Column

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In my laboratory, we have been developing devices for nanotechnology research that combine nanoprobes with MEMS to produce new functions. My first opportunity to study probes dates back to my early years working at a company. The company had a policy of proposing research topics to the junior employees in their second year so I began researching field emission displays, which was beginning to attract attention in those days. Primarily, I was etching silicon by a wet etching process to manufacture arrays of silicon electron guns. While silicon electron guns were normally manufactured by controlling the under-etching time with a circular mask, I wondered if the electron guns could not be produced without under-etching. My idea was to combine local oxidation with KOH etching. By performing anisotropic etching with KOH on pattern edges to expose the crystal face and subsequently protecting the face with an oxide film and repeating this process three times, I could produce an excellent needle shape with good uniformity and reproducibility. Moreover, when using the edges of the pattern, this process is not dependent on the precision of lithography. While the silicon electron guns formed through this technique had good properties, ultimately silicon did not come to be used for electron guns.

After taking up my new position at the University, I continued studying probe devices based on this technique. Through similar processes, we have produced DNA tweezers (currently being studied in a Japan Science and Technology Agency project on the development of systems and technology for advanced measurement and analysis) for stretching and fixing DNA, a nanoknife for cutting chromosomes, and AFM tweezers (currently being studied by the Consortium Research & Development for Regional Revitalization under METI) for gripping and recovering nanomaterial. Wet etching is advantageous for producing nanostructures reliably and at a low cost, with good uniformity over a large surface area.

I have also focused on self-sensitive AFM probes using the immittance properties of comb actuators. This probe uses variations in a resonant frequency produced when an atomic force is applied to a comb actuator subjected to self-excited vibrations in a circuit similar to a crystal oscillator. Currently we are able to produce two-dimensional images with this probe. In addition to its application as an AFM probe, this technology can also be used as a touch sensor or force sensor by applying the same principles to tweezers, and is being developed for such applications as cell tweezers used to grip soft material. Eventually I hope to work on developing a functionalized AFM probe for use in a solution so as to be able to link this technology to biotechnology research. Recently AOI Electronics Co., Ltd. has begun manufacturing and selling MEMS tweezers. They have made innovations not only in the MEMS part but in the control system as well. This device can be used for sample transport in transmission electron microscopes and in the recovery of foreign matter generated in manufacturing processes. The AFM tweezers will also likely be incorporated in products in the near future. It is my hope that the use of MEMS tweezers in AFM devices will become commonplace.

On a different subject, I read the transcript of a nanotechnology talk given by the well known physicist Richard Feynman in which he describes miniaturization achieved by first creating a mechanism on a scale of one-fourth and subsequently creating a mechanism at a scale of one-fourth the first mechanism, for an overall scale of one-sixteenth. Through the development of scanning probe microscopes, we are currently capable of manipulating atoms and molecules with a probe. However, we must also deal with the so-called meso-spaces in which antagonistic micromechanical forces such as electromagnetic forces and meniscus forces are quite complex. For example, it is possible to grip but not release some samples with AFM tweezers, and we are currently laboring over this resolution.

At this point, we have created micro-sized cutting mechanisms and handling mechanisms through MEMS aimed at applications in nano-spaces. While at last we can see the “bottom” in terms of miniaturizing mechanisms, I suspect we have a long battle ahead of us before we can produce nano-mesomechanical structures with micro-mechanisms.