Center for Nanoscale Chemical-Electrical-Mechanical Manufacturing Systems

Learning Activity Series

Printing CAD designed objects

Center for Nanoscale Chemical-Electrical-Mechanical Manufacturing Systems

CAD designed 3D printing

www.nano-cemms.illinois.edu

Description:
The students design and produce a three-dimensional objects using CAD, a data projector, and a photoreactive polymer

Prerequisites:
None

Instruction Time:
Two to five class periods The first period is for the Introduction PowerPoint presentation, and the rest are for designing and "printing" the three-dimensional objects

Audience:
High School science or technology classes.

Lesson Objective:
Students will create objects in a rapid prototyping technology. Students will make a product that created through a chemical reaction.

National Science Education Standards:

Content Standard A: Abilities Necessary To Do Scientific Inquiry.

Content Standard E: Understandings about Science and Technology.

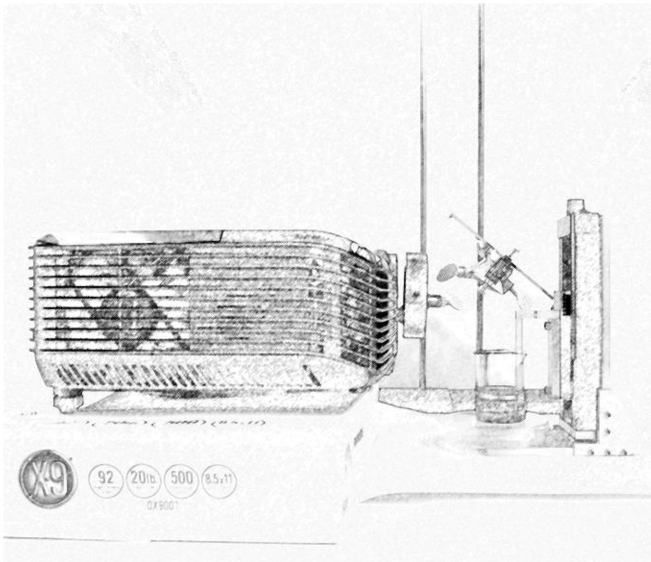
Illinois State Learning Standards:

11.B.5a Identify a design problem that has practical applications and propose possible solutions, considering such constraints as available tools, materials, time and costs.

12.C.5b Analyze the properties of materials in relation to their physical and/or chemical structures.

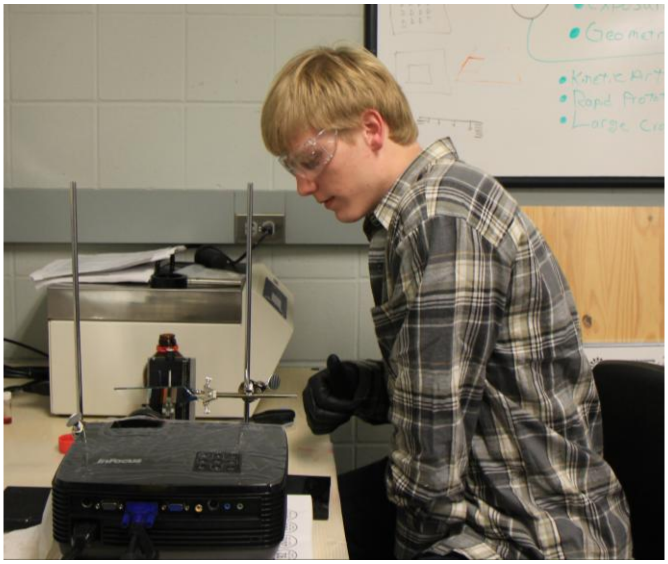
13.B.5b Analyze and describe the processes and effects of scientific and technological breakthroughs.

Contents



Instructional Method:

The instructor gives a presentation on microstereo lithography. Students design computer images to create a three-dimensional object. Students then use photoreactive polymer and their computer images to create an actual three-dimensional object



Background Information:

This lab uses a process based on a research project headed by Professor Nicholas Fang and developed at the Nano-CEMMS center at the University of Illinois. Dr. Fang's research group uses a UV sensitive monomer to do a form of three-dimensional printing called microstereo lithography. Using a video projector with a UV output, they are able to create incredibly thin polymer layers (on the order of 400 nm) and build objects layer by layer. This activity demonstrates the basic challenges of nanoscale engineering and manufacturing by using the same principle at a much larger scale.

The reaction will occur with white light from a regular video projector. The light initiates a photochemical reaction by cleaving a molecule to form free radicals. The free radicals polymerize a monomer through an addition polymerization reaction. The reaction polymerizes the solution, becoming solid only where the white light is projected. Elsewhere it remains an unreacted liquid.

The photosensitive monomer Polyethylene Glycol Diacrylate (PEG) works under the process of addition polymerization. The photoinitator, Phenylbis (2,4,6-trimethylbenzoyl)phosphine oxide, (Irgacure 819) absorbs UV-wavelength photons and produces free radicals. These free radicals react with the monomers (HDDA or PEG) to cause chain propagation, polymerizing the monomer.

Successive layers are made by lowering the polymerized shape into a beaker of the solution. A thin layer of fresh solution flows over the top, and light is again projected to solidify portions of the fresh layer. This is repeated, creating a three-dimensional object layer by layer.

Overview:

In this lab, students make a three-dimensional object of their own design. Students can design an object using a CAD program. They save their design as an STL file, a common format often used to translate designs to physical objects. They run a utility to slice the STL file containing their design into cross sections.

A photoreactive mixture of chemicals polymerizes when exposed to ultraviolet light, leaving nearby polymer unreacted. One can create their object by taking the cross sections to pattern the light of the data projector into a beaker of the photoreactive polymer. Adding an ultraviolet absorber prevents the light from penetrating into the polymer more than a fraction of a millimeter. By continually lowering the previous layer of hardened polymer into the beaker, a three-dimensional object is made one cross-sectional layer at a time.

Materials:

- Polyethylene glycol diacrylate (CAS: 26570-48-9)
- Phenylbis(2,4,6-trimethylbenzoyl)-phosphine oxide (CAS: 162881-26-7)
- Sudan I (CAS: 842-07-9)
- 100 mL amber bottle
- Balance
- Weighing paper
- Spatula
- Stir plate and stir bar
- 50 mL beaker
- Data Projector
- Computer (with PowerPoint)
- Magnifying glass
- First surface mirror
- Ring stands, clamps, and clamp holders
- Staging device*

Safety:

Goggles and aprons should be worn as in all chemistry laboratory activities. Staring at a white data projector image can cause damage to eyes.

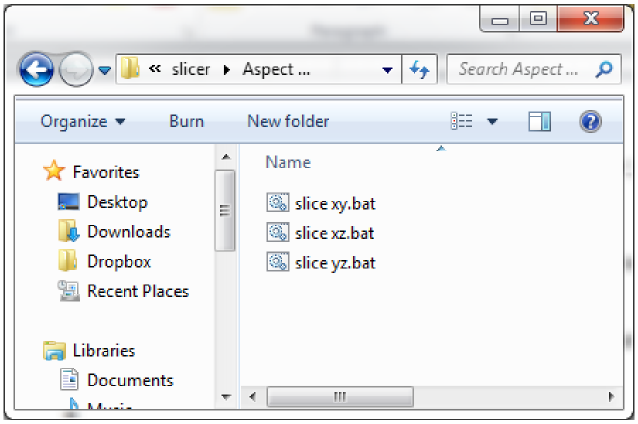
Chemical Safety:

- Polyethylene glycol diacrylate (CAS: 26570-48-9) – Irritating to eyes and skin.
- Irgacure 819 *phenylbis(2,4,6-trimethylbenzoyl)-phosphine oxide* (CAS 162881-26-7) – Skin sensitizer, avoid contact with skin, eyes, and clothing. Do not inhale.
- Sudan I (CAS 842-07-9) – May cause skin irritation by contact, limited evidence of a carcinogenic effect.

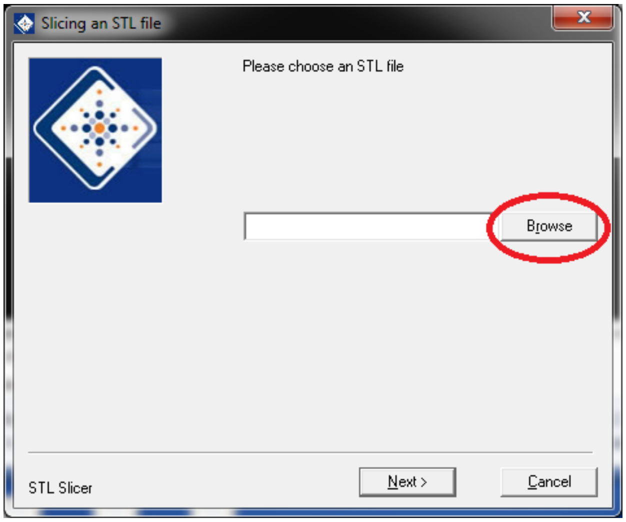
Preparation:

At least 24 hours before the experiment begins, mix up the solution. To make the PEG solution, combine 98mL of Polyethylene Glycol Diacrylate with 2.00 grams of Irgacure 819. Add 0.02 grams of Sudan I, used here as a UV absorber. The concentration of Sudan I can be adjusted to make thinner or thicker layers. Adding more Sudan I will make thinner layers because more UV light will be absorbed.

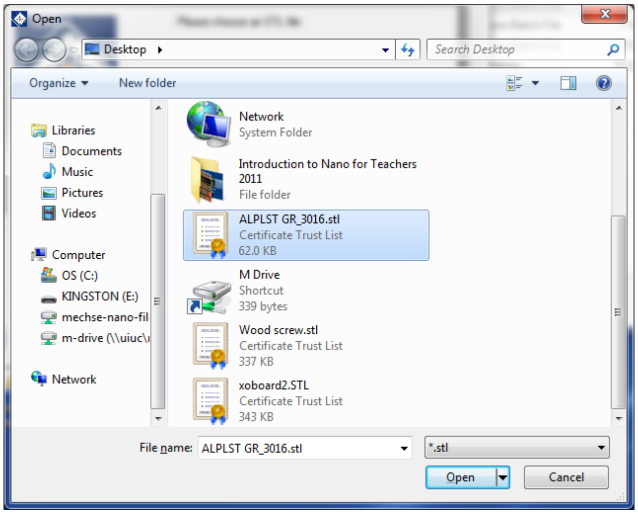
To slice an STL file



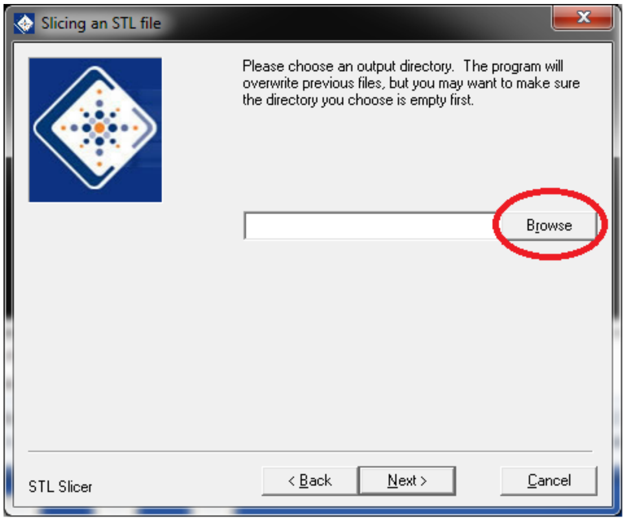
1. Select the program to run based on the direction you want to slice.



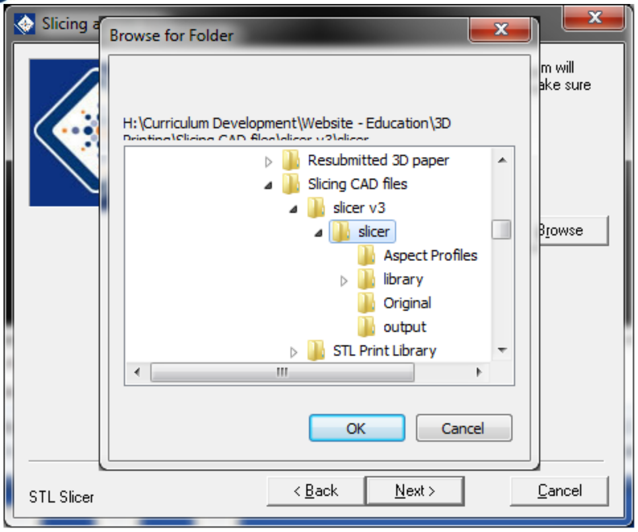
2. Select "Browse" to locate the STL file.



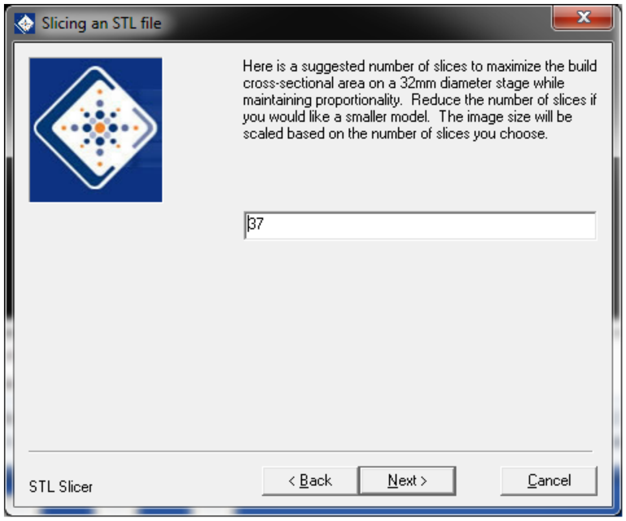
3. Navigate to the STL file to slice.



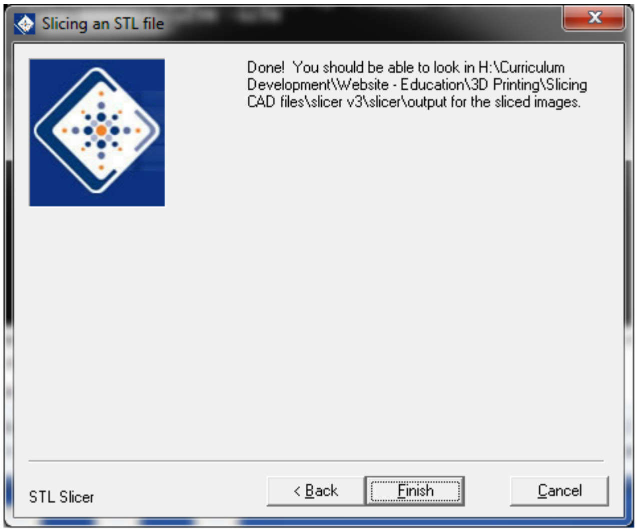
4. Select "Browse" to set the folder to save the output images. It is a good idea to have an empty folder so other files do not interfere later.



5. Navigate to a folder to save the output images.



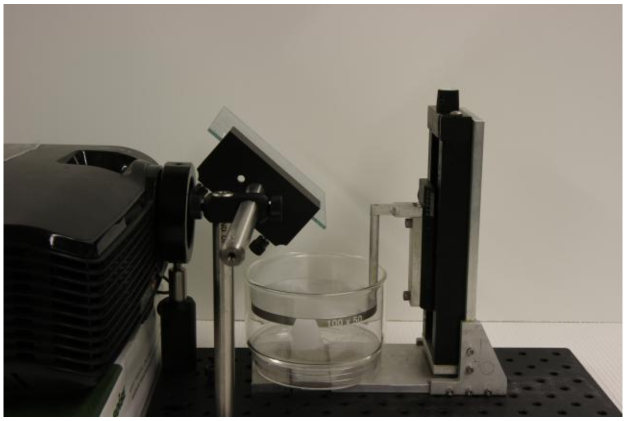
6. Select the number of cross sections to make. This number is calculated based on a scaling value where 32 cross sections lower the object 1 cm.



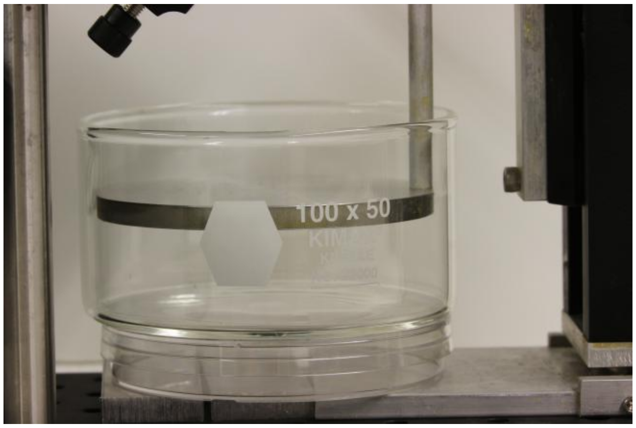
7. The final screen tells you where the slices are located. This is the same as the output folder you navigated to in step 5.

Prepare Printer

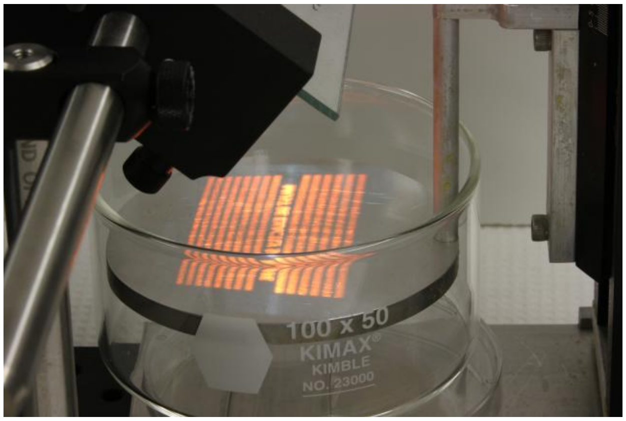
8. Place data projector high enough to shine through a mounted lens.



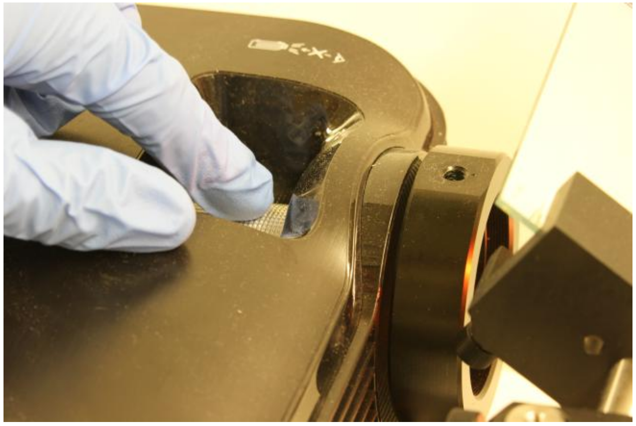
9. Place a magnifying lens and mirror in front of projector lens. Place stage with a lowering mechanism under mirror.



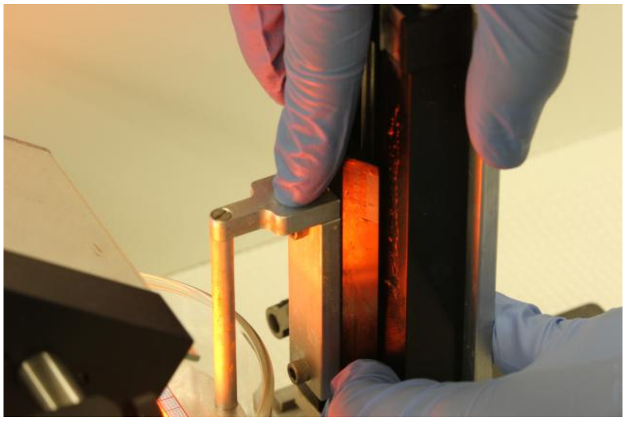
10. Place beaker such that stage fits within it below the lip. Beaker may have to be elevated; for example, with extra Petri dishes.



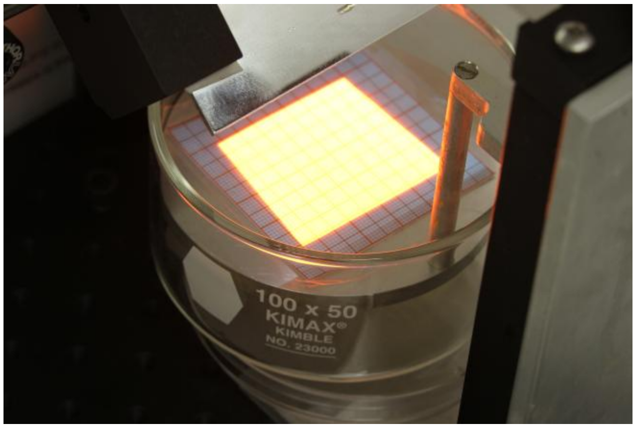
11. Focus the projector onto the stage using text from PowerPoint.



12. First focus with knobs on the projector lens.



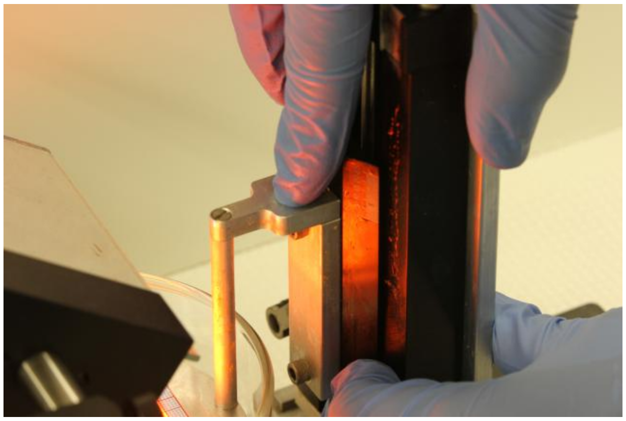
13. The stage height may also be adjusted to focus.



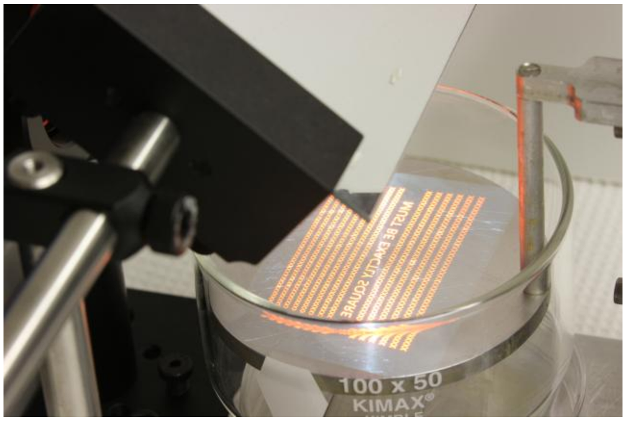
14. Place metric grid onto stage and advance to an image of a red square that resembles the size of the product to be printed.

15. Correct for Keystone first. Often buttons atop the projector will do this. Adjust until a square or rectangle is formed.

16. Angle the mirror to change length of the red rectangle along principle axis of lens. To shorten, angle the mirror closer to vertical.

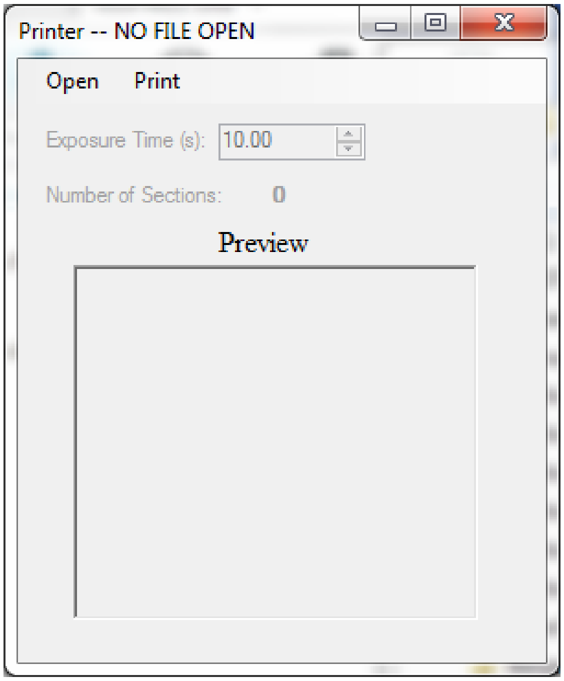


17. Change the height of the stage to correct the width (perpendicular to lens's principle axis). The mirror may have to move closer to the lens to shrink image under serious misalignments.

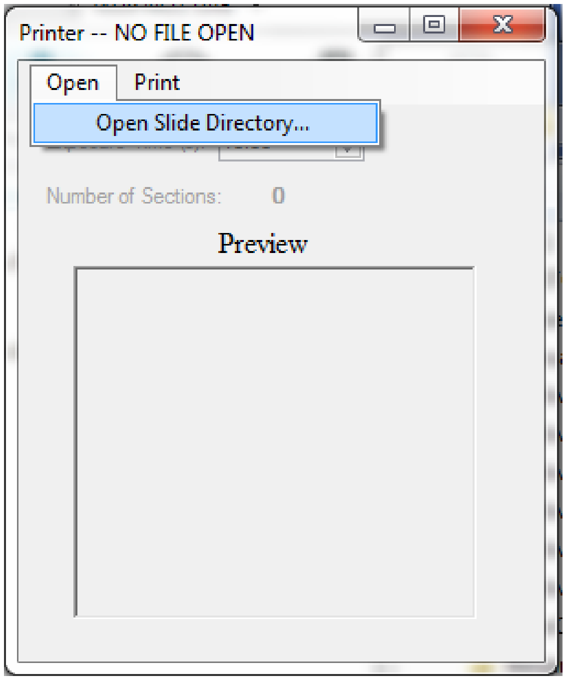


18. Make minor adjustments as needed to project a true square. Recheck focus before proceeding. Then remove the metric grid.

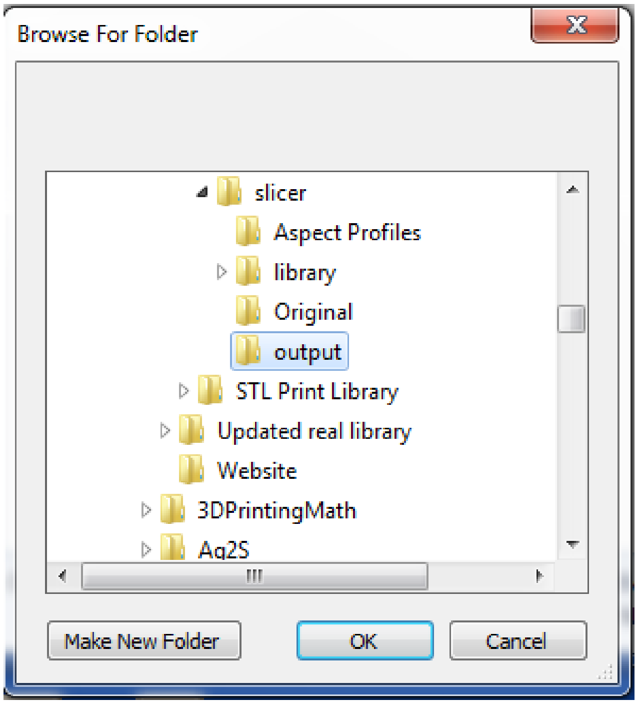
Load a series of slices



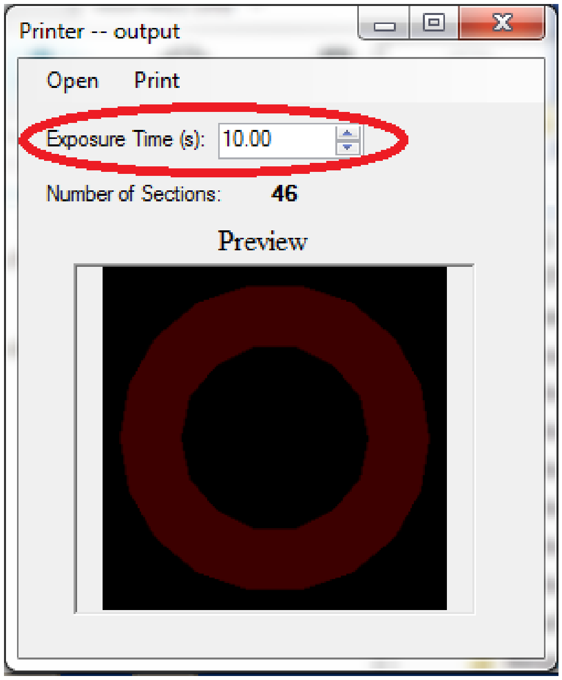
19. Run 3D Printer.exe.



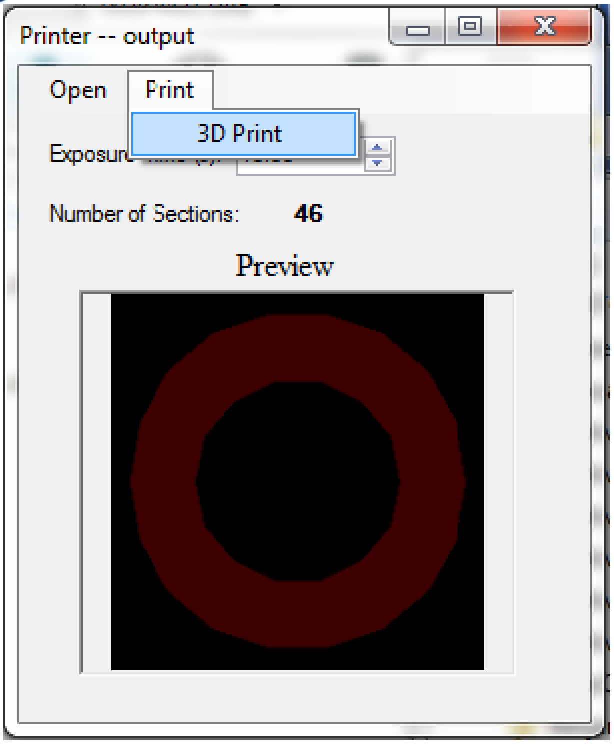
20. Select Open → Open Slide Directory.



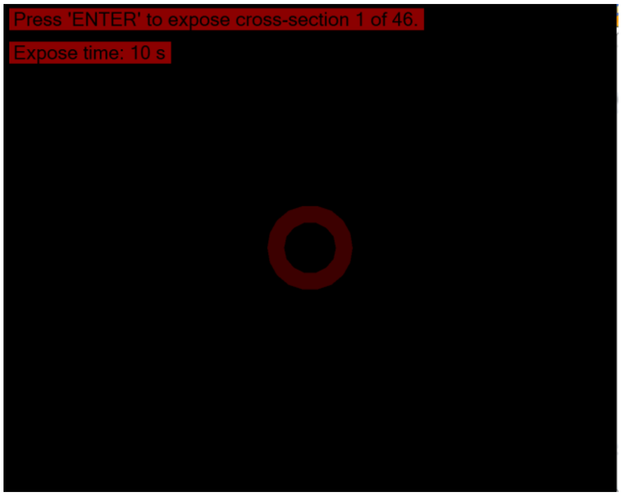
21. Browse to folder containing ONLY the cross sections to print.



22. Select the time to project the image.

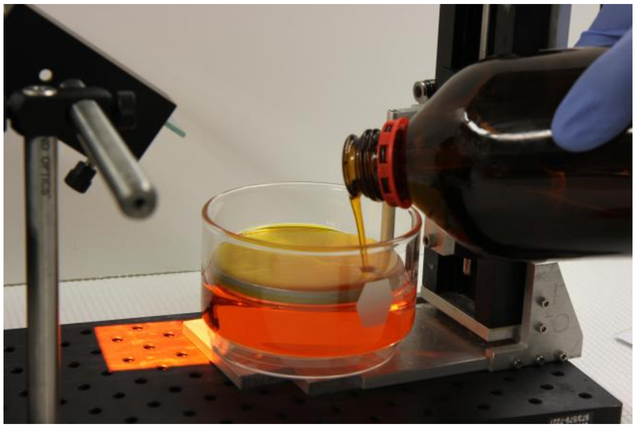


23. Select Print → 3D Print.

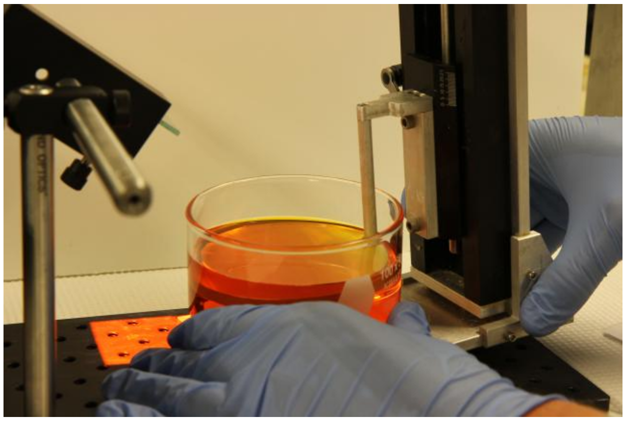


24. Align and focus 3D Printing apparatus.

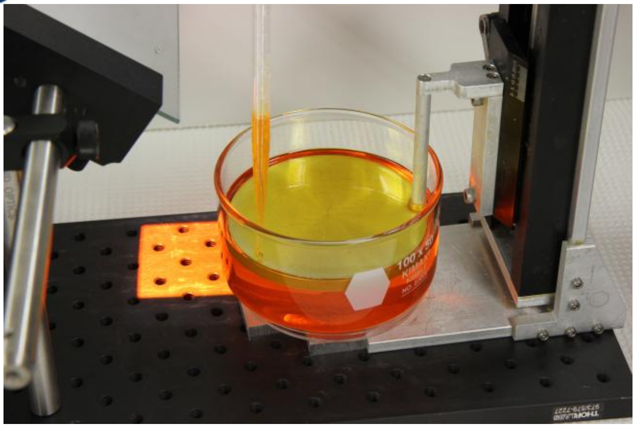
Print Object



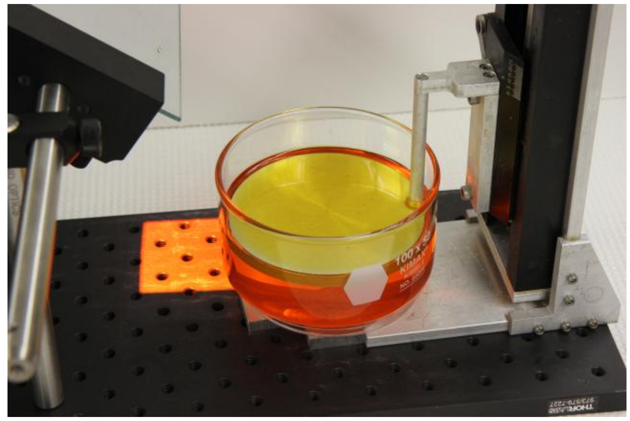
25. Fill beaker with solution so that it just covers the top of the stage.



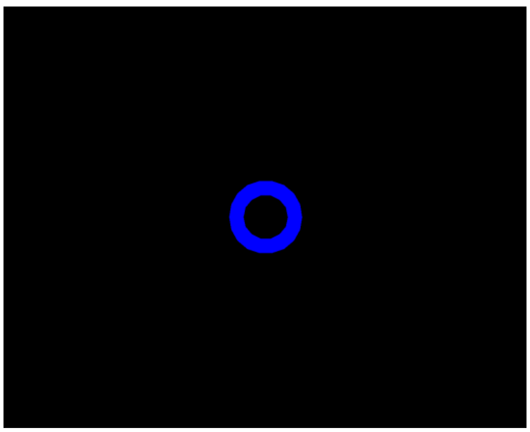
26. Remove bubbles trapped under the stage by tilting it.



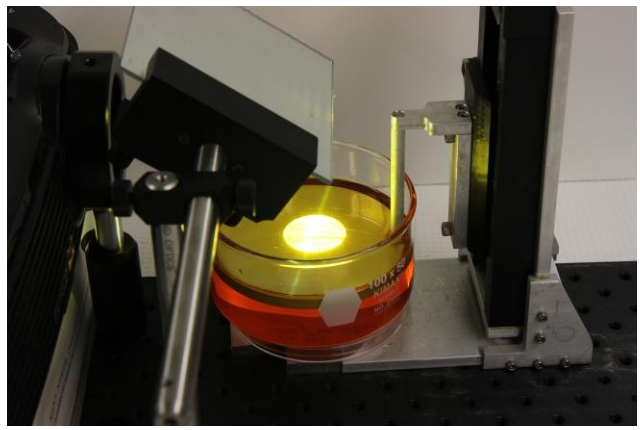
27. Use a pipette to remove excess solution atop the stage. Remove until the rim of the stage is almost devoid of fluid. Then add a little more around the edges.



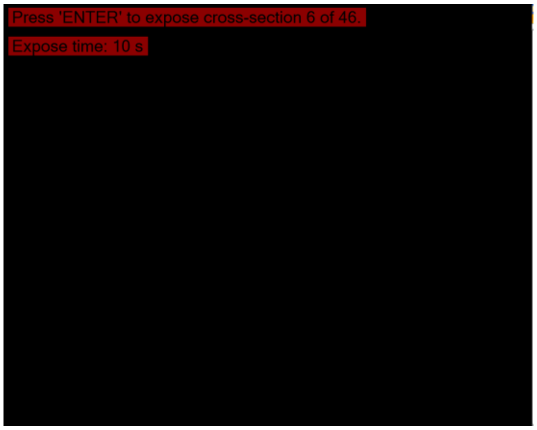
28. Make the first layer as thin as possible to maximize attachment of the first layer.



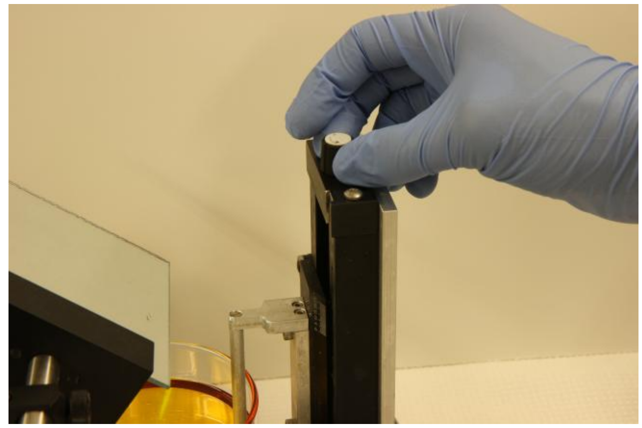
29. Project the first layer by advancing to next slide.



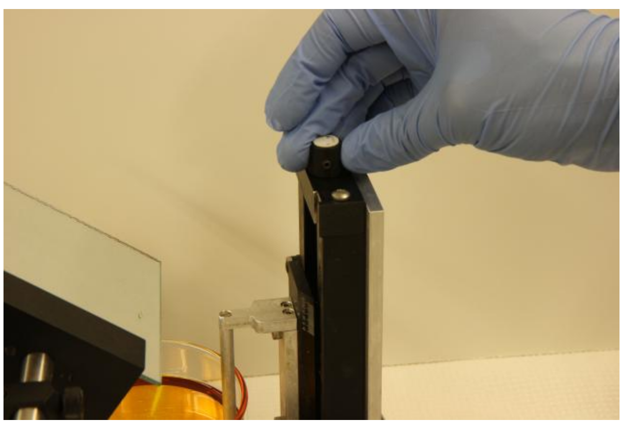
30. The program will automatically stop projection after the exposure time you entered has timed out.



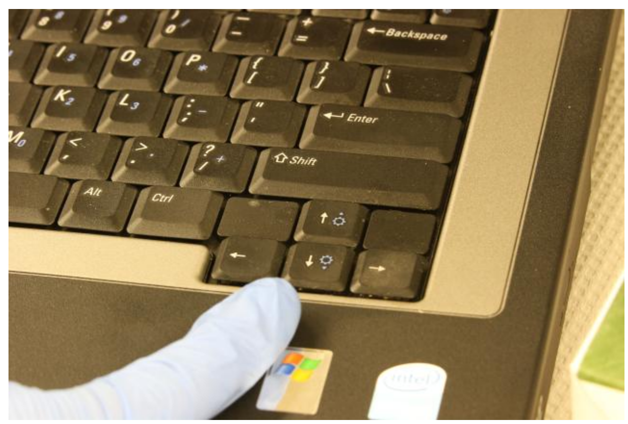
31. A blank slide without automatic advance should follow each projection



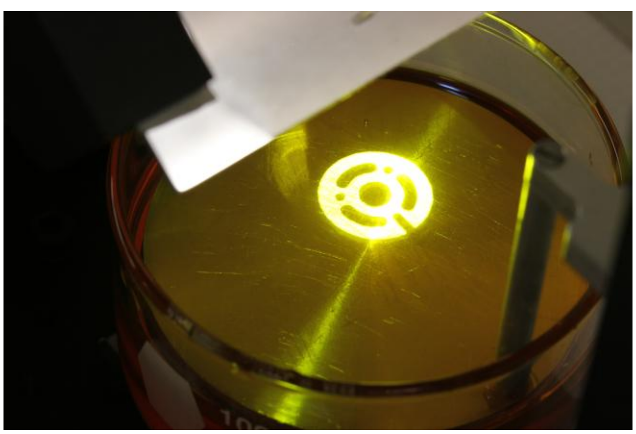
32. Lower the stage by one or even two turns to quickly disperse fresh solution over the previous layer.



33. Raise the stage by the appropriate amount such that a net drop of only ¼ or ½ turn occurs—be consistent with net depth increase per layer.

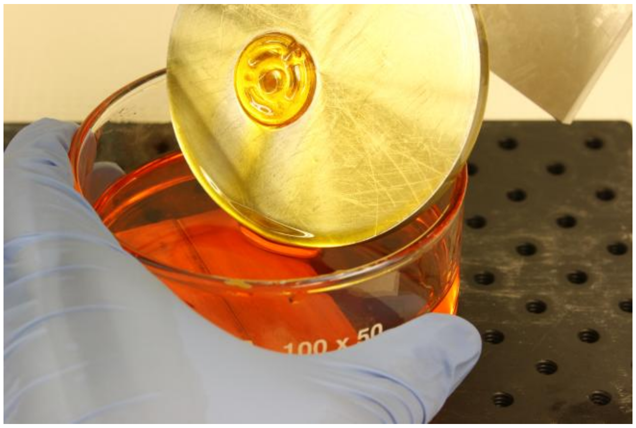


34. Click the down arrow to advance to the next slide.

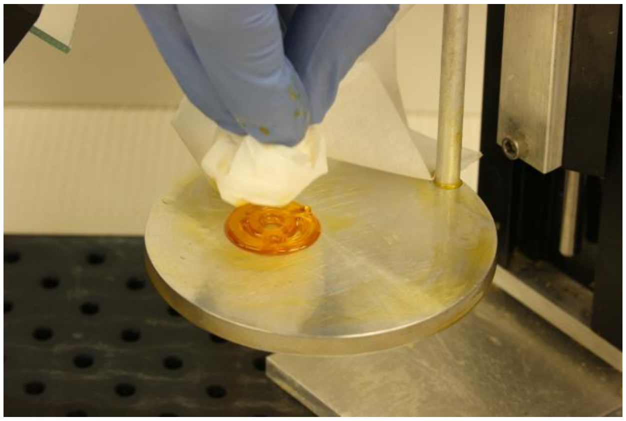


35. Repeat process until the slideshow is complete.

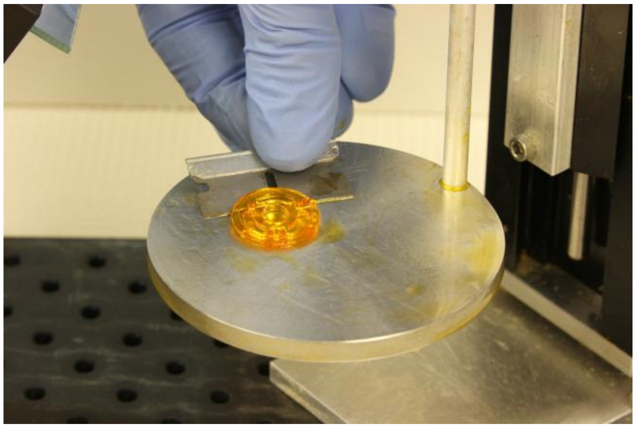
Finish Product



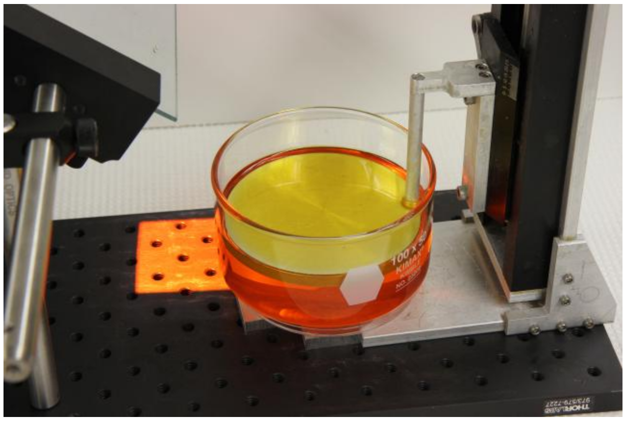
36. Fill beaker with solution so that it just covers the top of the stage.



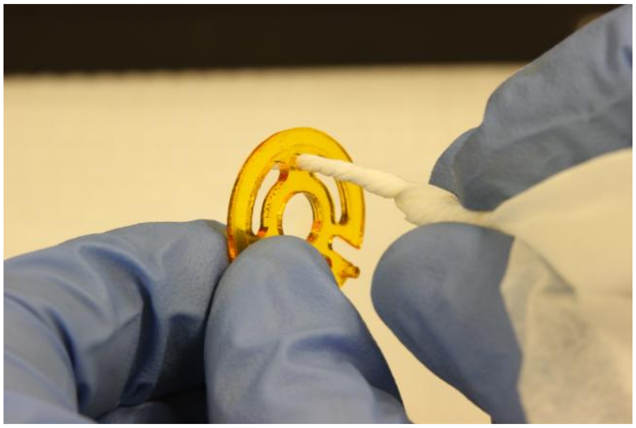
37. Soak up fluid remaining on the stage with chem-wipes. Make sure to dry the bottom of the stage, the top, and the product just printed.



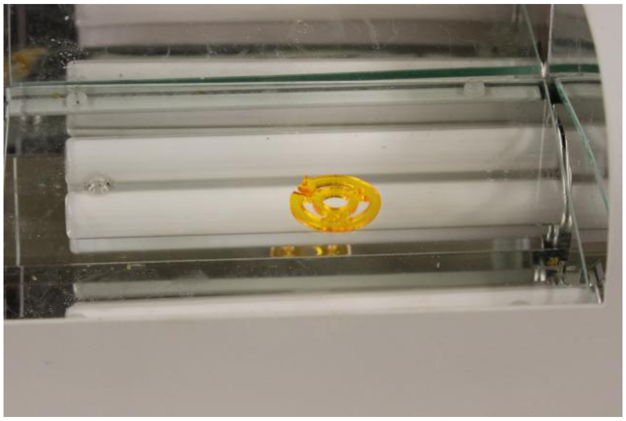
38. Use a razor to *evenly* detach the product. Slip razor under the perimeter and work towards the center. Repeat this from several sides.



39. Remove the product and dry thoroughly.



40. To dry fine details, twist the chem-wipe into a thin rod and probe any holes, contours, or reliefs that may collect fluid.



41. Bake for 5-10mins under UV light.

Notes:

Established in 2003, the Center for Nanoscale Chemical-Electrical-Mechanical Manufacturing Systems (Nano-CEMMS) is funded by the National Science Foundation. Partnering Institutions include the University of Illinois, North Carolina Agriculture and Technical State University, Stanford University, University of Notre Dame, University of California – Irvine, and Northwestern University. Researchers are developing a nanomanufacturing system that will build ultrahigh-density, complex nanostructures. The Center's research will ultimately result in a new way of working and has the potential to create millions of jobs for American workers. Our nation's school children must be prepared to assume the new roles that will be the inevitable outcome of these emerging technologies.

This learning module is one of a series that is designed to interest middle and high school students in pursuing this new field. The Center also offers ongoing professional development for teachers through a continuous series of workshops and institutes. To sign up for a workshop or to order more learning modules, visit our website at ***http://www.nano-cemms.illinois.edu***.

For more information, contact: Center for Nanoscale Chemical-Electrical-Mechanical Manufacturing Systems; University of Illinois at Urbana-Champaign, 4400 Mechanical Engineering Laboratory, 105 South Mathews Avenue, MC-244, Urbana, IL 61801

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