Micro-Electro-Mechanical-Systems (MEMS) In The K-12 Classroom

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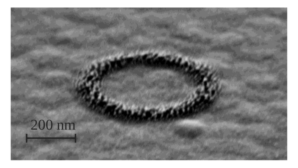
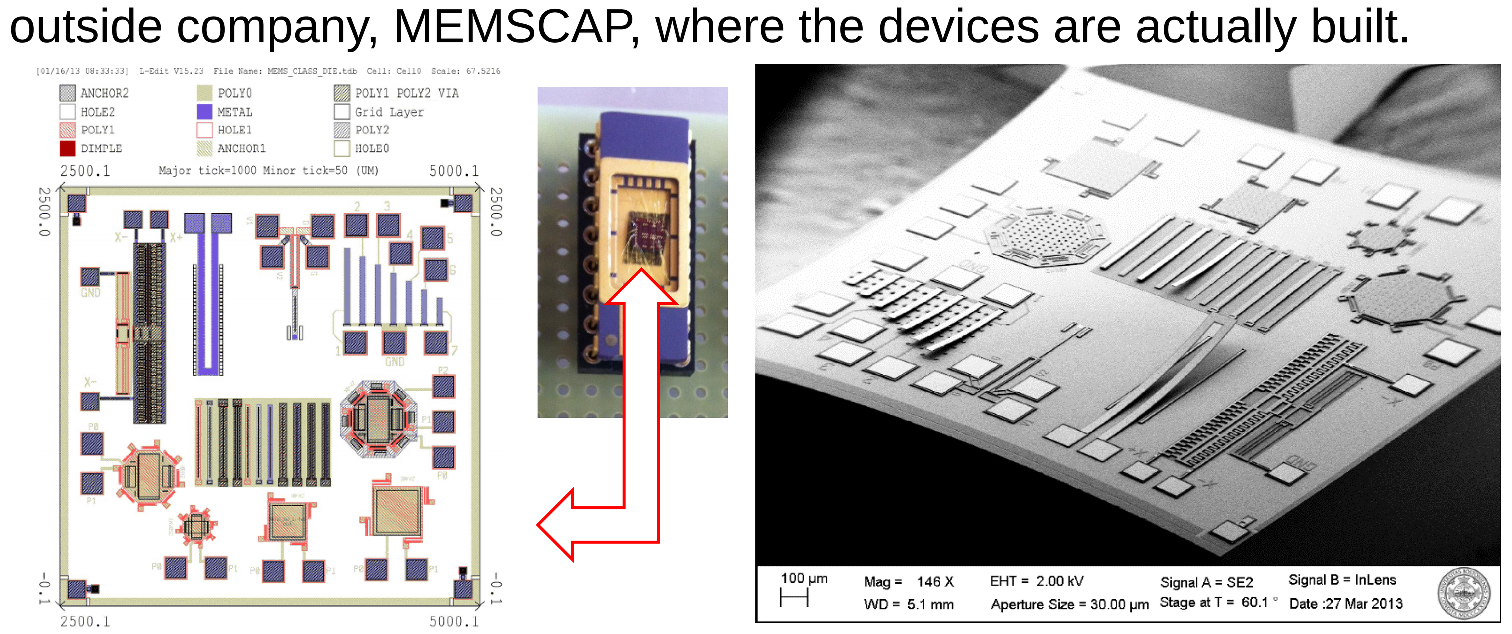
Solid State Research Laboratory



The National Science Foundation's (NSF), Research Experiences for Teachers (RET) at Boston University's Photonics Center, places science teachers in research laboratories through out the facility. Professor Bishop is the Primary Investigator (PI) of the Solid State Research laboratory, who has welcomed teachers from the program into his lab. The team of researchers at the Solid State Research Laboratory at Boston University include the PI, Professor David Bishop, Post-Doctoral Research Associate, Matthias Imboden, Research Engineer, Jackson Chang, as well as graduate and undergraduate students. These researchers are designing Micro-Electro-Mechanical-Systems (MEMS devices) that can write even smaller, nano-sized, structures by doing 3-Dimensional printing at the scale of atoms!

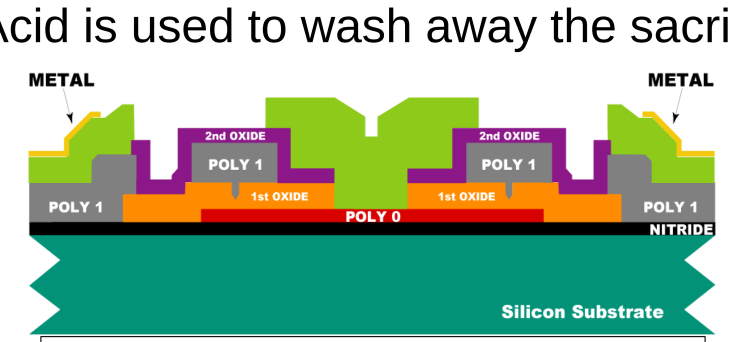
Introduction – What are MEMS?

Micro-Electro-Mechanical Systems (MEMS) can also be referred to as micromachines. The micro-sized devices are able to move, which is what classifies them as micromachines. In the Solid State Research Lab, the team of researchers design micro-sized devices using a software program called L-Edit. Then the designs are sent to an outside company, MEMSCAP, where the devices are actually built.

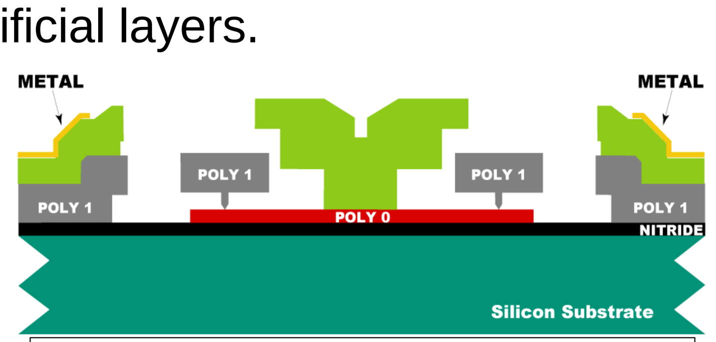


Fabrication – The Making of MEMS

MEMSCAP Inc. offers Multi-user MEMS Processes (MUMPs), where different users can submit designs of MEMS devices for fabrication by MEMSCAP. The Solid State Laboratory uses MEMSCAP's PolyMUMPs (three-layer polysilicon surface micromachining process) to make their MEMS devices. The devices are made by depositing up to three polysilicon layers and oxide layers onto a silicon wafer following a set of design rules. Photolithography is used to etch away unwanted parts of the layers in order to construct the intended design. When the device is built, a sacrificial release using Hydrofluoric (HF) Acid is used to wash away the sacrificial layers.



Side view of the MEMS device before the sacrificial release of the oxide layers

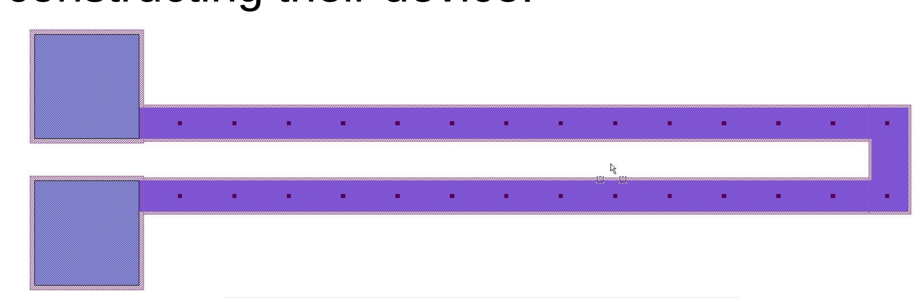


Side view of the MEMS device after the sacrificial release of the oxide layers

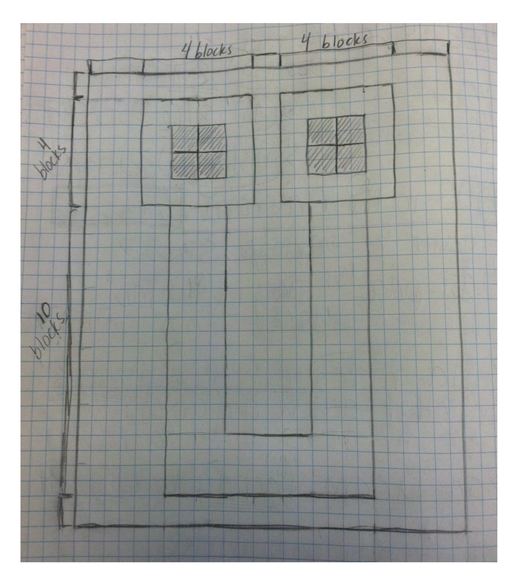
In The Classroom – Preparing to Build MEMS Models

Using various materials, pictured below, students can easily replicate the process of building MEMS devices in the classroom.

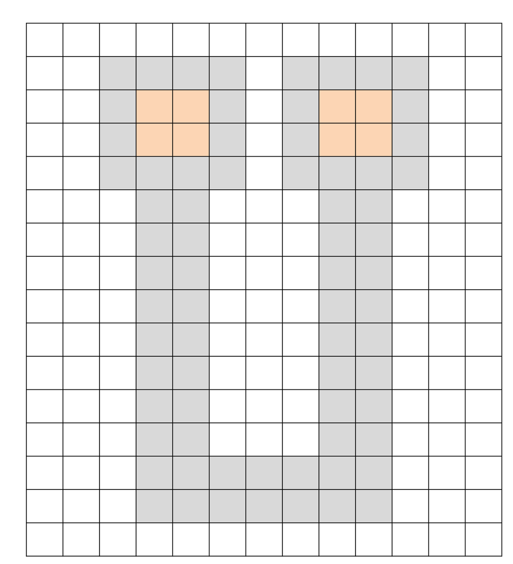
The final design for a MEMS device needs to be made using the program L-Edit before the design is submitted to MEMSCAP, but this program is not available in classrooms. Students can substitute Microsoft Excel for L-Edit to make their final design before constructing their device.



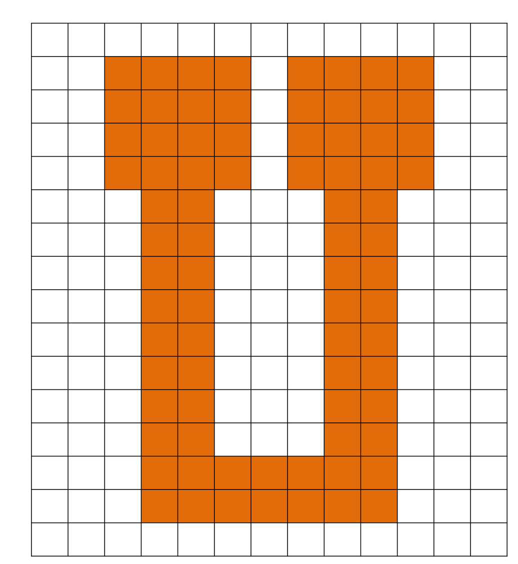
Design using L-Edit



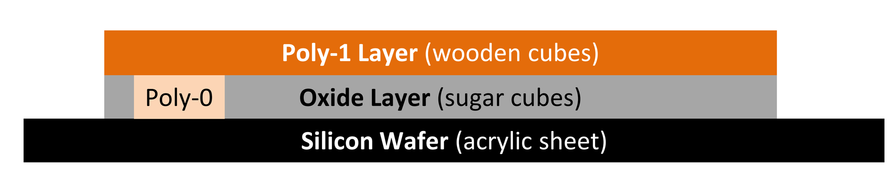
Design Sketch on Graph Paper



Excel Layout of First Layer



Excel Layout of Second Layer



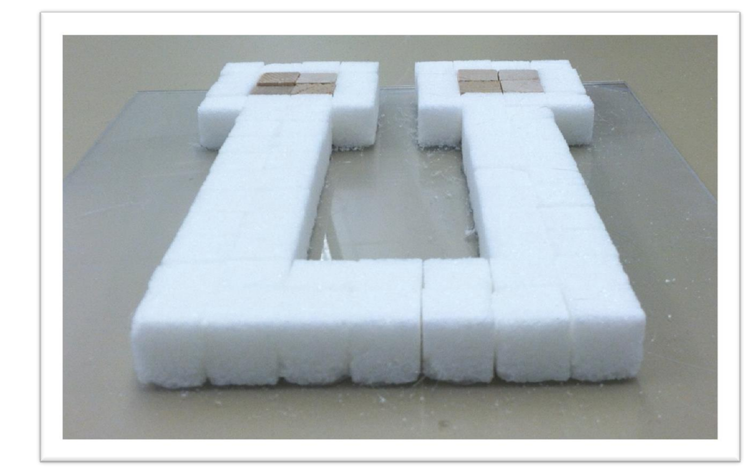
Side View of Design Using Excel

Once designs are completed using Microsoft Excel, students can then build a model of their MEMS design using the following materials:

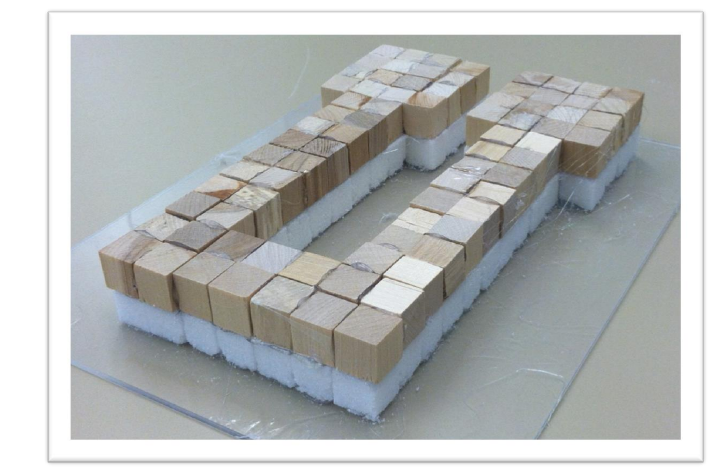
Actual MEMS Material	Materials for MEMS Models
silicon wafer	clear acrylic sheet (10"x8")
poly-silicon layers	wooden blocks
sacrificial layers (oxide layers)	sugar cubes
hydrofluoric acid etch	water for "water wash"
metal layer (usually gold)	aluminum foil

In The Classroom – Building MEMS Models

MEMS devices are made by depositing different layers of materials onto a silicon wafer, which in the classroom is represented by a clear acrylic sheet. The first layer consists of Poly-0 (wooden cubes) and the First Oxide (sugar cubes). The entire MEMS structure is secured to the silicon wafer by Poly-0. Once the first layer is deposited, then the second layer, Poly-1 (also represented by wooden cubes) can be deposited onto the silicon wafer.

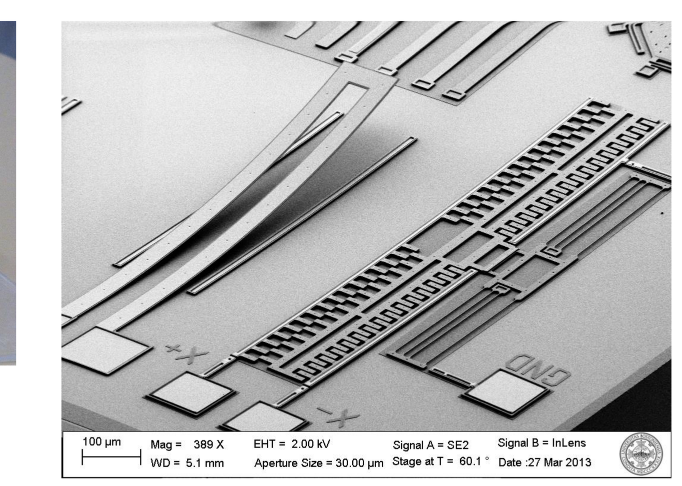


Poly-0 and First Oxide Layers



Poly-1 Layer

Final MEMS model after sacrificial release of the First Oxide layer



The process of designing and building this MEMS model requires a great deal of planning and analytical thinking, as well as spatial recognition. Projects such as this MEMS model activity can connect students to cutting edge research topics and encourages students to pursue careers in engineering and science fields.

Boston University Acknowledgements

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- Evan Lowell – Undergraduate Student
- Neeraj Basu – Undergraduate Student
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