Using Zyvex Microgrippers™ with Zyvex Nanomanipulators

By Ken Tsui and Taylor Cavanah, Zyvex Instruments

Introduction

The Zyvex nanomanipulator product line 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 that can be employed to probe, grasp, electrically bias, oscillate, and manipulate objects and materials on the micro- and nanoscale.

Capabilities at this level, which until recently were commercially unavailable, are standard features in Zyvex's nanomanipulator systems. One of Zyvex's most useful end-effector manipulation tools is a micro-electro-mechanical system (MEMS) microgripper. Zyvex has developed a complete microgripper end-effector attachment, along with all the necessary control electronics. This microgripper solution has been designed to easily integrate with any Zyvex nanomanipulator system. The Zyvex Microgripper allows small, delicate objects to be manipulated with nanometer-scale precision and accuracy. The tool has 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 microgripper is used.

Background

Zyvex Microgrippers are fabricated using doped single-crystal silicon (SCS) and standard bulk micromachining techniques common in the MEMS industry. The Microgrippers function on the basis of electrothermal actuation, a technique that enables large deflections and high gripping forces. The gripping motion is achieved from thermal expansion and motion amplification that has been optimized to achieve appropriate deflection at the tips (with sufficient force). Refer to the Zyvex Microgripper datasheet for more detailed information about microgripper specifications. The microgrippers have been designed for user-controlled movement with a given power input. The m icrogripper is packaged onto a heat dissipating, aluminum nitride (AlN), printed circuit board (PCB) (Figure 1).

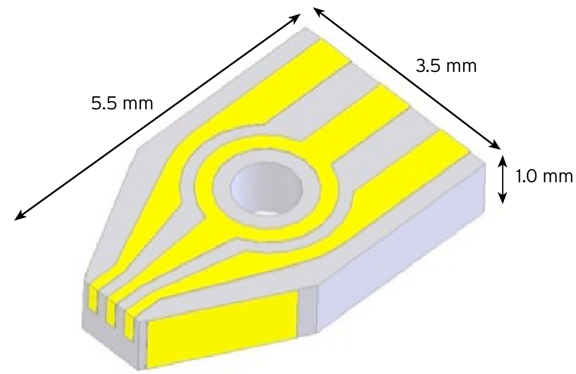

Figure 1 Dimensions of aluminum nitride printed circuit board Microgripper sub-mount.

The Microgrippers are mounted parallel to the AIN PCB (Figure 2).

Figure 2 Microgippers mounted.

The specific application typically dictates the orientation of the microgrippers. The sub-mount is placed into an end-effector interface (Figure 3); the entire assembly is then connected to the nanomanipulator positioner.

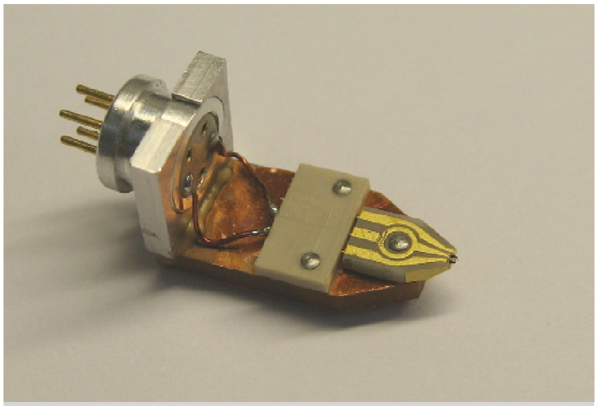

Figure 3a Zyvex Microgripper end-effector interface plug.

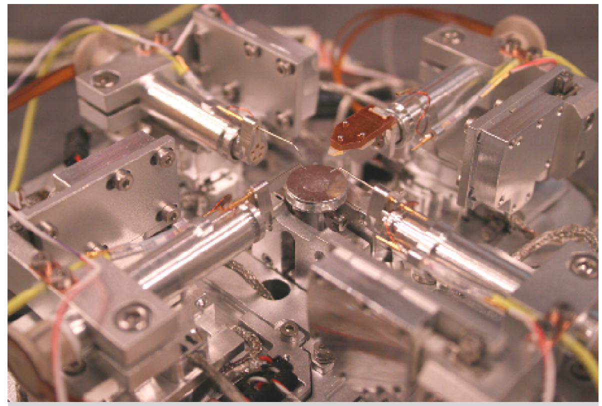

Figure 4a Zyvex sProber assembly with an installed Zyvex Microgripper end-effector.

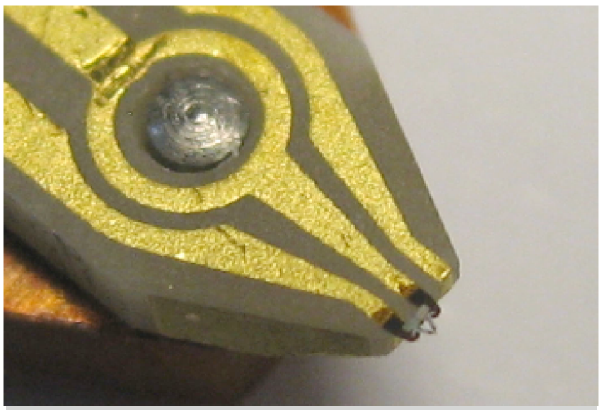

Figure 3b Close-up of a Zyvex Microgripper packaged onto the end-effector interface.

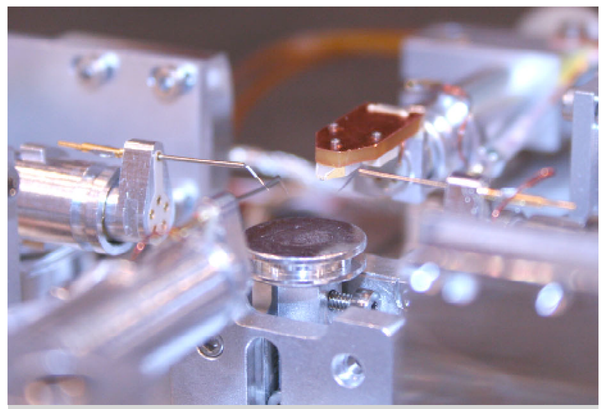

Figure 4b Close-up of the Zyvex Microgripper end-effector installed in a Zyvex sProber™.

The electrical leads required by the Zyvex Microgripper are brought out through the standard 5-pin connector, which is available on all positioners. The microgripper end-effector assembly is also designed to shield the ceramic sub-mount to avoid charging problems inside the Scanning Electron Microscope (SEM). The combination of the microgripper, the sub-mount, and the interface comprise the microgripper end-effector assembly for the Zyvex Nanomanipulator system. Figure 4 shows a Zyvex sProber™ head unit with four X, Y, Z positioners and a mounted microgripper end-effector.

Zyvex offers an array of microgripper designs tailored to a multitude of applications. Factors to consider when choosing a microgripper include: grasping force, microgripper opening, and tip dimensions.

For instance, a different microgripper would be used for TEM sample preparation than for microcomponent assembly. Since some microgrippers can close completely, there is practically no lower limit on gripped feature size (Figure 5).

Zyvex's Microgrippers can manipulate carbon nanotube bundles, nanowires, and other nano-sized materials. Our largest Microgripper can handle components approximately 500 microns in size. There are different styles and sizes of MEMS microgrippers that have been designed to accommodate different tasks.

Microgripper Control through Zyvex Nanomanipulator Software

Zyvex has developed a complete solution for using microgrippers with our Nanomanipulator product line. This solution includes custom microgripper control electronics connected to our host PC through a USB interface. The control electronics provides support for up to four individually-addressable microgrippers and uses BNC connectors to connect to our existing electronics cabinet. The microgripper control electronics are controlled through Zyvex's Nanomanipulator Software (Figure 6).

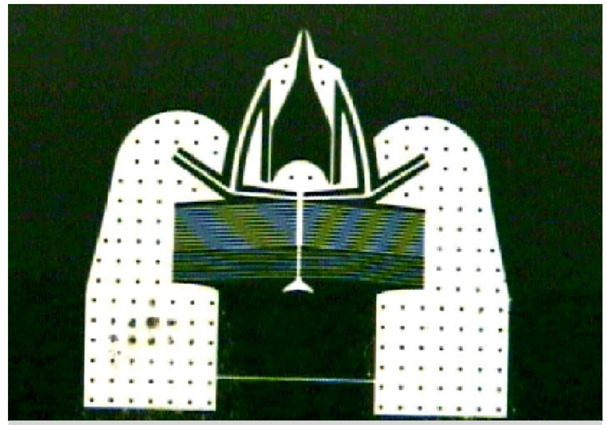

Figure 5 Optical image of a packaged Zyvex Microgipper.

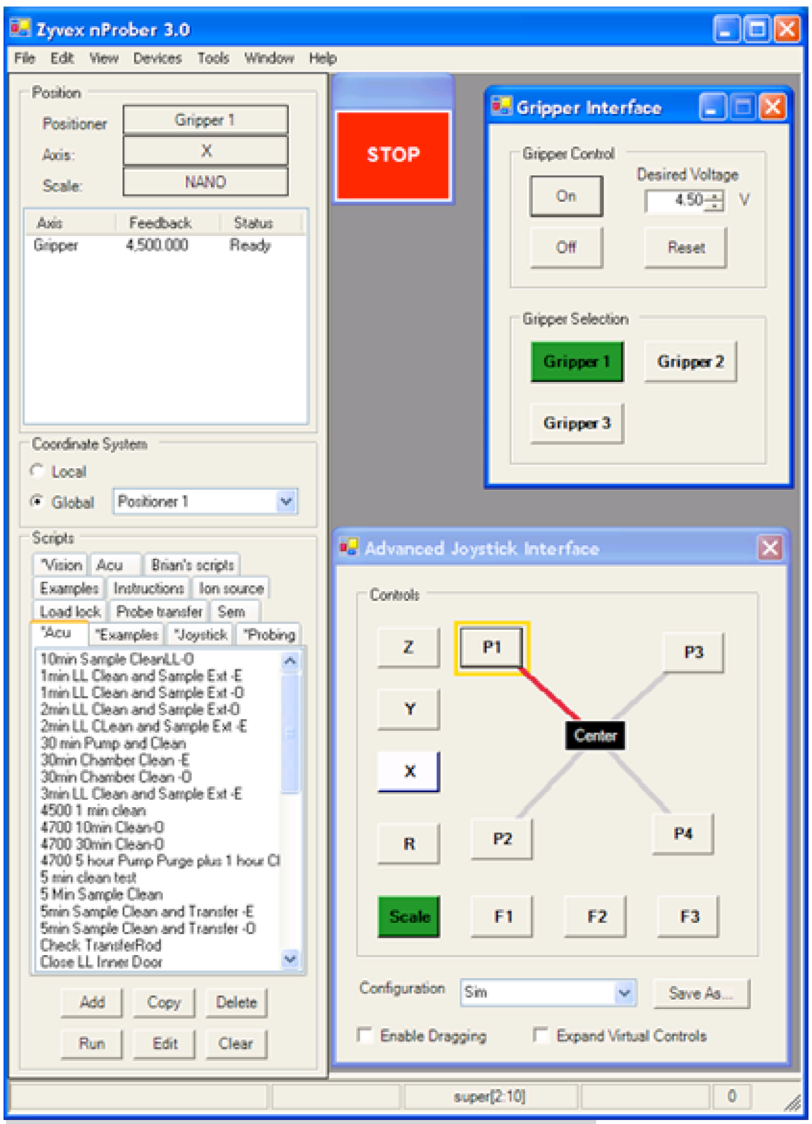

Figure 6 Zyvex's Nanomanipulator 3.0 software displaying Microgipper control interface.

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Zyvex's software interface allows the user to easily select desired voltages to power any of the detected microgrippers installed in the system. The microgrippers can also be controlled with our joystick to provide more interactive control. Figure 7a and 7b contain SEM images of a Zyvex Microgripper along side three tungsten probes in both powered and non-powered states.

Built-in hardware and software with over-voltage protection prevents damaging the microgrippers by limiting the amount of power supplied to the electrothermal actuators.

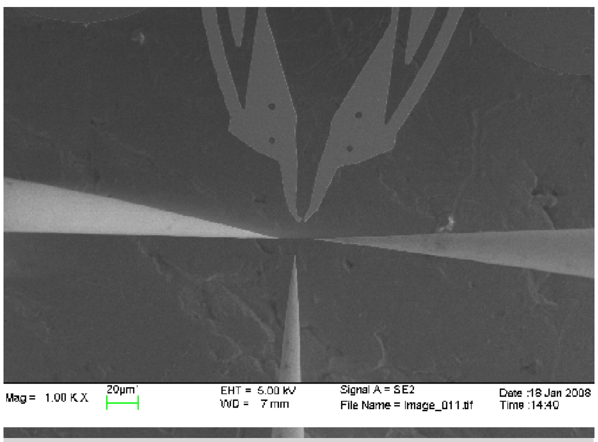

Figure 7a SEM image of a "power off" Microgripper along with Zyvex NanoEffector® Probes.

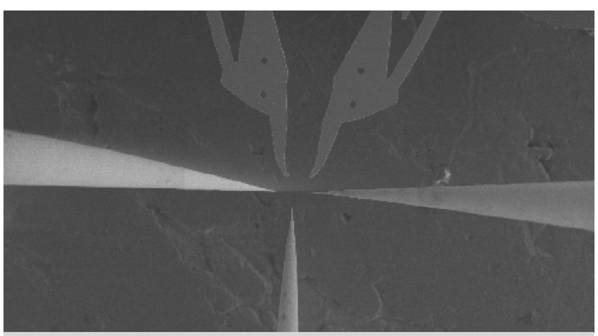

Figure 7b SEM image of a "power on" Microgripper along with Zyvex NanoEffector® Probes.

Applications

MEMS Assembly

Connecting microgrippers to the Zyvex Nanomanipulator opens up a wide range of new possibilities in micro- and nanomanipulation. Figure 8 shows microgrippers being used to grasp and place an electroplated nickel iron core onto a MEMS translation stage.

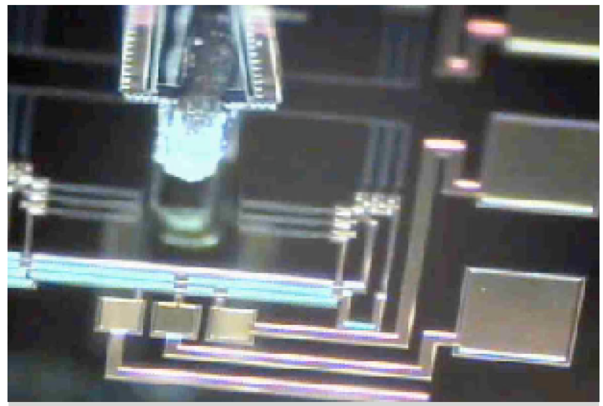

Figure 8a Microgripper placing a nickel iron core onto a MEMS stage.

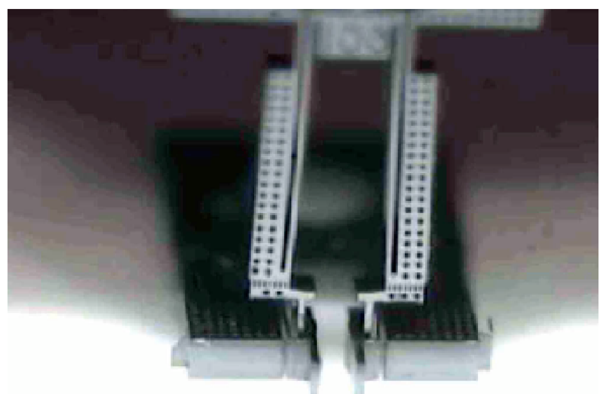

Figure 8b Microgipper picking up a MEMS component.

As the stage is translated, the nickel iron beam moves within a magnetic field to change inductance properties. These Microgrippers have also been used to create 3D structures by picking and placing MEMS connectors that are then inserted into specifically designed MEMS sockets (shown in Figure 9).

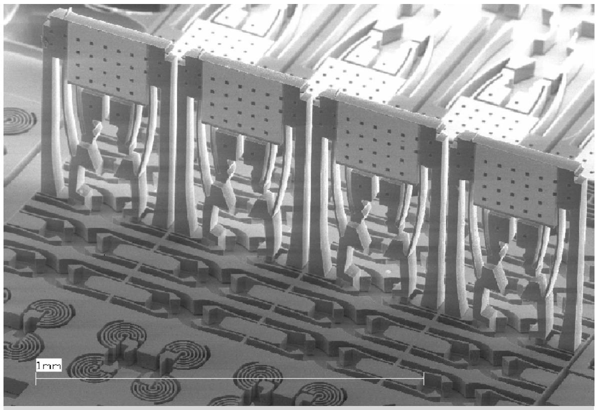

Figure 9 MEMS components microassembled into sockets.

The microgrippers in Figure 10 have been used to perform various pick-and-place experiments assembling connectors and creating 3D structures.

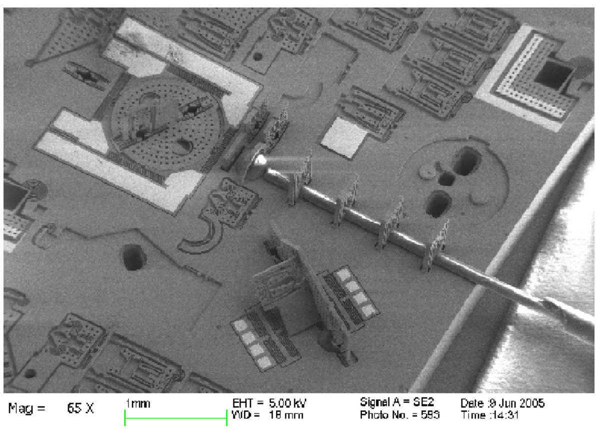

Figure 10 Complex assembly of a micro-optical spectrometer including gratings, ball lens, and optical fiber.

In this example, an optical microspectrometer has been assembled. This complex assembly contains MEMS gratings assembled onto a rotating MEMS actuator. In addition, an optical fiber is clamped down and aligned with a ball lens that was pick-and-placed and held down by a MEMS connector.

Nanostructured Materials

Carbon nanotubes are notoriously difficult to handle individually. The tubes clump and bind together in bundles, making extraction of individual strands difficult. The task is made much simpler using a Zyvex Nanomanipulator and a Microgripper end-effector. Figure 11 shows a single carbon nanotube bundle being removed from a larger bundle. Single carbon nanotubes can now be addressed using proves or other end-effectors.

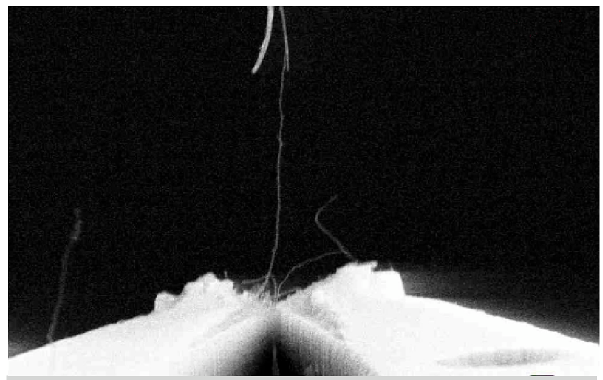

Figure 11 Microgripper grasping a single carbon nanotube.

Nanostructured Materials

Zyvex Microgrippers can be used to pick and place small structures for further study in other tools. Figure 12 shows a microgripper grasping a thin lamella that has been thinned in a SEM/FIB dualbeam system. The sample can then be placed on any number of sample holders for further study in other tools. Grippers have been used to prepare samples for TEM, atom probe microscopy, AFM, Raman, and many other tools. By combining the microgrippers and multiple probes, a user is able to pick and place very small structures in any orientation they need for optimal further study.

Bio Nano

Zyvex Microgrippers have also been used in bionano applications to handle and grip bionano samples. Figure 12 shows the grippers being used to pull apart collagen fibers. Multiple grippers can be used to hold the sample under study whiule another gripper delicately removes thin strands for further study. An assortment of other bionano samples can be similarly handled and manipulated.

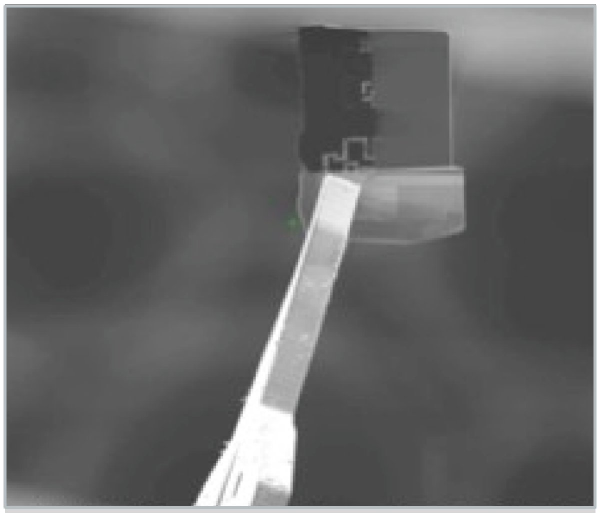

Figure 12 Zyvex Microgripper holding a thin lamella for further study.

Conclusions

Until recently, accurately manipulating and moving components and materials with dimensions of less than 1mm was a formidable task. Tools did not exist that 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, could not even accomplish the task. The difficult challenges of manipulating micro- and nanoscale objects are overcome using the precision-guided Zyvex Nanomanipulator with Microgripper end-effectors.