THE nanoFAB
Fabrication | Characterization | Expertise

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Zygo Optical Profilometer

Sept 22, 2014

Location: W6-024
Primary Trainer: Scott Munro (587-879-1517, smunro@ualberta.ca)

OVERVIEW

This document outlines the standard procedure for measuring and quantifying step heights, critical dimensions, surface roughness and surface topography. Typical sample types include fragile devices and surfaces that cannot be measured with a contact profilometer due to critical dimensions or step height limitations. Because of the optical nature of the measurement, samples that do not reflect light, or are too rough, cannot be measured. Transparent surfaces (SiO2, SiN, photoresists, etc) may be difficult if not impossible to be measured, but can be coated with gold for accurate measurements.

Depths up to 150um, with 0.1nm resolution and 0.4nm RMS repeatability are possible, dependent of objective magnification. Maximum scan length is 5mm using the extended scan mode, and will measure depths >150um, with reduced resolution. The maximum field of view using the 10X objective with the 0.4 zoom setting is 1.75mm x 1.325mm.

The profilometer method is based on scanning white light interferometry. Light from a white light lamp source is divided; one portion is reflected off the test surface, the other portion is reflected off an internal, high quality reference surface in the objective. Both portions are re-combined and directed onto a solid state camera.

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Interference between the two light wave fronts result in an image of light and dark bands, called fringes, that indicate the surface structure being tested. Vertical measurements, normal to the surface, are performed interferometrically. Lateral measurements in the plane of the surface are performed by calculating the pixel size from the field of view of the objective in use

There are two user manuals in addition to this SOP. Refer to the MetroPro Reference guide, and the System Manual for more detailed system information.

SAFETY PRECAUTIONS

Users must be careful when moving the z-axis due to the potential of crashing the lens into the sample and/or stage. The Z-Stop must be set before scanning begins. Refer to section 5 for instructions.

If you are bringing any new materials into the NanoFab for use in your process, it is necessary to fill out a chemical import form (available on our website, http://www.nanofab.ualberta.ca) and supply an MSDS data sheet to Stephanie Bozic.

PROCESS COMPONENTS OR FEATURES

Non-reflective samples can be sputter coated with a reflective layer; a gold sputtering unit (Denton) is available at the NanoFab for this purpose. Contact Scott Munro for training.

OPERATING INSTRUCTIONS

1. This procedure outlines routine sample analysis using the standard set-up. For more in depth instructions and information, refer to the manuals (the NewView 5000 System Manual and the MetroPro Reference Guide).

2. Windows should be running on the Zygo computer. Double-click the **MetroPro 8.3.5** to open the software. The lamp will turn on, and project onto the stage. Select an application; the **nanofab.app** is the standard app.

3. Place your sample on the stage, under the objective lens. Using the stage X+Y axis knobs, position the sample so a feature of interest is under the light source. Ensure the stage is roughly level to the eye, and adjust as necessary by turning the tilt knobs on the side and front of the stage.

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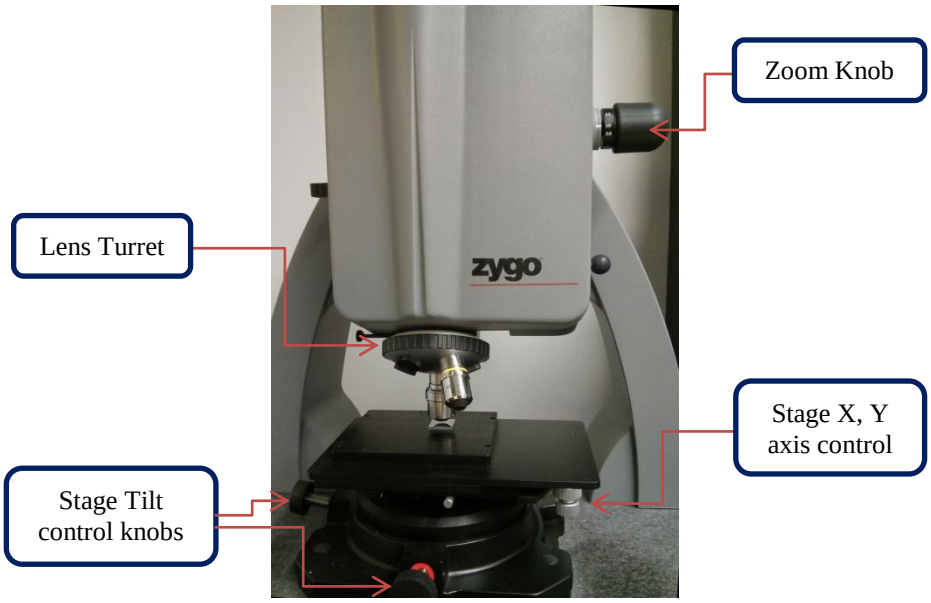
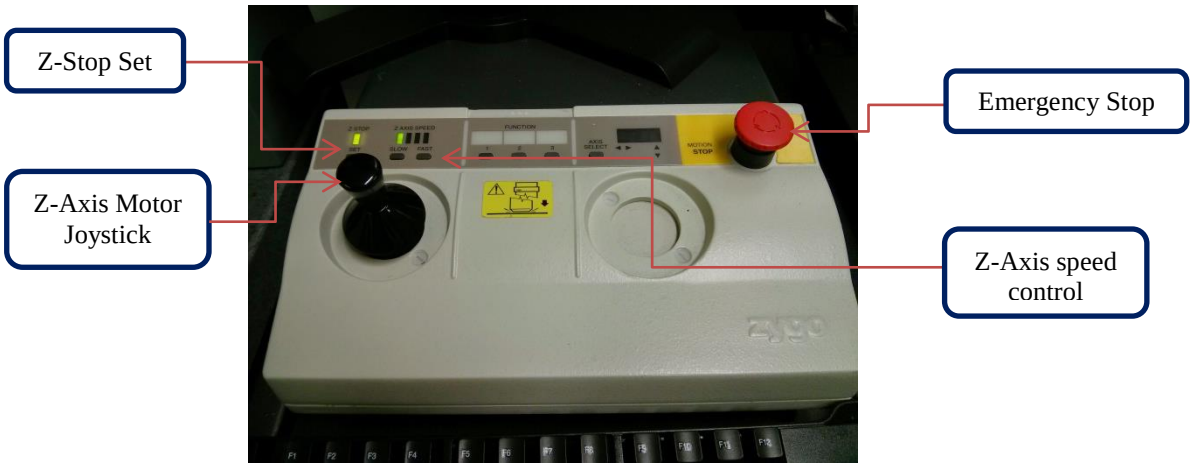
4. Select the desired objective by manually rotating the turret until you feel the lens click into position. Note that it is highly recommended to begin with the 10X objective before moving to the 50X objective. Also select the desired **Zoom** setting by rotating the **Zoom knob**, and again you should feel the knob "click" into position.



5. To set the Z-stop position, press the **Z-Stop** button twice, which will make the light turn red and begin blinking. Using the joystick, lower the objective until it is ~5mm above the surface of the sample. Do not touch the objective to the sample in any circumstance! Press the **Z-Stop** button again to set the lower limit. The light should turn solid red, and you will be unable to move below this height. The Z speed can be controlled by pressing slow/fast as required. Note that a speed of 1 is very slow, and is really only useful when the sample is in focus and the fringes are in view, while a speed of 4 is for course adjustments.



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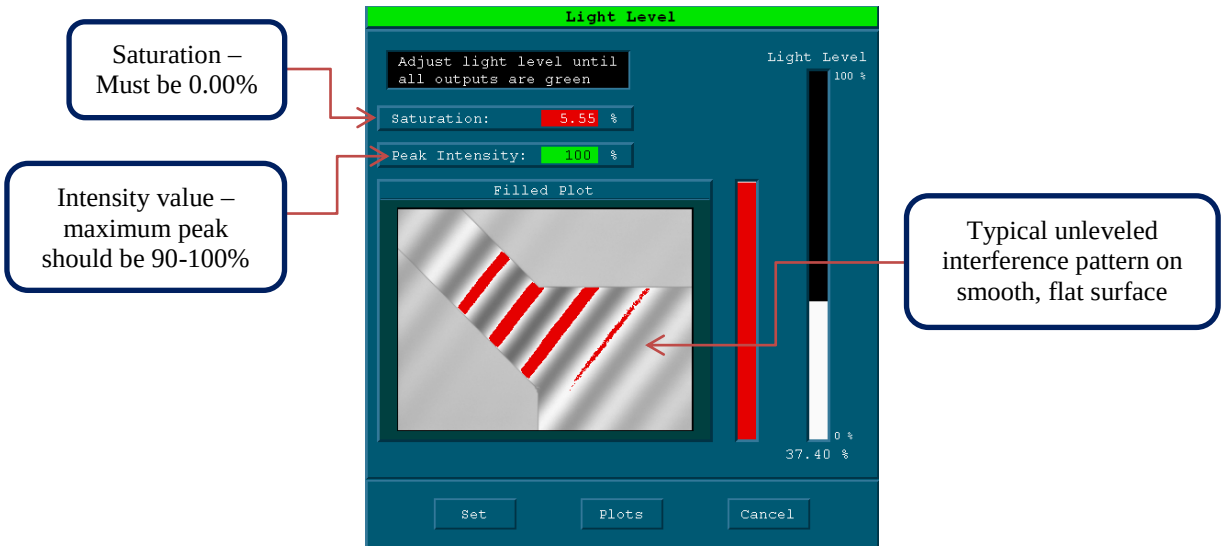
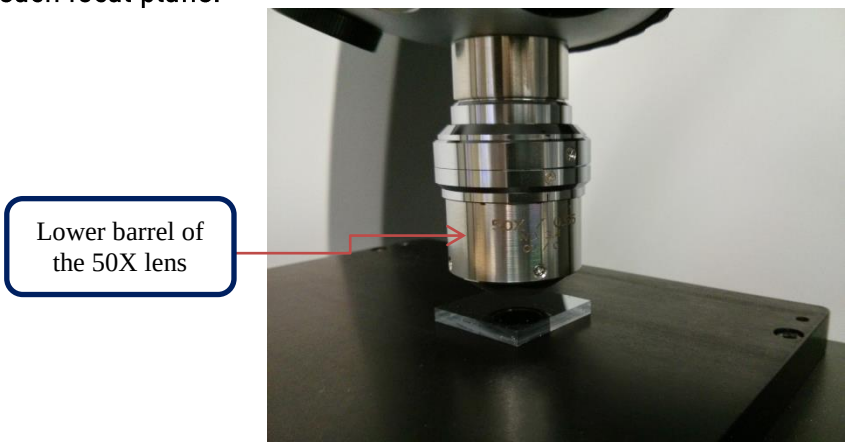
6. To set the initial light setting, press the **F5** button to begin the auto-adjustment, and then press **F4** to view the light settings, and to manually adjust as required. To manually change the level, press the "–"or" /" to decrease, or "+" or "*" to increase.



7. Using the joystick, adjust the z position to focus your sample. For flat samples, it may be easier to start by focusing on an edge, then moving to an area of interest. As the focal point nears, the light level should increase. If the level is decreasing, move the opposite direction. If saturation is >0, the light intensity should be reduced until the saturation is 0, ensuring the maximum intensity remains between 90-100%.

8. Once focused, lower the Z-axis speed and find the interference pattern, which will be at the focal point (for the 10X lens). If using the 50X lens and the sample is in focus, but the interference pattern is not in view, rotate the barrel (the lower part of the objective) until the interference pattern is displayed. Note that there will be an interference pattern for each focal plane.



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9. Most samples require leveling to maximize reflection to the detector. To level, rotate the tilt knobs on the left hand side and front of the stage, alternating as required. It's suggested to set the fringe orientation first, which should be either horizontal or vertical, then adjusting the fringe spread until the fringes are spread as far as possible.

10. A smooth, flat, level sample will have either vertical or horizontal fringes, with a large fringe spread. Typically only one fringe will be visible once completely levelled. Rough or uneven samples may be difficult to level; it may take several attempts to obtain a reasonable level. If there is an area known to be level somewhere on the sample, it may be ideal to level using this area, then moving to the rough/uneven area to scan.

11. With the sample now level, the saturation should once again be checked. Using the lowest scan speed, scan through the entire interference pattern and eliminate areas of saturation. If a large step is being analyzed, or there are materials with different reflectivities, adjust the z-axis to inspect the pattern on each plane. Adjust the light level as required until the saturation is 0, with the maximum light level as close to 100% as possible. Press the **Set** button to fix the light level.

12. Find the starting position to begin a scan. For surface roughness scans <150um, simply find the fringe centre point, where the light level is highest. For scans measuring two step heights <150um, centre the objective between the two sets of fringes. For extended scans (>150um), position the objective below the set of fringes on the lowest plane.

13. Click on the **Measure Control** button to load the control window. Typical adjustments and setting include:

14. Min Mod (%) – **5%** default value, lower values (ie **0.1%**) required for rough samples, or samples with layers with large differences in reflectivities.
    Image Zoom –Matches the **Zoom knob** setting set previously on the side of tool.
    Remove Fringes – For image display only, camera view with fringes on/off.
    Number of Averages - Set to scan x number of times, and analyze the averaged data.
    Scan Length – Set to a distance larger than your step. Default values from 2-150um, and an extended scan option (150um-5000um).
    Extended Scan Length – Only required and used if using the Extended Scan setting in the Scan Length, will use this value as the vertical scan length.
    FDA Res – Typically **High 2G**, must be set to **Low** if using **Extended Scan**.

    Click the **X** button (top left) to close the window.

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15. To begin the measurement, press the **Measure** button. Watch the monitor to ensure all fringes were capture on all surfaces. Due to the sensitivity of the scan, it is recommended not to touch the tool during a scan. Once complete, you should see images of the surface in the software.

16. If the error message "**Scan contains no data**" appears, or it looks like areas of the scan are missing, there is likely something not set correctly. Double check to see if there is any saturation, that the starting point is correct for the scan, the Min Mod % is set low enough, and that the correct scan length setting is selected for your scan.

Data Analysis

17. The software should now display several windows, including a **Surface Map, 3D Model, Surface Profile,** and **Intensity Map**.

18. Right-clicking the mouse button in any given window will open several options available to change. The **Show Controller** options vary depending on the window, but will allow you to change multiple settings, such as axis values, colours, scaling etc.

19. If the profile data looks tilted, or you are measuring the surface roughness of a shaped feature and need the shape removed, the data can be fitted to a shape as required. Click the **Analyze Control** button, and select a desired **Removal** setting. The setting is sample dependent, and may require a few guesses to determine which one works best. Once selected, press **Analyze** to apply the removal parameter.

    Another useful option in the **Analyze** window is the **Spike Removal**. If the data appears noisy, with large spikes that don't appear real, the spike removal setting can be turned **On**. Once on, enter a value (**xRMS** – from the rms value in the profile window), which will remove any spike larger than the multiplier setting of the RMS.

20. The **3D Model** window displays a filled plot of the scan in 3D. The image can be rotated in any direction by left clicking while on the window. Clicking with the cursor above or below the midpoint of the image will rotate in the Y direction, and with the cursor placed to the left or right of the midpoint will rotate in the X direction.

    The zoom can be controlled by right clicking on the image; above the midpoint will zoom in, below the midpoint will zoom out.

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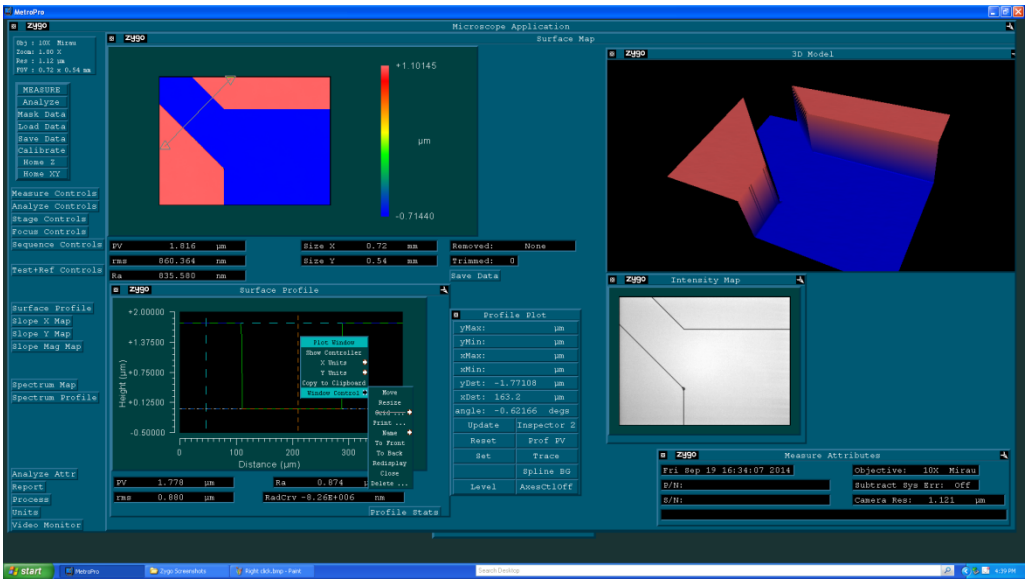
21. The **Surface Map** window contains 2D data. A cross section of the data can be measured by left-clicking and dragging the mouse across a desired area. The cross sectional data will be displayed in the **Surface Map** window. Additional lines may be added, but may complicate the surface map. Delete unwanted lines by pressing and holding **CTRL-D** and clicking the desired line.

22. A number of results are also displayed in the **Surface Map** window, with the standard set being PV, RMS, RA, and Size (X,Y). These results are based on the entire scanning window. There is also a **Save Data** button, which saves any processed data, and is different than the Save Data button located on the left hand column, which saves the raw data.

23. The **Surface Profile** window corresponds with the cross section applied in the surface map. This is likely the most useful plot for step height measurements. Bring up the **Profile Plot** by right-clicking while one the plot and selecting → **Show Controller**. Click the **Inspect Off** button twice until it reads **Inspector 2**. This will load two cursors onto the plot.

    To obtain useful data, again move the cursors to the position you would like to measure between. The **yDst** and **xDst** values are the differences between the two cursors. If the plot requires levelling, click and drag each cursor so they are located on the same plane on a flat (level) area. Click the **Level** button.



    To save the surface profile data as a .txt file, first right click on the plot window, and select the **Print** option. Again, change the data type to **Data**, select **File**, then select **Print**. Enter a .txt extension. If you right click while outside the plot window, a different set of options will appear. Users may select the appropriate data type or option for their scan as required.

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24. The raw scan data may be saved by clicking the **Save Data** button located on the left hand side of the window. There are several data format options to choose from, select the desired one from the drop down box.

25. Images in the form of screen captures can be taken by clicking the **Zygo** logo on each Profile window, or the entire screen by clicking the **Zygo** logo on the top left hand side. There is no printer connected to this computer, ensure the **File** destination is selected,.

26. Another useful data analysis function is the **Mask Data** option, located on the left hand column. With the Mask Data window open, you are able to select, omit, or reference certain areas of the scan for analysis. Begin by selecting the desired shape, and highlighting the area of interest. Click **BG Incl** to select the highlighted area. Close the window, then click **Analyze** to update the plots.

27. When moving to a different area on the same sample, you'll likely have to re-focus slightly to find the interference pattern, and re-level a small amount, if required at all. If changing Zoom setting or objectives, the light levels will have to be adjusted with each change.

28. Once scanning and data analysis are complete, simply close the Zygo MetroPro software to turn off the lamp.

TROUBLESHOOTING

If you encounter an unexpected error or require assistance please contact the primary or secondary trainer listed above. Should they not be available, please contact any staff member for assistance.

APPROVAL

Qualified Trainer: Scott Munro
Training Coordinator: Stephanie Bozic