROSPECTS OF APPLICATION THE MICROELECTROMECHANICAL SYSTEMS IN SPACE TECHNOLOGY

Ph.D. V.E. Ovcharenko[1], Ph.D. E.V. Tokareva[2], N.V. Kononenko[2]

1. *State Enterprise Scientific Research Institute of Instrument Technology , Kharkiv*
2. *Kharkiv National Automobile and Highway University*

The article describes the promising areas of microsystems technology for various applications.

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Introduction

The unique properties, high quality and reliability of microsystems technology devices (MST) for decades attracted the attention of specialists in various areas of science and technology.

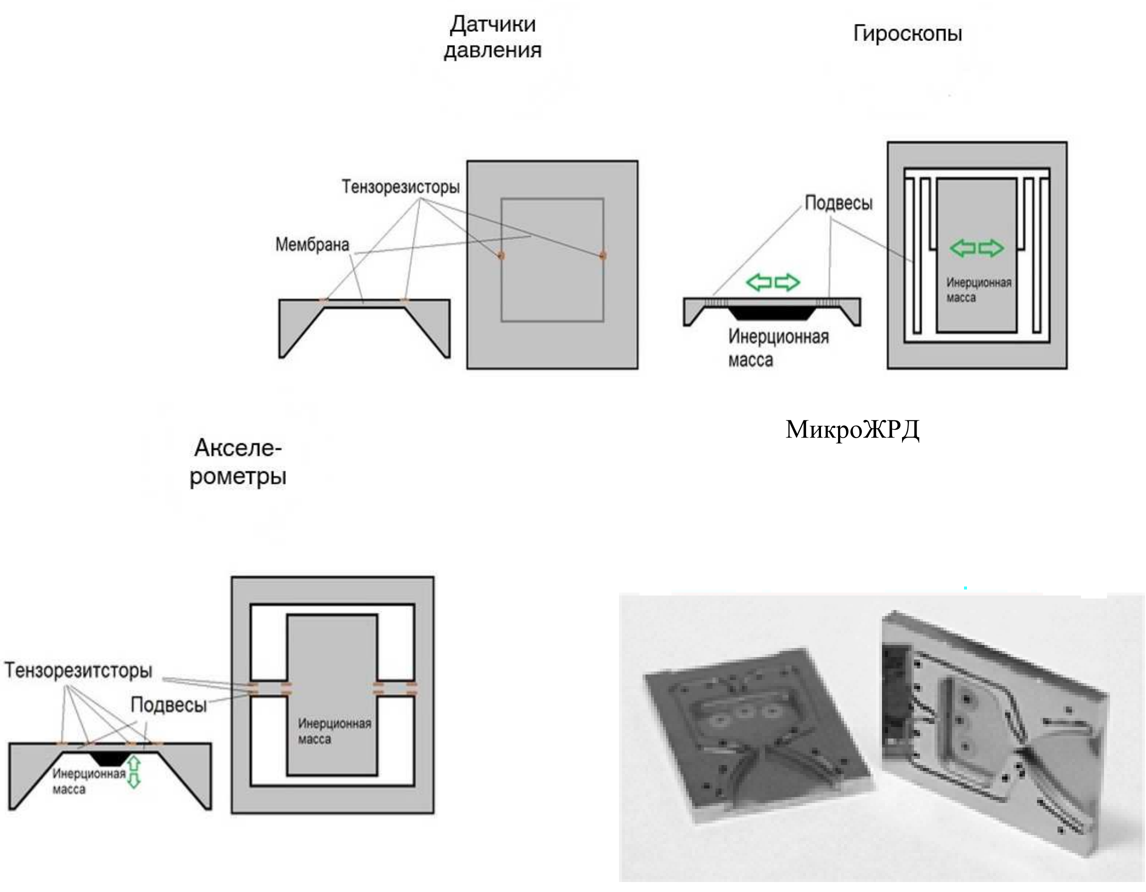
The precision execution units, sensitivity of sensors and energy converters, high-speed performance, small sizes, weight and power consumption are provided by a high level intelligence of developers, designers and technologists. In technically developed countries the level of investment in MST production is increasing every year.

The development of microsystems technology is an urgent task for the national space instrument.

Analysis of development prospects

Microelectromechanical systems (MEMS) are the microsystem technology devices formed by locally etching the substrate, doping, application material etc. The substrates are usually made of silicon. MEMS dimensions range from 1 micron to several millimeters, depending on capacity, application areas, the presence of embedded processing circuits and the number of elements (pic.1).

All MEMS devices have the elements of various physical nature unified with the principle of similarity of physical and chemical processes [1].



Pic. 1. Examples of MEMS implementation

Thus, it is possible to select such combinations of components, which provide the device properties beyond the capabilities of the original components.

In addition, the minituarization process of these components is accomponied with a change in the balance of forces operating in them.

Sensors and actuators are the acquired components of MST, which are produced on the silicon substrates using the volumetric, surface and combined technological processes.

The MST uses various materials, such as ceramics, polymers (organic and inorganic, volume and cell), allotropic forms of carbon, ferromagnetic fluids, photonic crystals, intelligent materials, glasses, various metals, multilayer metal structures etc. [2]. The properties of these materials in membranous, linear, and dot structures may differ significantly from the properties at a volume state.

An application of MEMS technology allows to receive micromechanical and optical units much smaller, than it might be possible using traditional technologies. The idea of manufacturing the sensors and processing circuits in a single device provides an excellent opportunity to create a ready-made, relatively high complex products in a single, relatively small body, which is beneficial to developers of end devices, as it allows to carry out the project on the basis of ready-made solutions at the level of complete functional modules.

Another advantage of MEMS is its electronic part and electrical connections between sensors and gears performed by integral technology and small sizes, which allow to improve such properties as working frequencies, signal/noise ratio etc. The high repeatability of the sensing elements and their integral manufacturing with processing circuit make it possible to improve significantly the accuracy of measurements. Due to the integrated technology the reliability of MEMS is higher, than the reliability of a similar system, which is assembled from discrete components. Also, greater reliability and durability represent the optical systems, since they are placed in a hermetic enclosure and protected from environmental influences.

Application of MEMS reduces the cost of both mechanical and electronic parts of device, since the processing electronics and the MEMS have been integrated into a single substrate, thereby avoiding additional compounds, and in some cases, the use of matching circuits.

Nowadays there are different types of magnetoresistance or so-called ferromagnetic fluids, which are colloids with magnetic particles of about 10 nm, and which have been already applied in practice.

A promising area of using the ferromagnetic fluids could be their application in miniature jet engines, that can provide the ability to move nano-satellites of almost any class and size in space, proposed by researchers from Michigan Technological University. Almost all of miniature jet engines have gratings arrays consisting of the thinnest needles, the thickness of which is less, than the one of a human hair. Due to the applied electrical fields to them and other physical effects, the needles emit the "fluid" ion flows in space, that provide a small draught sufficient to move the tiny spacecraft. The average engine need about two hundred of such needles to provide it the total draught sufficient for movements and maneuvers in space. But the needle manufacturing process is quite complex and expensive, and the needles are very fragile and can be destroyed by exposure of different adverse factors, including traction force created by themselves. That is why this technology is considered as unacceptable, and has not been widespread.

The solution to this problem could be a magnetic fluid, where dissolved the ferromagnetic nanoparticles, whereby it can flow and take certain forms under the influence of external magnetic fields. Under the impact of a point magnetic field induced by a permanent or electric magnet, such liquid may form tiny "peak", that acts as a jet engine needle, where flows an ion "liquid".

Obviously, the scientists have still to do a lot of work and create many prototypes of such engines, before the magnetic fluids become a real basis of jet engines, moving nanosatellites in space. The major task, that have to be accomplished, is the composition of the magnetic fluid solvent, which must remain fluid even at extremely low temperatures, which can almost instantly be changed in space with the high temperature, that occurs at the moment of the spacecraft transition from the shady to the illuminated side of the Earth's orbit.

Solar energy is on the threshold of rapid development. Along with the silicon solar cells on monosilicon, polysilicon and amorphous, appear new promising materials: titanium dioxide, zinc oxide, and other organic compounds etc. The materials of this class have to satisfy the requirements of the effective absorption of the light radiation in a wide range of frequencies, the effective separation of positive and negative charges by nanostructures complex due to the absorption of the sun energy, ensuring the recombination of positive and negative charges with the release of the Coulomb energy by closing the external circuit of current load, preservation of material efficiency for a long time (up to 50 000 hours).

One of the most promising materials of recent years have become perovskites [3], the $CaTiO_3$ compound. They are simply obtained at low temperatures (100-500 ° C) in a form of highly crystalline films. The electrons in the film of solar cell remains connected to their atoms, because it is an insulator. Under a sunlight exposure some electrons get extra energy and move through the crystal lattice until they get to the electrode to form a current. Unlike the thick and rigid silicon wafer, the perovskite films are thin (about 300 nm - 1 micron) and flexible.

Over the past ten years, the conversion efficiency has been increased from 3.8% to 20.1% by producing films with few defects. Adding supplements in the perovskites allows it to change the band gap and the sensitivity to the length of the absorption spectrum of the waves, that allows to absorb the energy of light in the whole visible frequency range. It is possible to obtain the multilayer structures with layer absorption at different wavelengths. In addition to translucency of thin layers, they can complement the silicon structures, increasing the conversion rate of other types of solar cells. The perovskite compositions without harmful impurities of lead (replaced tin) were found.

The material is almost 5 times cheaper than silicon cells. The maximum load on the perovskite elements reaches 1,07V (vs. 0.7V in silicon).

Perovskites are considered the revolutionary direction of solar energy in the world. They will be widely used as a building material for the walls and windows of houses, which generate an electricity from the sun. Problematic issues are the increasing lifetime of the films by protecting against moisture.

The pace of miniaturization of power supplies is approximately 40 times lower than the downsizing of electronic equipment, that is why the various types of converters of currently unused energies like jolts, bumps, deformation of structural elements and noise, etc. are so important. One of the important aspects of creating electrical energy are piezoelectric transducers, in particular, working under a load of vehicles and fuel cells of different principles of operation [4].

The future plans for the improvement of aviation and space technology envisage a reduction of size and mass of cosmic objects in 50 thousand times during the period 2000-2030. A significant contribution to solving the problem is being made by MST. MST is a technique of microsatellites [5].

The physical magnitude sensors including MEMS, among which are accelerometers and gyroscopes, mikroturbogenerators, liquid and solid rocket microengines, thermoelements, inertial navigation and communication systems, diagnostic systems, are successfully replaced in some applications by makroanalogues of these devices. Apart from reducing gauge and mass characteristics on several levels, the cost of production and operation of such systems, security, reliability and manageability is decreasing as well.

The use of piezoelectric sensors is promising in adaptive self-controlling structures, such as boarding of space and deep-diving vehicles, devices, that operate in a corrosive medium with the objective to a constant control of mechanical integrity and change the settings depending on the operating conditions.

Conclusion

An application of MEMS technology for research and manufacture of space technology instruments provides a highly effective solution to a wide range of problems.

The promising areas of MEMS technologies are their use in the development of micro- and nano-satellites constructions, including liquid and electroheat engines.

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