

Nanotechnology Symposium

1-May-06 - 8:30 am - 10:15 am

Zarbin: Thank you Mike, appreciate it. Our next speaker is Dr. George Skidmore. Who is going about creation of nanotools for nanomedicine. Thank you for joining us.

Skidmore: Thank you. I do want to thank the organizers for inviting me to speak here today. This is my first visit to ARVO. I'm actually a member of a different scientific community, you know that of micro- and nanofabrication. And I do want to correct a couple of things in the program. I have changed jobs since printing, so I am affiliated now with a different institution. And I do have a couple of commercial relationship disclosures. I do have a commercial interest in a company that sells micro- and nanotools as well as, I am a patenter in that field.

So what I want to do is give an overview presentation on MEMS and NEMS. It's been mentioned in some of the previous talks so I will do that first with definitions and then length scales. And then go over some of the product examples and biomedical product examples that we have in our field. And then what I want to do is touch on just a couple of the fabrication processes that we use that might be useful to you. And hopefully give some examples of things that are going on.

So first I want to define MEMS (Microelectromechanical systems) is the acronym. And they're really electromechanical devices that are made with integrated circuit fabrication technology. This definition is about 90 percent correct. We use a lot of the same materials, processes, and equipment that are used to make integrated circuits or computer chips, only we make mechanical devices. So what I have showing there is a movie that is a real time movie of silicon micromachines, silicon gears, turning, that are made with a lot of these techniques.

And so most of our processing steps include thin film deposition, we pattern lithography, we etch, we repeat, and so we build up layers and we can make what are relatively small micromachines. So some length scale definitions. For MEMS we usually talk about things that are microscale where we talk about the minimum feature size of our lithography. If you are familiar with the integrated circuit field of computer chips, the Moore's Law curve always talks about the minimum feature size that they can put onto a integrated circuit. And that's been coming down over the years. They're now at the 90 nanometer and 65 nanometer nodes. What we do with micro- and nanosystems is borrow their equipment effectively and so we can kind of follow their downtrend. MEMS now, you know, kind of, you start getting below a micron we still call it MEMS; somewhere around 100 nanometers we started calling it NEMS for nanosystems. And there is quite a bit of overlap between those two. Molecular machines were mentioned in the very first talk. They're not built with lithographic techniques but if they were to fit this model they would be down in the one nanometer sort of length scales. Another thing that I want to make sure I'm clear about is that we build things that are too small to be useful on an optical microscope. You can't see these minimum feature sizes. So a lot of these nanomanipulation tools and end effectors that we make with 100 nanometers or ten nanometer feature sizes, totally, we have to use them in electron microscopes so that's effectively what we do. Some of the main products from our field, inkjet print heads are the main one. Accelerometers for airbags, the third one, the DLP (digital light processor) is probably what's being used in the projector to project this image. There are a million mirrors, 14 micron x 14 micron, that oscillate back and forth to reflect that

light. So we actually have a moving micromachine in a very large scale and evident in application.

It's not until kind of the forth thing on the list, pressure sensors, where we start to get into the biomedical type applications, and that does include blood pressure sensors. There's pressure sensors for many other application as well. The field that I am now moving into is that of infrared imaging where we use these microsystems to detect infrared light, or make night vision equipment.

So some of the MEMS/NEMS products, the blood pressure sensor thoroughly swamps the market. But the biochips are chemical analyzers, lab on a chips, that Dr. Richards mentioned is a field of its own now sort of micro total analysis systems, its kind of a subfield of MEMS. And they have their own meetings, and they're kind of their own scientific community. There's also other products, electronic nodes, DNA arrays, they're all outside the body type applications. For inside the body, transdermal patches for drug delivery are microneedle-based made with these techniques. Here are _____ catheter stents and so forth. These are all very small market sizes compared to what else is going on.

So what I want to do is kind of give you an intro to some of the techniques we use to build these devices in the hopes that I can inspire you know some collaborative work on your part with one of your local micro or nanofabricators. So surface micromachines is one I've described before, anisotropic wet etching, and anisotropic deep RIE, I will talk about next. And then focused INB nanomachining is something you should be aware of though I don't have a lot of time to talk about it.

So like I said, surface micromachine. These techniques are similar to what we do in integrated circuit manufacturing. Feature sizes are below 100 nanometers at this point. Anisotropic wet etching is a technique that's been prevalent since the 60's, since the birth of micromachines. And these are what are used to make pressure sensors. Effectively we pattern a rectangle at the top of the silicon wafer and then etch down, and crystallographic-dependant etches such as potassium hydroxide will etch along crystallographic faces. And what's interesting about this technique is the one, one, one face will etch about 1,000 times slower. And if you etch all the way through a wafer and stop on your _____, you'll be left with a really sharp point here and by very sharp, I mean a couple of nanometer radius. So this technique is what's used for atomic force microscope, cantilevers, and tips. Multiple etching for multiple sizes of wafer will give you some very, very sharp points all the way down to a couple of nanometers. And these are tools that we've been using in nanotechnology research for about a decade. And you would think that maybe we could make a very sharp knife or a nanosurgical tool this way. It turns out there is now a company marketing a diamond coated silicon knives that are built in this manner, etched down to the sharp point. They are advertising three nanometer tip radiuses and I believe these are large-scale scalpels so, but with a nanometer size feature.

The second technique is that of deep reactive ion etching. And that's a very straight sidewall etch that we can do into silicon and then we etch out this material underneath and release our structure. And with this technique we are building things like microgrippers out of silicon that we can pattern lithographically down to micron or submicron sizes. Typically this technique's used with two micron minimum feature sizes but you can go as small as 50. And so you can build grippers, which are now commercially available, or have been commercially available for close to ten years.

Some research applications that I had seen, tissue extraction for analysis or microsurgery. These are areas of research where I'm seeing papers, non-biomedical applications really, where these are being used and where we effectively dissect integrated circuits for failure analysis.

And then the last thing, these are the transdermal drug delivery needles. They're a combined surface plus deep RIE technique to make very small needles.

So, in summary, what I wanted to leave you with is the idea that MEMS and now NEMS is really a field that's been around since the 60s and a lot of these techniques that we've been doing for a long time. They're many fabrication techniques that exist. I've only touched on a couple of them. There's a whole field. Most of these are based on IC type processing. And you'll find that there's active research at hundreds of universities and companies worldwide, probably a university that you work at. Mostly in electrical engineering departments and that multidisciplinary departments and that multidisciplinary research is key, I think, to trying to combine some activities that might be relevant to ophthalmology with what we do in micro and nanofabrication. And if you have any questions please feel free to email me, I'll leave my email there at the bottom of the page and with that I'll conclude the talk.

Zarbin: Really interesting talk. Any questions?

Q: One of the disadvantages of using silica is the fragility in handling. What types of materials are being used to coat or develop some of these chips that would stand up to manipulations by surgeons?

A: Yeah, that's a pretty good point. One of the points I didn't make is that for all of the micro/nano scale grippers we would never actually use our hands to move them around we would always have a tele-operated robotic system. Fragility is a very big issue with silicon. The coatings that are being used, the diamond like coatings or silicon oxide and so forth, are not really improving the fragility at least to my knowledge. There are other materials that we can use some metals, nickel and gold and so forth, but I don't know if there's much better biocompatibility. So right now I would say that we don't really have a good answer to increasing the toughness of these devices.

Q: Does the current state of engineering allow you to manipulate machines that are that small with enough precision so that you can actually move from point A to point B and not in a controlled manner?

A: Yeah. In an automated manner we can pick and place components that are as small as 100 microns x 100 microns x 5 microns. That's kind of the current record. And that's definitely sort of a research level thing. And the precision that we can do that with is sub-micron. And if you want to put a human in the loop and slowly manipulate something you can work at 100 nanometers or below. Inside of an electron microscope you can have nanometer level precision.

Q: But in real time how do you see these things since you can't even be looking through a high resolution light microscope? Like how would a surgeon even with robotic controls see what they're manipulating?

A: Yeah, that's something we don't have an answer at the nanoscale certainly. The only way we can see what we're doing is with an electron microscope. And so we work with inorganic materials for the most part.