Nanoimprinting

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Overview: In this demonstration lab students replicate a nano-scale grating structure from old DVD using nanoimprinting. They explore the technique could be used in improving solar cell efficiency

Background:

Small features on the surface of materials can create a variety of useful properties. Repeated small pit or lines on the scale of 10-100 nm cause some interesting effects with light. The rainbow color of DVD or diffraction gratings is caused by interference of waves as they are blocked or reflected by nanostructures. Other features can be used to block or transmit certain wavelengths of light creating non-reflective coatings. Nano features can be etched one at a time in expensive equipment such as an ion beam etcher. For efficient manufacturing the method of imprinting is used. A high quality durable master is made using some etching process. Then a plastic is cast or pressed against the master creating a replica. This is how mass produced DVDs are made. In this demo a plastic called PDMS is cast on the inner layer of a DVD which serves as a master.

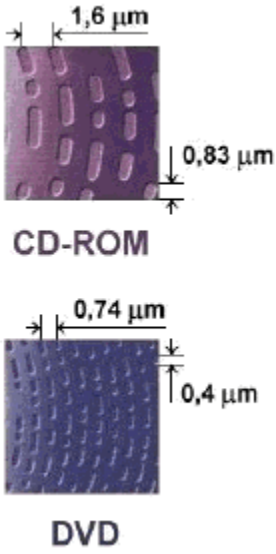

Figure 1 Micrometer scale pits from a CD-ROM

Image source (https://en.wikipedia.org/wiki/File:DVD_CD_pits.PNG)

The as-fabricated PDMS mold can be used as the nanoimprint template. We can press this PDMS mold onto organic polymer which is the active layer in solar cells. After heating the organic polymer above glass transition and providing a high pressure, the grating structure can be pressed onto organic polymer layer, which can improve the absorption of light due to better photon management in solar cells, thus improve solar cell efficiency 20%. More details can be referred to a paper published in nature communication: Smith, Alexander J., et al. "Repurposing Blu-ray movie discs as quasi-random nanoimprinting templates for photon management." *Nature communications* 5 (2014): 5517.

Research Connection: Researchers at the Washington Clean Energy Testbeds are researching ways that processing and printing techniques can be scaled up for mass production of high efficiency solar devices.

NGSS Standards: correlates to performance expectation statements and DCI, CCC, SEPs if possible.

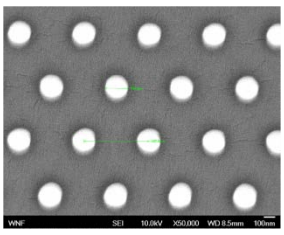

Figure 2 200 nanometer scale dots for antireflective coating.

Standard Number	Standard text

MS-PS4-2	Develop and use a model to describe that waves are reflected, absorbed, or transmitted through various materials.
HS-PS4-5.	Communicate technical information about how some technological devices use the principles of wave behavior and wave interactions with matter to transmit and capture information and energy.*
HS-PS3-3. b	Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.*
CCC	Scale, proportion, and quantity

Materials:

- DVD
- Ethanol
- Dow Corning company silicone elastomer kit and mix it strongly.
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Procedure:

https://youtu.be/ukQn0F2IG9o?list=PLiadNLX1inqLBhLQWBFScz60OQ1_pVmEh

1. This use the razor to separate the old DVD to two polycarbonate substrates

2. Select the one without label and protective lacquer.

3. Put the polycarbonate substrate in ethanol to washing away organic dye.

4. Blow off ethanol and dry this substrate using nitrogen gun.

5. Prepare PDMS solution, weight PDMS 20g and curing agent 2g from Dow Corning company silicone elastomer kit and mix it strongly.

6. Put the mixed solution to vacuum chamber for half an hour to remove bubbles.

7. Pour PDMS onto the dry polycarbonate substrate and put them in a oven.

8. Keep the oven temperature at 80 °C for 2 hours.

9. Open the oven and peel of PDMS mold carefully.

Extensions: You can attempt imprinting from other iridescent objects like rainbow ribbon, diffraction grating, or a hologram. Read about making holograms imprinted on chocolate.

Sources:

PDMS https://www.ebay.com/i/172542720937?chn=ps