PECVD Deposition – AFM Measurement Project

Prepared by: Yimin Zhou, Edward Xu

Reviewed by: Henry Lee, Aju Jugessur

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Emerging Communications Technology Institute

The Edward S. Rogers. Sr. Department of Electrical and Computer Engineering

University of Toronto

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1. Objective

The new Oxford PECVD machine has been installed in Bahen cleanroom. We have been conducting tests to evaluate its performances. This project is designed to test two wafers deposited with PECVD silicon nitride (SiN) and silicon oxide (SiO_2) individually. Photolithography patterning and wet etching of the films are used to prepare them for atomic force microscope (AFM) measurements. The AFM results on deposition thickness and roughness can be used as a guide for depositing films on the PECVD.

2. Process and Schedule

Step	Description	Performer	March 4-11	March 12-18
1	Clean 2 bare wafers	Yimin		
2	Scan roughness using AFM	Jianzhao		
3	Clean again and use PECVD to deposit SiN and SiO_2	Yimin		
4	Use AFM to measure the roughness again	Jianzhao and Edward		
5	Clean mask	Yimin		
6	Process the photolithography for the pattern (cleaning, spinning, exposure, development…)	Yimin		
7	Clean wafers and use profilometer for scanning the photoresist surface roughness and the total thickness including the photoresist	Edward and Yimin		
8	Do BOE (1:10) wet etching with agitation by hand	Yimin		
9	Remove the photoresist and clean	Yimin		
10	Use profilometer to scan the surface again	Yimin		
11	Measure the thickness and roughness using AFM the third time	Edward		

3. Descriptions and Analysis

We use two silicon wafers for all processes and tests. To get roughness results, we did AFM scan three times: first on bare wafers, then after PECVD deposition and finally after the final process in cleanroom has been done. Figure 1 shows a wafer has been patterned after Step 6 of processing. For the thickness measurement, AFM was used to measure the finished SiN deposited wafer. A contact profilometer was employed to scan the steps on SiO_2 deposited wafer because the SiO_2 deposition is out of the AFM's vertical range (4.602 μm maximum). On each wafer, three spots (at top, center and bottom) were selected for sampling.

The two bare wafers have an average roughness (RMS) of 0.2 nm and 0.3 nm for SiO_2 and SiN wafer respectively (see figures 2 and 3).

After PECVD deposition, we used the AFM to scan the two wafers again. On SiO_2-Si wafer (twenty-minute deposition of SiO_2 on Si wafer), the roughness is 9.2 nm, while on the SiN-Si wafer (one minute deposition of SiN on the Si wafer), the roughness is 0.3 nm (see figure 4 and 5). According to the Oxford recipes, SiN deposition rate is 10 nm per minute, so it is less than 10 atoms thick; hence the measure roughness is the same as the bare wafer. In contrast, the SiO_2 deposition rate is 230 nm per minute according to Oxford and we did it in 20 minutes, which means the expected SiO_2 layer thickness is 4.6 microns, a factor of 460 thicker than the SiN. Comparing to the original blank wafer, the thick SiO2 film's roughness is 45 times more.

After we patterned a step on both wafers, we performed a profilometer scan on SiO_2-Si wafer and an AFM scan on SiN-Si wafer. According to Figures 6 and 7, the thickness of SiN is 21.9 nm, which is 2.2 times the estimate, and the thickness of SiO_2 is 6.6μm, which is 1.4 times the estimate.

4. Conclusions

The measurements on the samples are summarized in the Table below.

	Bare wafer 1	Bare wafer 2	SiO_2 film	SiN film
Thickness (by AFM)			(Out of range)	21.9 nm
Thickness (by Profilometer)			6.6 μm	20.2 nm
Roughness (by AFM)	0.2 nm	0.3 nm	9.2 nm	0.3 nm

(The experimental uncertainties are ± 0.05 μm and ± 0.05 nm respectively)

The thickest deposition we have done so far on the PECVD is a 6.6 μm SiO_2 film with a rate of 330 nm/min; while the thinnest deposition is a 21.9 nm SiN film with a rate of 21.9 nm/min. According to the recipes Oxford provided, the rate for SiO_2 is 230 nm/min and for SiN is 10nm/min; hence, the actual deposition rates are respectively 143% and 219% higher than expected. To resolve the discrepancy would require further studies.

Compared to a bare wafer, the roughness of the thinnest film doesn't change. The thickest film has a roughness of 9.2 nm compared to 0.2 nm for a bare wafer. The 9.2 nm roughness is at a level of 0.1% of the total thick film thickness. The two results suggest that as a film gets thicker, the roughness increases.

We suggest a literature search be done to find other studies of roughness on PECVD deposited silicon oxide and silicon nitride films.

Acknowledgement

We are grateful to Dr. Li Jianzhao for his generous research time and valuable assistance in the AFM measurements on the nitride and oxide films.

A. Appendices

- **Tools used**

  a. Spinner

  b. Karl Suss MA6 mask aligner

  c. Oxford System 100 PECVD tool

  d. AlphaStep contact profilometer

  e. Atomic Force Microscope: VEECO (Digital Instruments) DI-3100

  (Prof. Herman's Group)

- **Process data**

  a. PECVD recipes: Oxford SiN recipe: 10 nm/min, 300 C, 1min; Oxford SiO2 recipe: 230 nm/min, 300 C, 20 min

  b. Photolithography:

  Spinning: P-20 primer, S1818 positive resists, 4000 rpm, 40 sec, and acceleration index 6

  Soft bake: 95 C, 1 min, hotplate

  Mask: 5 inch chrome on quartz glass, line pattern with minimum 2 micron separation

  Exposure: 5 sec, soft contact

  Development: MF321 developer, 1min

  Hard bake: 115 C, 1min

  c. Buffered oxide etch (JT Baker) 1:10 concentration for wet etching

- **Figures**

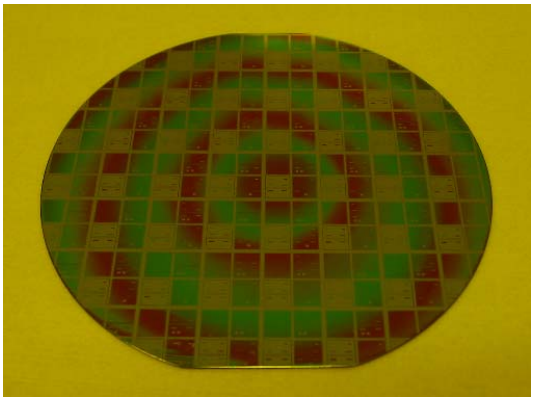

Figure 1 Patterned wafer after process step 6

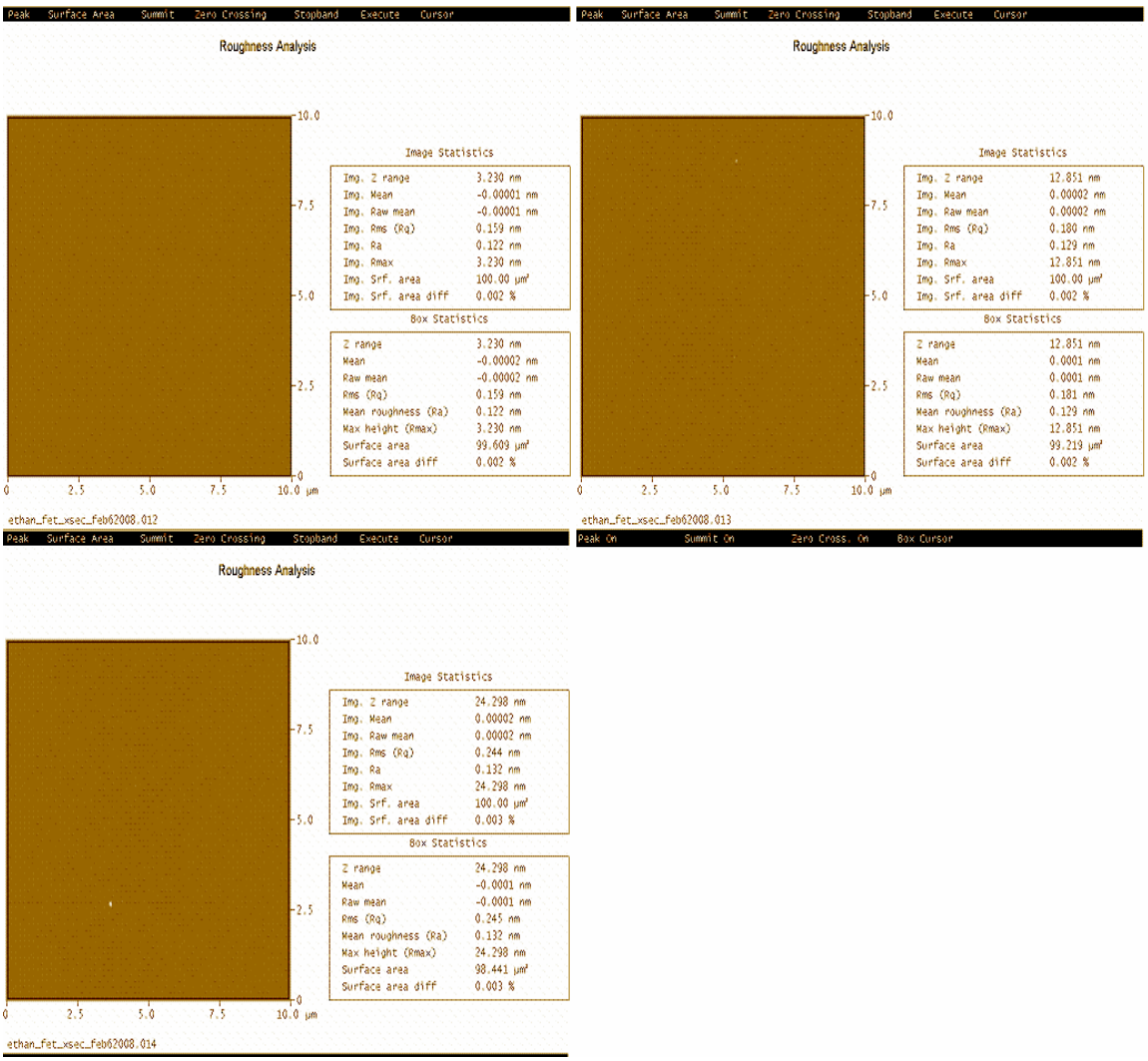

Figure 2 AFM scans of bare wafer #1 for SiO_2 film ("RMS" is the roughness)

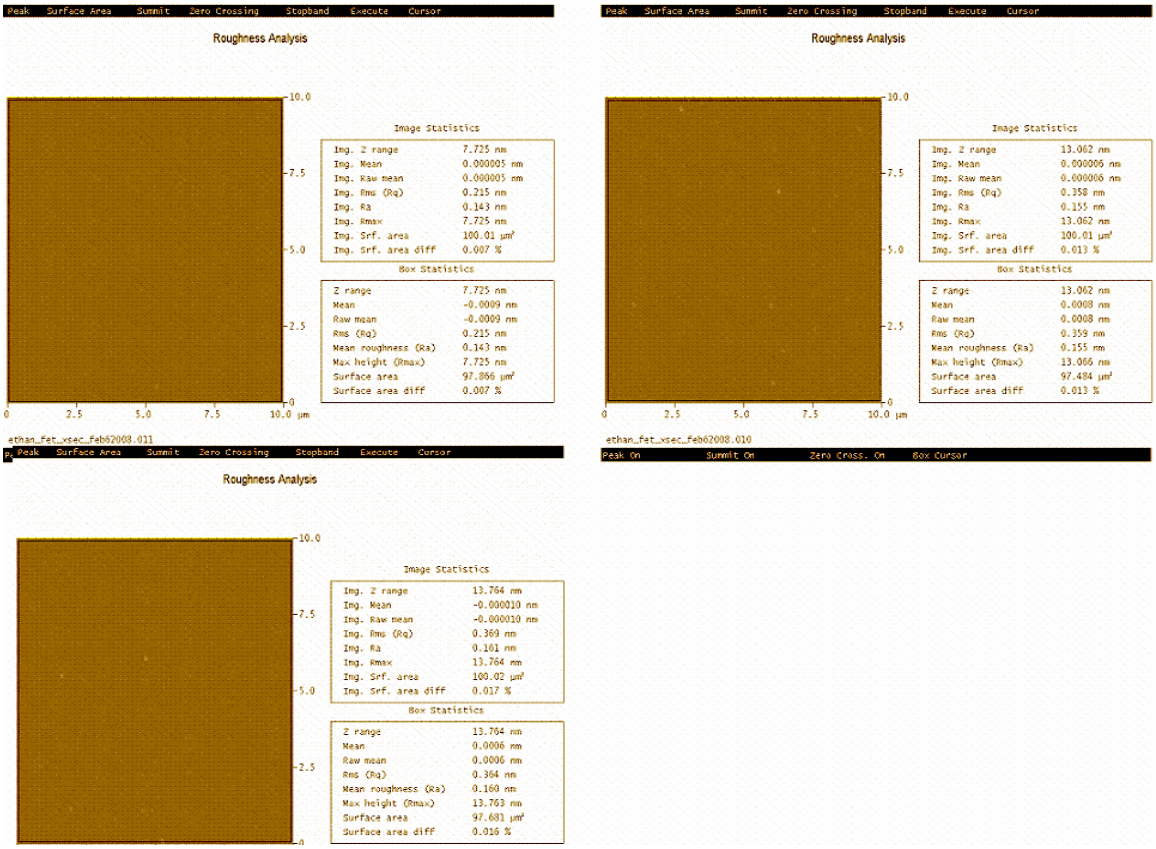

Figure 3 AFM scans of bare wafer #2 for SiN_2 film ("RMS" is the roughness)

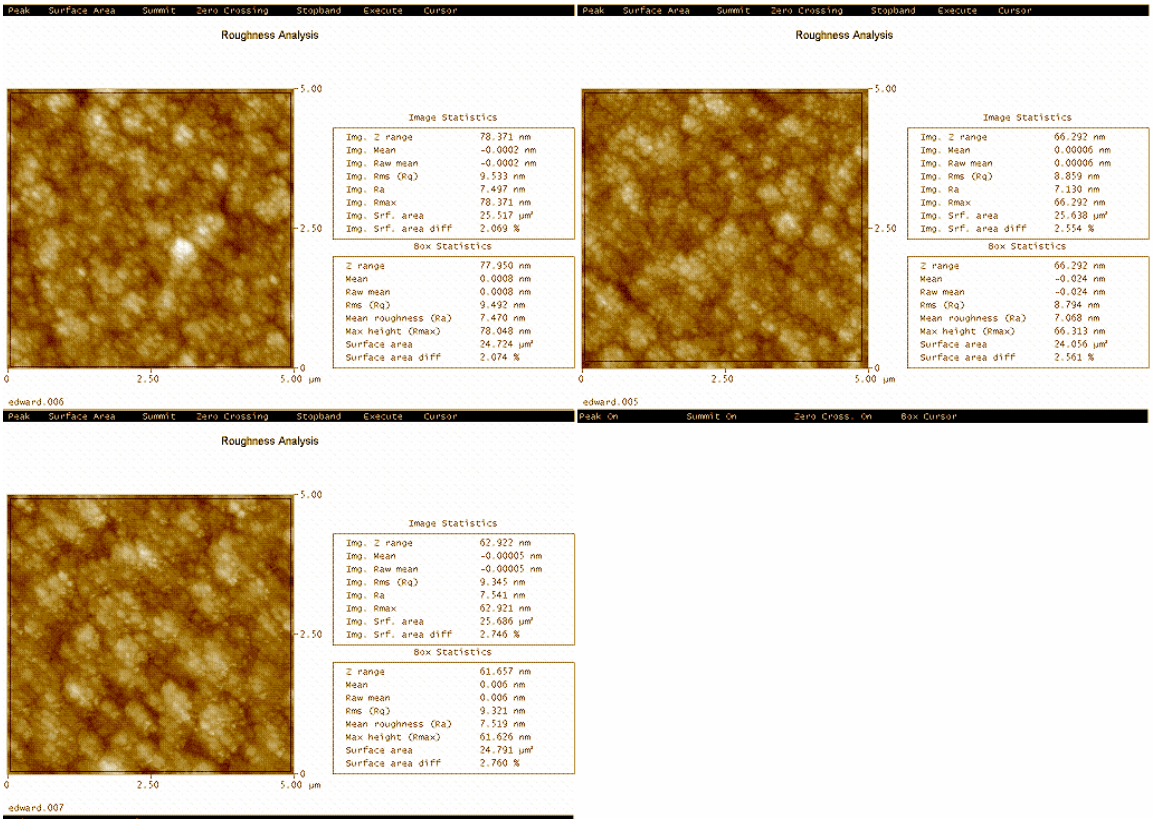

Figure 4 AFM scans of wafer #1 (after SiO_2 deposition, "RMS" is the roughness)

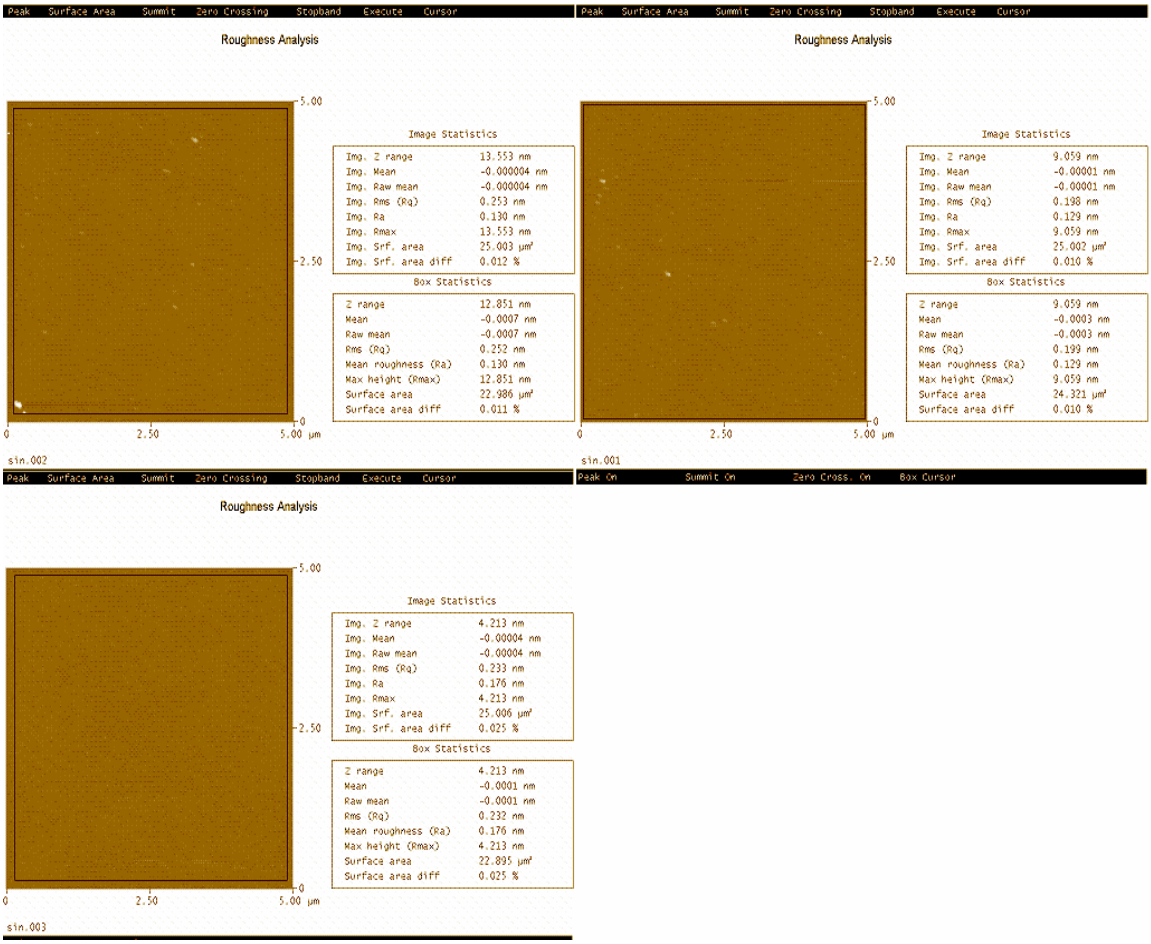

Figure 5 AFM scans of wafer #2 (after SiN deposition, "RMS" is the roughness)

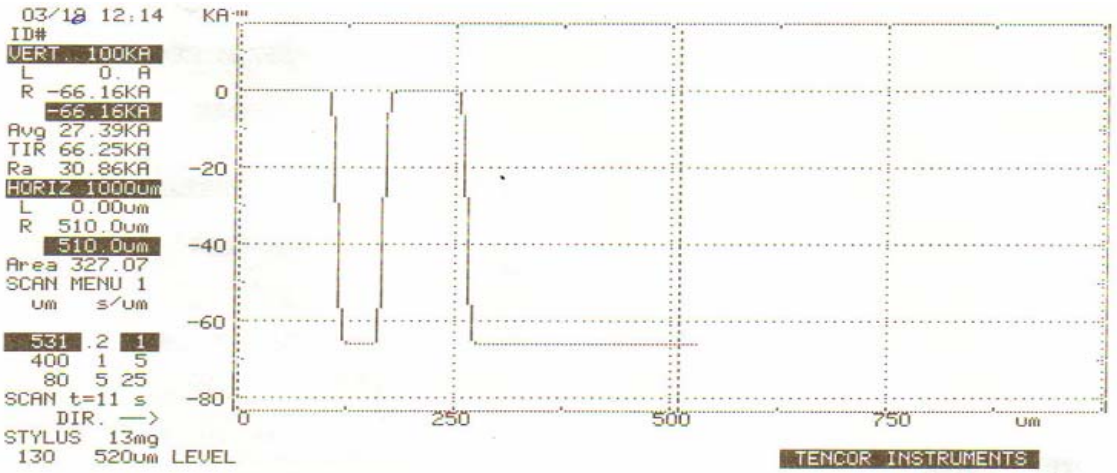

Figure 6 Contact profilometer scan of SiO2 film, wafer #1

("-66.16kA" under "Vert" indicates the thickness)

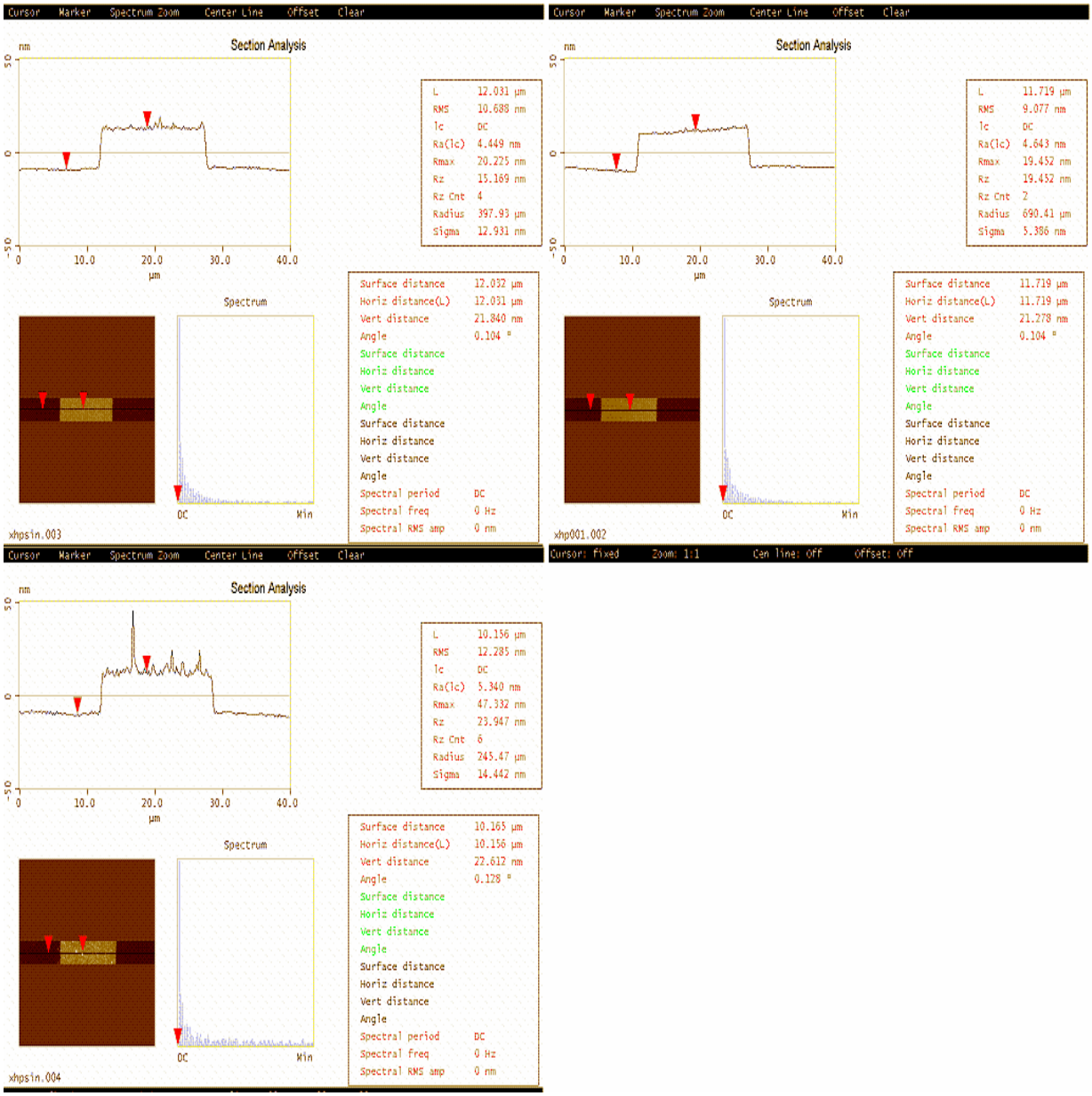

Figure 7 AFM scan of SiN film, wafer #2 ("Vert distance" is the thickness.

The third scan has some surface contamination.)