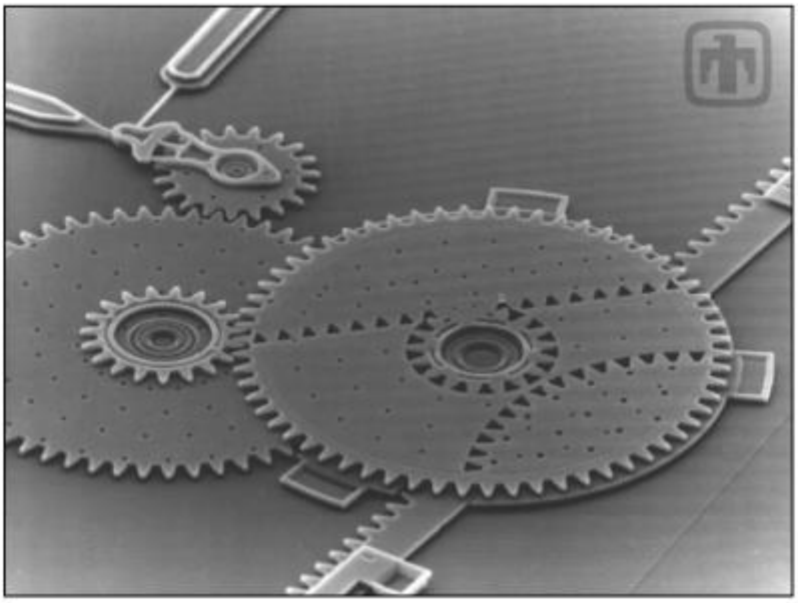
Lecture-12. MEMS

A micro-electromechanical system, or MEMS, is, logically enough, a mechanical system or machine that exists at the micro level. To quantify sizes down there, the best unit of measurement is the micrometer ("micro-meter," not "mi-crom-eter," which is an everyday-size precision tool). This unit, often referred to as the micron, equals one millionth of a meter (about one hundredth the width of a human hair). Imagine machines built to the scale of microns. As with many more familiar machines, a MEMS might have gears, motors, levers, bearings, and so on that are capable of moving things — say, adjust a very tiny mirror to shine a pinprick of light on a flat-panel TV display.

If you've been paying attention to the details of the nano-size world, you may be asking yourself, why are they talking about micro-electromechanical systems, when they should be talking about nano-electromechanical systems? Well, for openers, right now nobody can make nano-scale electromechanical systems. (Details, details.) Remember, a nanometer is one billionth of a meter in size — way smaller than a micrometer. But it's quite possible that by using micro systems we can build smaller and smaller elements to help us reach the nano level some day.

So how are people building MEMS today? Well, traditional manufacturing techniques that you might use to build a regular motor just won't handle micro-scale precision work. Instead, folks are rolling out the same techniques used to make computer chips. Using that approach, eventually we can make these devices in large quantities (potentially in the millions), at low cost, and with uniform performance. At the end of the manufacturing process, instead of having a chip that processes information, you have a mechanical chip — a nano-scale machine that performs an action. It's entirely possible to have a MEMS chip that contains an informationprocessing component as well as a mechanical component. For example, you might create circuitry to analyze signals from a sensor on the same chip that controls a mechanical device.

Even this early in the nano story, folks have applied MEMS techniques to a variety of sensors. One example is an accelerometer (a sensor that detects sudden changes in speed) — handy in applications such as release mechanisms for car airbags. The MEMS version of the accelerometer uses a silicon shaft that holds a weight. One side of a capacitor is built into the shaft. When the acceleration changes, the shaft bends, and this changes its capacitance. The electrical circuit in the chip measures that change in capacitance — and determines the amount of acceleration. This type of accelerometer has the necessary precision to trigger automotive air bags in a collision, and is already in use — at a cost that's about 80 to 90 percent lower than for conventional accelerometers. Another MEMS application is already in extensive use in medical settings: MEMS-based blood-pressure sensors. As with standard pressure sensors, these measure the movement of a diaphragm built into the device — but they're also disposable. Such sensors can be used at a small fraction of the cost of more traditional pressure sensors — and the use-once-and-throwaway approach is often safer if the patient has a highly infectious disease. But MEMS don’t have to just sit around sensing things; they can also manipulate or move things around. One of the few commercial applications currently marketed concerns MEMS chips that contain an array of microscopic mirrors. These mirrors act as optical switches that produce the picture in many large-screen TVs. Each mirror is assigned a 1 or 0 (on or off) — just like a memory cell. Electrostatic forces can then cause each mirror to either align so it transmits light to the TV screen (lighting up a pixel) or to move out of alignment (darkening a pixel). Researchers are busy developing all kinds of MEMS that can manipulate tiny objects. Figure 8-4 shows a MEMS transmission (basically a bunch of gears) that takes the output of a microengine on a chip and then manipulates another object on the same chip.



All we need now are some tiny brains (no cheap remarks, please) to go with the tiny fingers . . . and we’re partway there already: Computer chips have been miraculously shrinking over the years to become more powerful. But as the components of chips — stuff like transistors, diodes, and memory cells — continue to shrink, there’s less distance between those components; the increased density in the chip creates problems. Nanotechnology may take us the rest of the way to creating computer chips based on molecular-scale devices (or even smaller nano-devices) that can solve many of these problems.