

Microgripper for Micro- and Nanoresearch

Innovations and superb product ideas are found by creative thinkers and invention-driven visionaries. To gather such individuals the Department of Micro-electronic and Nanoelectronic Systems managed by Professor Ivo W. Rangelow has held a workshop on »Nanotools – Microgripper« in 2009 at the Ilmenau University of Technology. Some 50 attendees took their chance to enhance their knowledge on the latest trends and developments in the area of nanotools and to expertise network.

Microgripper are used for microassembly and micromanipulation. Typical applications are the positioning of fiberoptics or the assembly of silicon-based systems such as resonators. The dimensions of these applications are within the micrometer range and standard precision mechanic forceps made out of metal fail to function. The solution for enabling these kinds of applications is given by silicon-based microgripper.

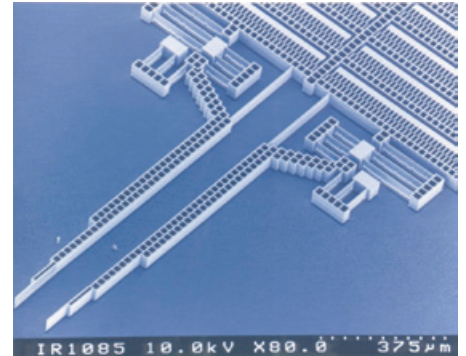
Microgripper further enable completely new applications. For example in medical or biotechnical research they can be used for manipulating single cells or for tissue-engineering.

Furthermore microgripper allow to position carbon-nanowires precisely which opens a new application in technical research and development. The diameter of such nanowires is only a few nanometers or below. The positioning of these elements has to be extremely precisely, in fact within the nanometer range. Only microgripper allow this application. In addition another function is crucial for manipulating nanowires; to ensure that the

structures do not get destroyed while being handled the gripper has to be able to control the holding forces as well as the opening and closing within few nanometers.

The operation for opening and closing, with other words the function of a microgripper is enabled by an integrated microactuator. To realize such a drive following physical principles can be used; electrostatic, electrothermal, optothermal, piezoelectric or memory alloys. Simple translator motions of few micrometers can be realized with these actuators. A microgear unit, consisting of levers and articulated joints converts the translator motion into the required »grabbing motion«.

The most important function of the integrated microactuator is to enable a high enough propelling force. At this point there are two types of propelling forces; either a surface force or a volume force depending on their physical functionality. For instance, a weight force after Newton's Second Law is a volume force, whereas a friction force is being considered as a surface force. In the micro- and nano-



▲ Fig. 1: Electrostatic microgripper

world, where structures are being scaled down, the surface scales down to the squared and volumes scale down cubically. This fact results in a very different proportion to what we are used in our macroworld; surface forces exceed volume forces in micro- and nanodimensions.

Different propelling forces are used for different applications. To ensure that both kinds of forces, the surface and the volume one are being used, our workgroup decided to use electrostatic and the electrothermal drives as microactuators. The electrostatic effect is categorized as a surface force while the electrothermal as a volume force.

The microactuators, as the microgear unit and further the microgripper can all be produced out of silicon as given by standard silicon wafers. The today's silicon technology is very enhanced and sophisticated; microstructures

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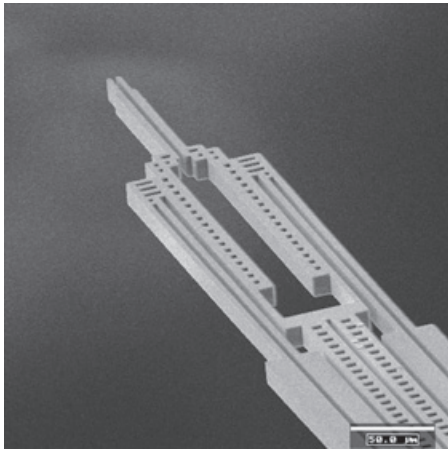
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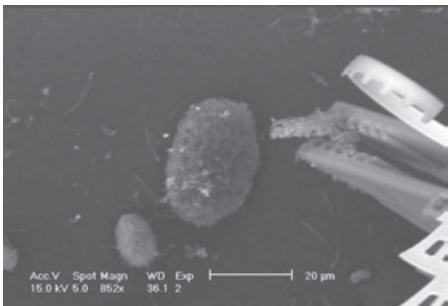


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▲ Fig. 2: Electrothermal microgripper



▲ Fig. 3: Microgripper 'at work'

and systems can be produced via lithographic, etching and deposition processes. In addition silicon has advantageous mechanical properties and it is fully bio-compatible. The functionality of the chosen microactuators will now be described; Electrostatic microactuators are based on the electrostatic attraction effect of two contrarily charged electrodes. In the configuration one electrode is fixed while the other one can move. Furthermore, to operate the microdrive with minimal voltage and to multiply the applying forces the drive's acting area needs to be increased and the shape looks somewhere »comb-like«. For even higher acting forces the distance between the acting electrodes is decreased. These optimization methods are limited by the lithographic process, where the smallest structures have a resolution of 2-3 μm. Theoretically it is possible to further optimize the relation between input voltage to acting force by design, however the microgripper is

planned to be produced in a standard batch process where standard contact-lithography sets the structure's geometrical boundaries.

As described the electrostatic microactuator consists of numerous electrode-pairs which are aligned and look »comb-like«. This configuration is attached to a cross bar which applies the sum of all acting forces into the main drive axle. This structure has to withstand high acting forces and the shape's stiffness is given by a framework construction. In addition cascading is being applied to further increase the final propelling force which results in an increase in the gripper's deflection. Such system of a microgripper can be seen in Fig. 1; the forceps are attached via a lever system with the »comb-like« cascading actuator constellation. The input voltage of the system reaches values between 10 and 100 Volts.

In contrast to the electrostatic drive, the electrothermal microactuator is based on the thermal expansion effect. To maximize the deflection of the microgripper a bi-layer system is being used, where one component stays unheated while the other one gets heated. Both components have a cantilever (leg) shape and are attached to each other only at both ends. Further, one end is attached to the holder while the other end is experiencing the mechanical deflection. This configuration is called »hot leg/cold leg«. The heating of the »hot leg« is being realized by electric current in-feed, which typical values are about 10 mA at ca. 5 V.

The advantage of this microactuator system is that there is no need of complex microgear boxes or lever arm systems. The »hot leg/cold leg« configuration enables a mechanical deflection which is much greater as if only single »hot leg«-units would be used.

Finally, to realize a microgripper two of these systems are used oppositely. Each »hot leg/cold leg« configuration has forceps at the moving end.

The main disadvantage of an electro-

thermal driven microgripper is that electrical energy has to be used at all times while operating. Once the microgripper is holding an object the »hot leg« has to be heated constantly to apply the desired holding forces. This kind of thermoelectric driven microgripper is called »normally open«.

To overcome this disadvantage a »normally closed« microgripper can be used. The gripper-forceps are closed when no heat/energy is applied. However there is always a minimal gap in between the gripper-arms even when they are closed due to fabrication tolerance.

If current is being switched on, the gripper opens, the object can be placed in between and to grab the object the current is then being switched off. The object is being held with no energy input into the microelectromechanical system (MEMS). This kind is called »intelligent/active holder«.

To combine the advantages of both microgripper systems a sophisticated »duo-action microgripper« has been produced. Fig. 2 shows an electrothermal driven microgripper, while Fig. 3 shows a microgripper »at work«.

The most astonishing fact is that microgripper are able to open and close within milliseconds. Once again this is enabled through the physics of the micro- and nanoworld; the miniature geometry with a minimal volumetric thermal capacity at a relative huge surface leads to an extremely swiftly heat dissipation.

► INFO

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