Wrinkling of a floating sheet - Experiment

Teachers' programme on Patterns in Nature

Context

You've already heard about wrinkling in various contexts. Today we'll be looking at an exceptionally clean wrinkle pattern based on a recent research experiment conducted at UMass. This experiment is relatively simple, and can be conducted in your school, with a little practice. If you liked the pattern you create today, please contact us for materials for you to use at school.

Goals

The objective of today's work will be to generate wrinkle patterns on very thin polymer films using the forces generated by the surface tension of a water drop. You'll do a few sizes of water drop and we'll give you a couple of thicknesses of film. Digital images of the pattern will allow us to make observations of the number and size of the wrinkles generated. We will try to develop an understanding of the dependence of the pattern on the materials used and the forces applied

Materials

Slides with film; Plastic rulers; Plastic or glass dishes; Clean water; Syringes; Camera; Table lamps; Paper Tissue

Procedure

<u>Making the film</u>

This part of the action happens off-stage but it's perhaps of interest to you. We provide you with ultrathin sheets coated on to glass microscope slides. The sheets are made of a very common polymer – polystyrene. The sheets are made by a process called spin-coating, which is extremely common in the industries that make electronic chips[1]. Spin-coating is very similar to applying a coat of varnish to a table-top or to a finger nail. You take the polymer in powder form and dissolve it in a solvent. A drop of this solution is put on a microscope slide, and spun around at a high rotation rate so that it spreads out uniformly. The solvent then evaporates leaving a thin layer of the solid film. It's just like watching paint dry!

Handle the slides by their edges and don't put your fingers on them. The films you're given have a thickness in the range of 50 to 100 nanometres – this is about a thousand times thinner than a typical human hair.

<u>Floating the film and making wrinkle patterns</u>

The next task is to get the polymer film off the microscope slide on to the surface of water. Use a razor blade to cut an approximately square shape on the film – you should be able to get about three such pieces off the slide. Then, holding the slide by the edge, insert it into the water surface. The square piece of film should peel off and float on the water. (Question: *Why doesn't it sink inside even though the plastic is denser than water*).

[1] The first part of making a chip is to lay down a thin layer of polymer by spin-coating. Then they carve trenches using light (or electron beams) in the polymer where they would like to lay down metal or semiconductor. Once this is done, they wash away the rest of the polymer. The whole process is called photolithography.

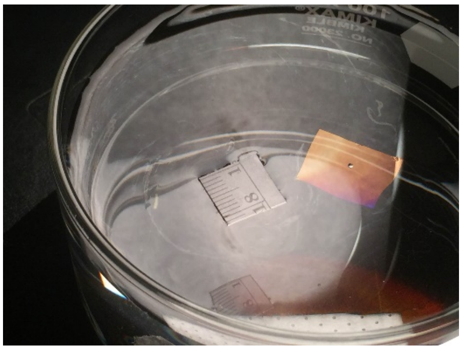
Look at the colours from light reflected off the film. (Question: *Why do you see colours? The sheet is thinner than the wavelength of light).* You should be at least a little surprised that you can see something from the nano world with your eyes!

Creating a wrinkle pattern

Now take a syringe filled with water – be careful not to poke yourself with the metal tip – and place the smallest drop of water that you can near the centre of the film. Don't squeeze out a large drop of water. If you do so, use the edge of a tissue to absorb it. We suggest that you practice ejecting a water drop on the table top first. Try not to do this with a splash, by bringing the needle as close to the surface as possible. If you do this successfully, you should have a round drop, decorated with a starburst of uniform wrinkles radiating out from the edge. Examine this pattern with a magnifying glass or a microscope, if available. The details of the pattern are beautiful.

Capturing the image

Take a picture with your camera at the highest magnification, zoomed in as tightly as your camera will allow. Try to hold the camera as steady as possible while doing so. In order to be able to convert the distance in the image to a known distance, also take a picture of a piece of a plastic ruler in the same frame. Focus on the plastic ruler. It's much harder to focus on the drop or sheet (image below).



We suggest taking at least three pictures, with three drops of different size. You can add small drops to the first drop you placed on the film.

All groups will be given two thicknesses of film. Repeat this procedure of cutting, floating and placing a water drop with both films. We'll tell you the thickness of the film.

Image analysis

There are two types of attributes of these patterns we might want to study and understand. The first is the number (N) of the wrinkles, and the second is the length (L) of the wrinkle. Here we focus on the number, N.

Load your images into the ADI programme or any other programme you are used to. Measure the conversion between pixels and millimetres using the ruler. Now use this to measure the radius of the drop (a) in each image.

Next, in every image, count the number of wrinkles you see. This needs patience, and maybe some strategy to mark wrinkles you have counted. If you do not have good enough contrast in your photograph to see the wrinkles all around the drop, then find a section of wrinkles that span, say 90°, count the wrinkles in that section and multiply by four to get N, the number of wrinkles in 360°.

Data collection

Get data for N (# of wrinkles) vs a (drop's radius), for two (or more) different thicknesses t .

[Get also data for L (radius of wrinkled zone) vs a (we won't do this in class, and will leave analysis of this data for you to try later].

Pool data from all groups on a google spreadsheet (http://tinyurl.com/wrinkle2017).