

Report of Summer Research Project at CML, UC Berkeley
TFC Protrusion measured using ZYGO Interferometer

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1. Introduction

This is a report on an experiment to measure the TFC protrusions on a hard disk drive's head under different voltages. The instrument used to observe the slider's air bearing surface (ABS) and obtain the surface profile of the reader and the writer zone is the ZYGO Interferometer. The software is ZYGO MetroPro. The software used for post experiment data processing is matlab. But before deciding to apply the voltages to the TFC resistor, a fair idea of the power capacity of the TFC is needed.

2. TFC power capacity calculation:

An experiment was performed to determine the power limit for a particular TFC resistance. An electrical circuit was built as shown in the fig 1 below. A 50 ohms resistor was added in series with the TFC. The voltage across the combined setup was varied at intervals of 0.1 V. It was observed that the TFC resistor blew out at a 253 mW applied power. So it was decided to keep the power supplied to the TFC below 250 mW for the experiment.

Apparatus used for the above mentioned experiment:

1. A power Source
2. A digital Multimeter
3. A breadboard
4. A 50 ohm resistor
5. A hard disk drive head
6. Wires
7. An aluminum plate
8. A clamp
9. An electric board to hold the clamp
10. A cello Tape
11. An air tight box (to keep the head)
12. Screws

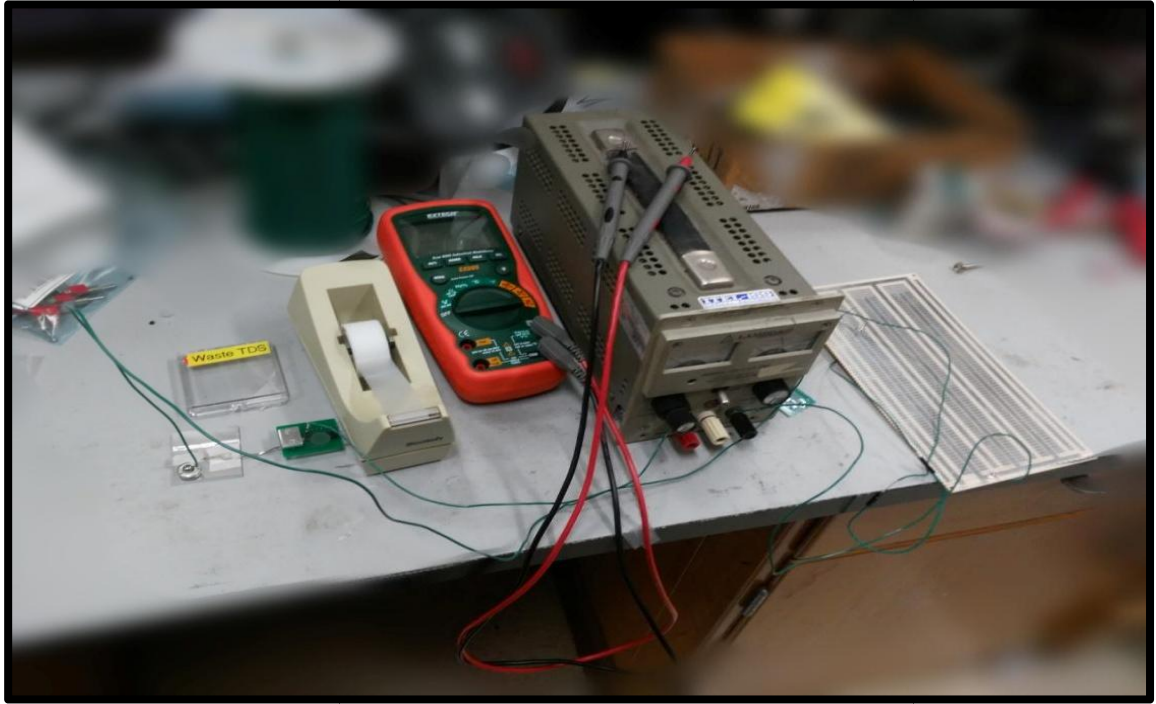


Fig 1: Experimental Setup to determine the approximate TFC Power limit

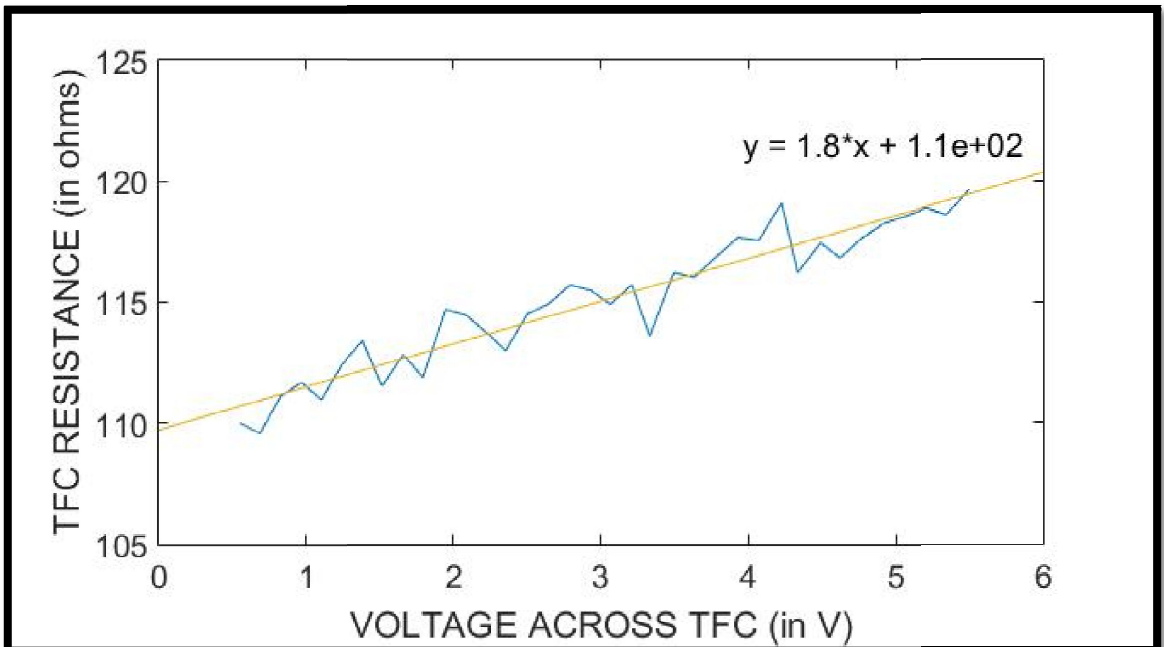


Fig 2: Max current through TFC= 45.98 mA, Max Voltage across TFC= 5.501 V

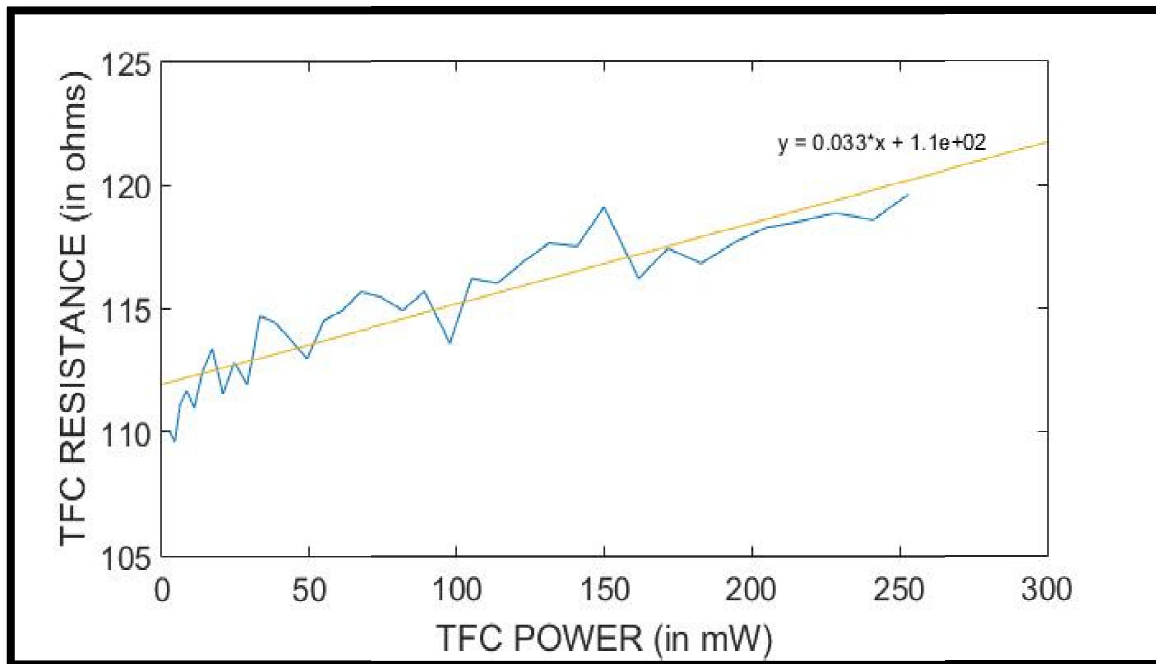


Fig 3: Max Power Supplied to TFC= 253 mW

Once this experiment was done, the setup was moved to the Zygo machine.

3. Observing the air bearing surface (ABS) under Zygo

The head was placed under the Zygo microscope and properly aligned to make sure that there was no tilt of the sample under 0 Volts power supply to the TFC. The 10X magnification lens was used to ensure that the fringes seen on the computer screen were vertical and reduced to one. The 40X lens was then used to observe the reader and the writer zone more clearly. It took multiple experiments to get the visual of the image clearly with all the data points around the writer and reader zone still intact. Many of the properties like light intensity, type of scan, zoom ratio, removing the spikes, etc were optimized to get a better image.

The voltage to the complete setup was varied from 0V to 7V in steps of 1V. The voltage across the 50 ohms resistor was measured to calculate the voltage and the current across the TFC. The power to the TFC could be now determined using this data.

4. Transferring data to a PC

Once the data was obtained and saved corresponding to each of the desired voltages, the next task was to transfer the data to a PC for further processing. This part was a little tricky. The data was first converted to ascii format from the binary format in Zygo and then copied onto a floppy disk. It was then saved onto a PC.

The following commands were used to perform this transfer.

- Conversion from binary to ascii: `dat_to_asc filename.dat filename.asc`
- Format a floppy disk: `flopinit`
- List the contents of the floppy disk: `dosls /dev/rfloppy/c20Ad1s0:`
- Write data in the floppy disk: `doscp filepath /dev/rfloppy/c20Ad1s0:`
- Write image file in the floppy disk: `doscp file.tif /dev/fdd0:image.tif`

5. Post experiment data processing & results

The ascii data file contains 3 sections: header, intensity data matrix and phase data matrix. The header contains the useful information like the intf scale factor, acquire mode, size of the matrices, origin, lens type, obliquity factor, wavelength of light used, etc. The intensity data matrix, after some transformation of rows and columns, can be used to get a clear image of the surface. The phase data matrix was of primary importance. The height data matrix can be obtained from the phase matrix by the following conversion:

$$\text{To convert a phase data value to heights: } Height = zygo \left(\frac{S * O * \lambda}{R} \right)$$

Where: `zygo` = the connected phase data value, `S` = `IntfScaleFactor`, `O` = `ObliquityFactor`, λ = `WavelengthIn`, `R` = 4096 for normal `PhaseRes` or 32768 for high `PhaseRes`.

High `PhaseRes` was used for the experiment. The wavelength of light used was 633 nm. `S`=0.5 and `O`=1

The rows and columns of the height data matrix were then transformed to get a matrix such that it can be used to obtain a proper surface profile of the ABS. The noise and the unwanted spikes were removed from the data. The data had a tilt which needed to be removed before further processing the data. The ABS surface was aligned with the horizontal plane. After the tilt removal, clear and crisp height profiles were obtained for different voltages.

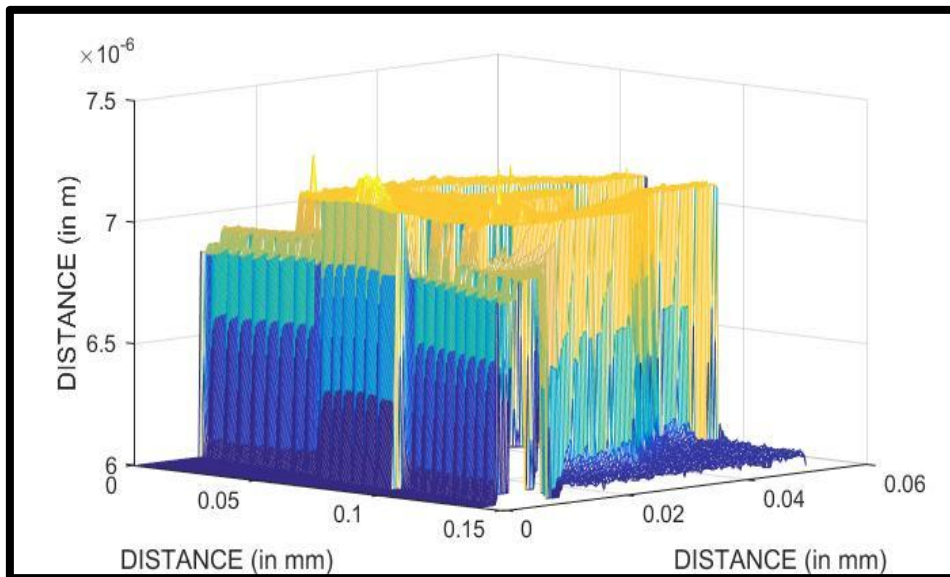


Fig 4: Surface profile of the ASB under 40X magnification at 4 volts

Though the height matrix was now horizontal, but it was not aligned with the X-axis and Y-axis. (Refer fig 5) The height matrix was rotated about the z-axis and interpolation was used to obtain the surface profile near the reader and writer region because the rotated graph had data points on lines at an angle to the actual surface profile.

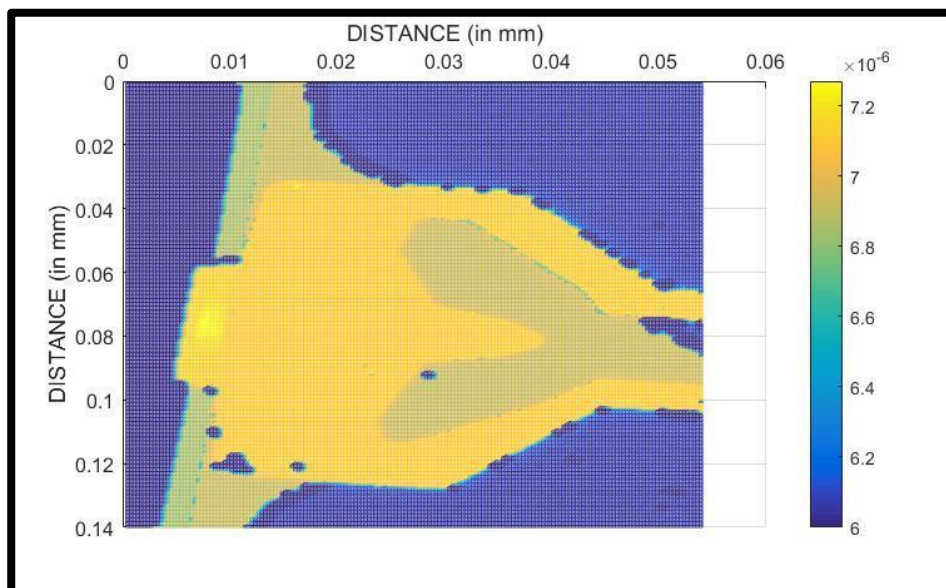


Fig 5: 2D surface profile after tilt removal at 4 Volts

After taking an average of the data points in the interested reader and writer region, the 2D surface plot for each voltage was created to compare the profiles for different voltages with 0 Volts. (Refer fig 6) Similarly other images were obtained.

The final TFC protrusion was assumed to be the maximum of the height difference of the 2 surface profiles (for corresponding voltages and 0 volt)

The various TFC protrusions for different TFC powers are plotted in the fig 7.

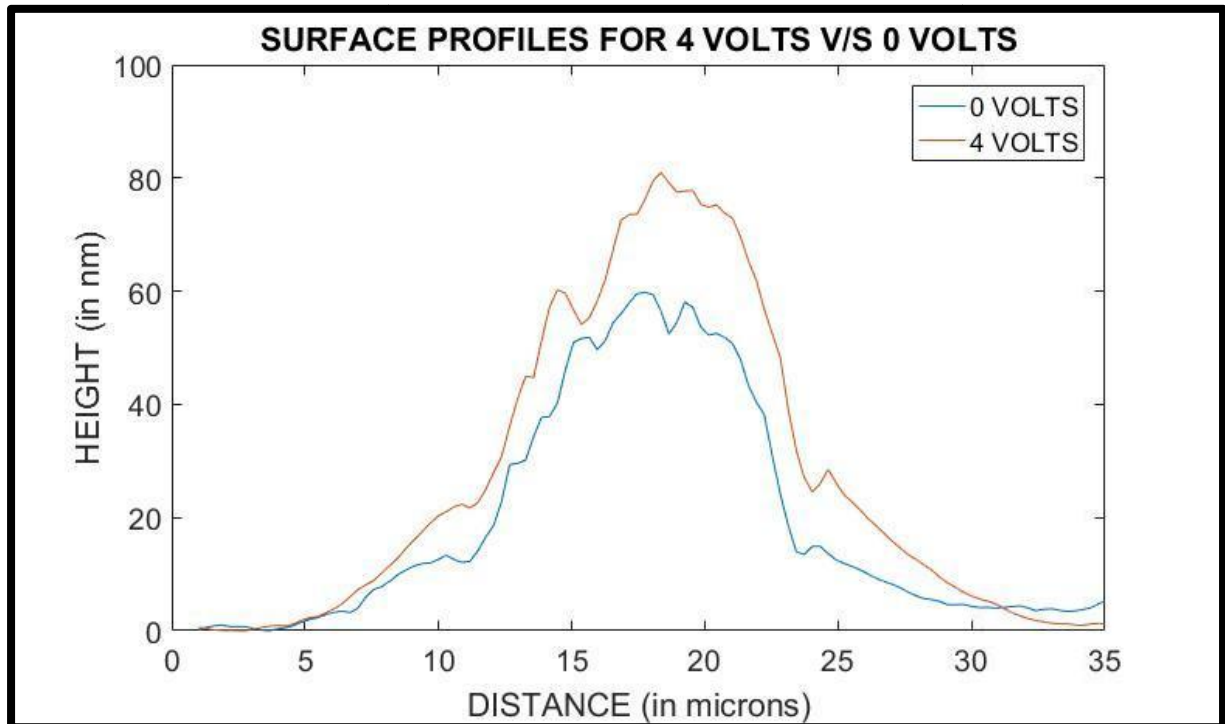


Fig 6: 2D Surface Profile comparison for 4 Volts & 0 Volts

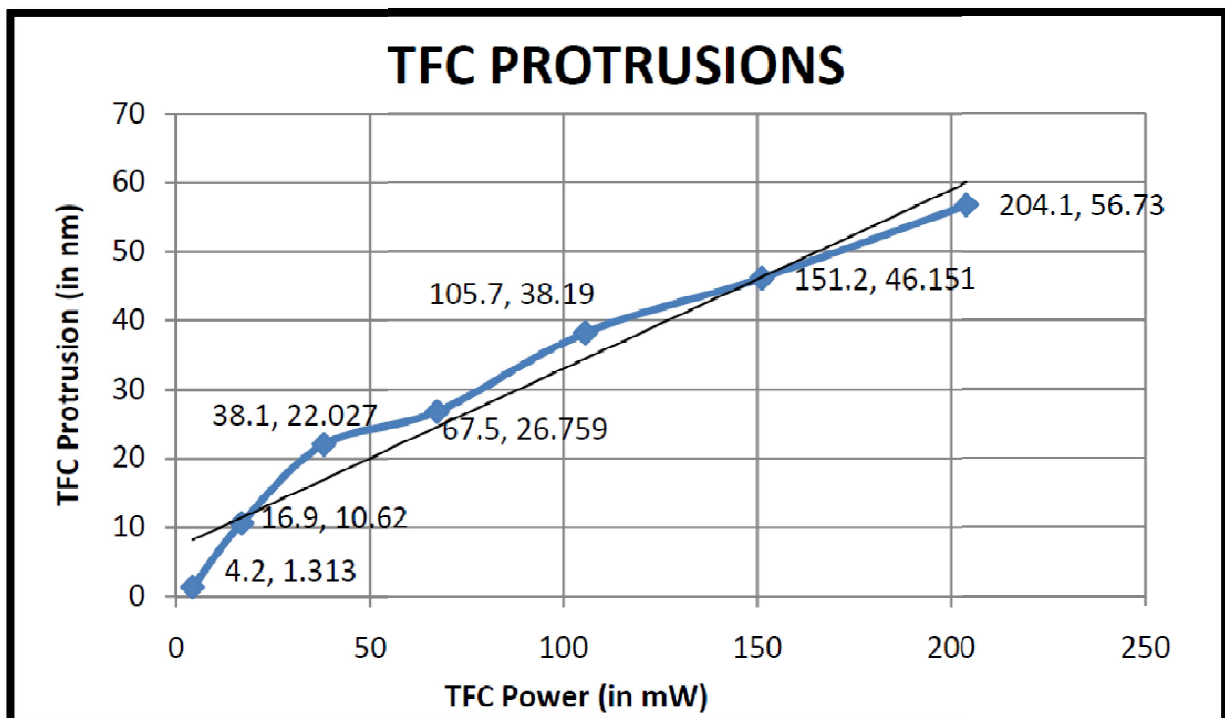


Fig 7: TFC Protrusions at different voltages

6. Summary:

The overall experiment involved performing sub-experiments such as taking multiple measurements using Zygo, transferring the data to a PC, processing the data using matlab and finally calculating the TFC protrusions corresponding to different voltages.

An experiment was performed to determine the power limit for a particular TFC resistance. It was decided to keep the power supplied to the TFC below 250 mW after the TFC blew out at 253 mW.

The head was then placed under the Zygo microscope for further analysis. The voltage to the complete setup was varied from 0V to 7V in steps of 1V. Multiple experiments were done to get the visual of the image clearly and obtain the data corresponding to each voltage. The data was converted to ascii format in Zygo and then copied onto a floppy disk. It was then saved onto a PC. The height data matrix was obtained from the phase matrix by doing suitable conversion.

After a little more transformation and processing (like the removal of noise and tilt, rotating and aligning with the axes, interpolation and averaging the data) of the height matrix, the 2D surface profiles for each voltages were obtained and compared to calculate the protrusions.

7. Conclusion:

The TFC Protrusion appears to vary almost linearly with the applied TFC Power. The protrusion is in the scale of nanometers and spreads over the reader and writer region.