Using Micrograppers with the S100

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Introduction

The S100 platform of robotics tools can be used for electrical characterization, failure analysis, materials evaluation and physical property measurements. The ability to address such a wide array of applications is enabled by a suite of end-effectors which can be employed to probe, grasp, bias, oscillate, and manipulate objects and materials on the micro- and nanoscale. Such capabilities at this level, which until recently were commercially unavailable, are standard features of the S100 Nanomanipulator System.

One of the most useful manipulation end-effector tools used with the S100 is a microelectromechanical system (MEMS-based) microgripper. This tool allows small delicate objects to be maneuvered with nanometer-scale precision and accuracy. Microgrippers have uses in a number of applications including Transmission Electron Microscope (TEM) sample preparation, micro-assembly, and materials analysis where biological or inorganic materials must be held, stretched, or moved. The size of the sample being manipulated determines which gripper is used.

Background

Zyvex microgrippers function on the basis of electrothermal actuation, a technique which enables large deflections and high gripping forces. The gripping motion is achieved from thermal expansion and motion amplification which has been optimized to achieve appropriate deflection at the tips with sufficient force. These grippers have been designed for user-controlled movement with a given power input.

The microgripper is packaged onto a heat dissipating sub-mount **(Figure 1)**. The microgrippers can be mounted at either 90° or at 180° on the sub-mount **(Figure 2)**. The orientation of the part being manipulated and grasped decides the orientation of the microgrippers. The sub-mount is placed into an end-effector interface **(Figure 3)** which connects the end-effector assembly to the S100 positioner. The interface has been designed to connect the electrical traces from the sub-mount to a circuit which inserts into the positioner via a 5-pin connector plug. The holder is also designed to shield the ceramic sub-mount to avoid

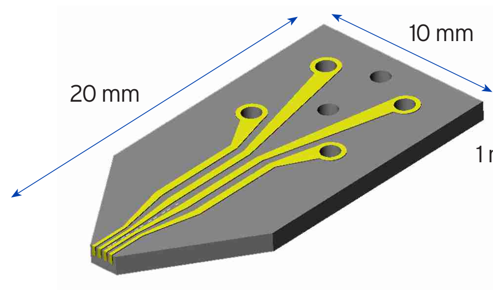

Figure 1 Microgripper sub-mount and dimensions

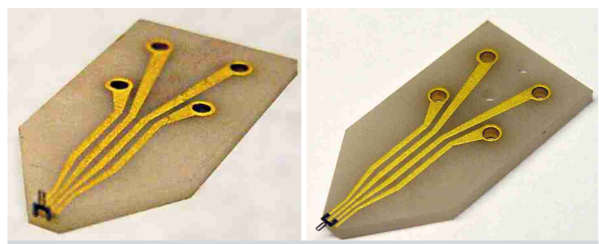

Figure 2 Microgripper with horizontal (left) or perpendicular (right) sub-mount

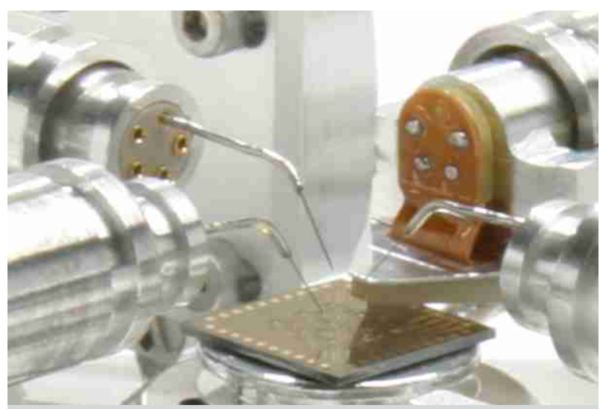

Figure 3 Microgripper end-effector interface

charging problems inside the Scanning Electron Microscope (SEM). The combination of the gripper, the sub-mount, and the interface comprise the microgripper end-effector for the S100. **Figure 4** shows the S100 head unit with four X, Y, Z positioners and a mounted microgripper end-effector.

Zyvex offers an array of gripper designs tailored to a multitude of applications. Factors to consider when choosing a gripper include grasping force, gripper opening, and pincher dimensions. For instance, a different gripper would be used for TEM sample preparation than for micro-component assembly.

Since the grippers can close completely, there is practically no lower limit on gripped feature size. Carbon nanotubes with a diameter of 10 nanometers or less can be manipulated. Our largest gripper can handle components approximately 500 microns in size.

There are different styles and sizes of MEMS grippers that have been designed to accommodate different tasks. The voltage necessary to close the grippers varies depending on the design and the fabrication process.

Applications

Figure 5 shows a 50 μm thick SCS gripper with a minimum gap opening of 36 μm when unpowered, opening up to a maximum opening of 80 μm. This gripper design is used for pick and place of other MEMS components. **Figure 6** shows these grippers being used to grasp and place an iron beam onto an assembly. This electroplated nickel iron beam is grasped and placed onto a MEMS translating stage. As the stage is translated, the nickel iron beam moves within a magnetic field to change inductance properties. These grippers have also been used to create 3D structures, by picking and placing MEMS connectors which are then inserted into specifically designed MEMS sockets (**Figure** 7).

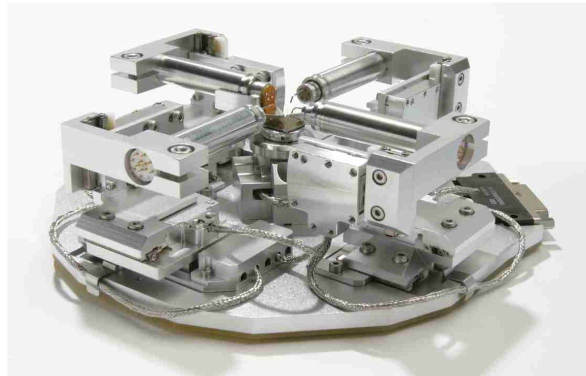

Figure 4 S100 head assembly with microgripper end-effectors installed

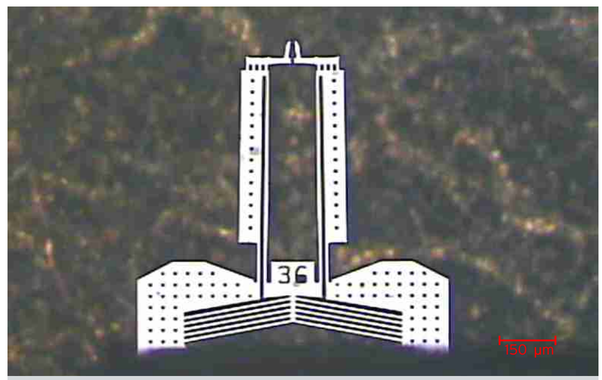

Figure 5 50 micron thick SCS microgrippers

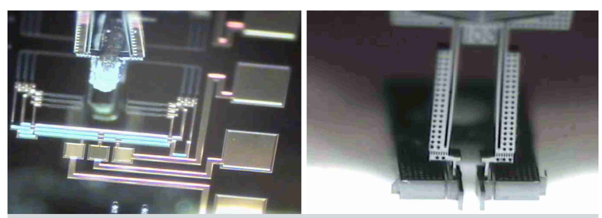

Figure 6 Pick and place using microgrippers

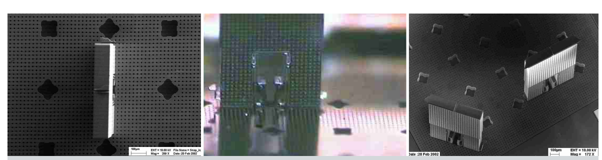

Figure 7 MEMS connectors inserted in sockets

Figure 8 displays a pair of 2 μm thick grippers that are actuated using the bimorph principle. This gripper is manipulating a polysilicon block, and uses two bimorph actuators oriented so that the tips move toward each other when current passes through the device.

A typical MEMS bimorph is shown in **Figure 9**. Current passes through the device from anchor to anchor. There is higher current density in the thinner arm (hot arm), and higher resistance, which causes joule heating. The joule heating causes the hot arm to expand more than the cold arm. The arms are joined at the end, which constrains the tip of the actuator making it move laterally in an arc motion toward the wider arm.

The grippers shown in **Figure 10** are different from those in **Figure 8**. Although the gripping motion is achieved from thermal expansion, the motion is amplified and optimized for maximum deflection of the tips using a bent beam configuration (as shown). The beams thermally expand causing a downward force which then causes the gripper tips to squeeze together. This design has been used to make grippers with minimum feature size of 500 nm (scaled MEMS) as shown in **Figure 10** (left). These scaled MEMS grippers are 5 μm thick and are capable of closing completely. The same grippers shown in **Figure 10** (left) have been used to do TEM sample lift-out, and have picked up smaller MEMS components. They have also been used to pick up nanotubes. These grippers have also been designed in another process where the grippers are 50 μm thick and the minimum feature size is 5 μm. The grippers in **Figure 10** (right) have been used to perform various pick and place experiments assembling connectors and creating 3D structures.

Carbon nanotubes are notoriously difficult material to handle individually. The tubes clump and bind together in bundles, making extraction of individual strands difficult. The task is made much simpler using an S100 and a microgripper end-effector. **Figure 11** shows a single carbon nanotube strand, about 10 nm in diameter, being removed from a bundle.

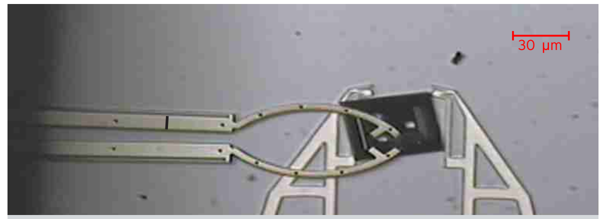

Figure 8 Bimorph-type grippers manipulating a MEMS component

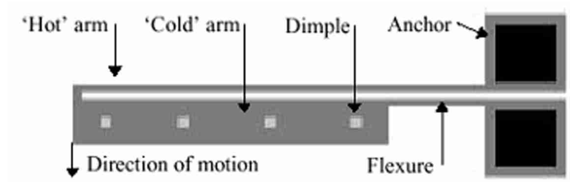

Figure 9 An electrothermal bimorph MEMS device

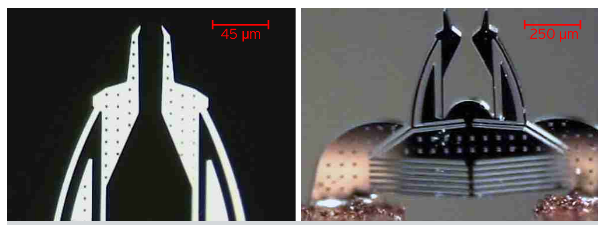

Figure 10 Scaled MEMS microgrippers 5 μm thick (left) and 50 μm thick microgrippers (right)

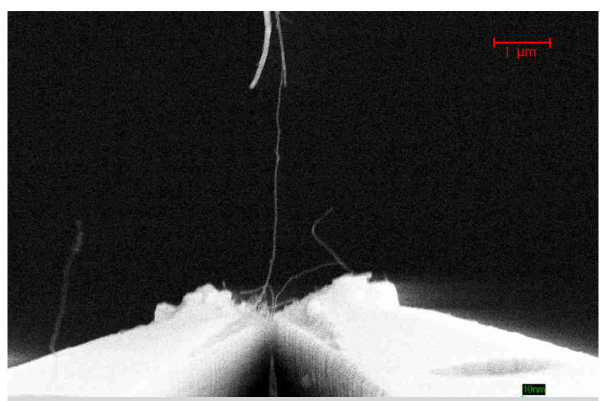

Figure 11 Gripper grasping a single carbon nanotube

Figures 12 shows one of the most exciting recent applications for microgrippers. The top two images depict the approach of the gripper into a FIB-cut coupon trench. The bottom two images show the acquisition and removal of the FIB-cut coupon. Using the S100 Nanomanipulator, coupled with sub-5 nm movement resolution, the FIB-cut coupon can be lifted, moved, and placed very accurately on a TEM grid.

Conclusion

Until recently, accurately acquiring and moving components and materials with dimensions less than 1 mm was a formidable task. Tools did not exist which could mechanically grasp elements with feature sizes that small. The engineer/technician was forced to use push-pull motions using needles, or in many cases, just admit defeat. The difficult challenges of manipulating micro- and nanoscale objects are overcome using the precision-guided S100 with microgripper end-effectors.

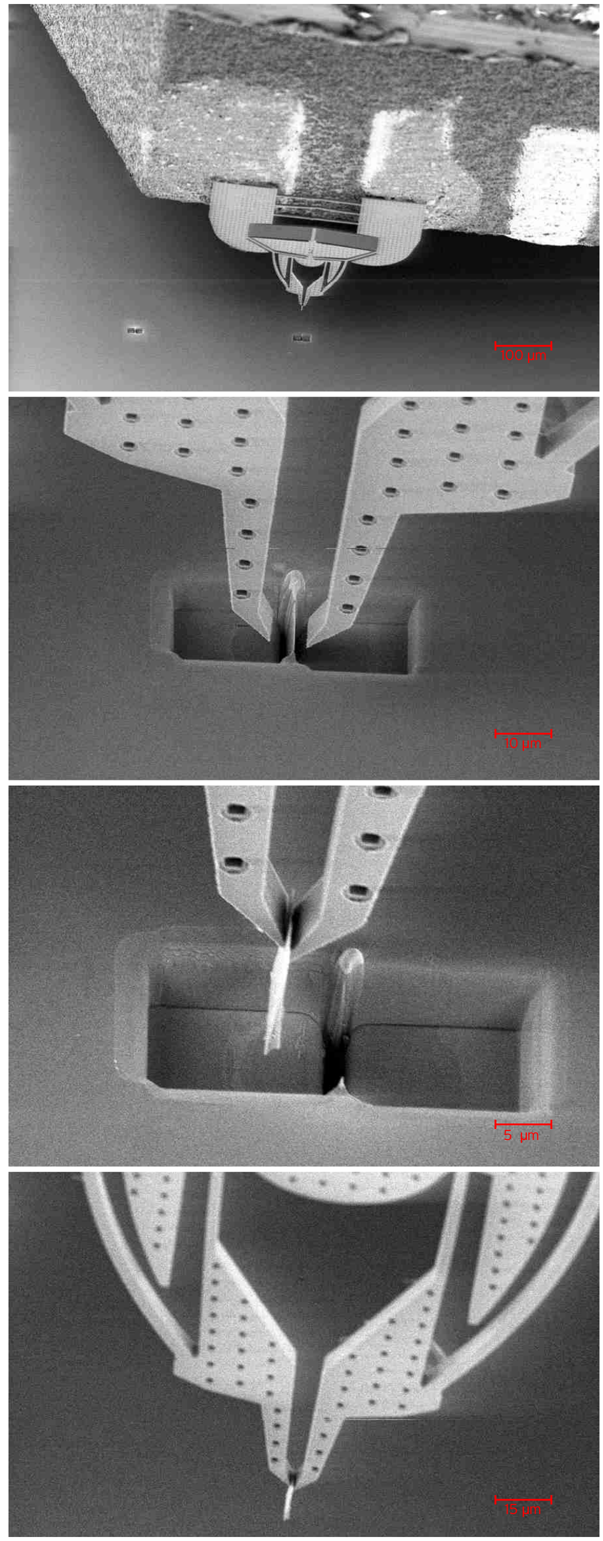

Figure 12 MEMS gripper picking up FIB-cut coupon

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