Mechanistic Evaluation of Nickel-Phosphorous (NiP) CMP

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NCCAVS CMP User Group Meeting
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Overview

- Clarkson University
- Center for Advanced Surface Technology (CAST)
- Laboratory for Advanced Surface Planarization (LASP)
- XPS Evaluation of NiP Substrate
- CMP of NiP

Clarkson University

--Located in Potsdam, NY (north of Adirondack National Park)

--Small, private University with 50+ degree programs

--Top Tier University and third smallest, nationally ranked university

--Approximately 3,000 Undergraduate students; ~700 Graduate students

--Center for Advanced Materials Processing and CMP Service Center

CMP at LASP/CAST

Why LASP/CAST?

A unique atmosphere with the synergy of academic and industrial environments utilized to improvise and improve the current challenges prevailing in semiconductor and electronic industries.

Services Provide:

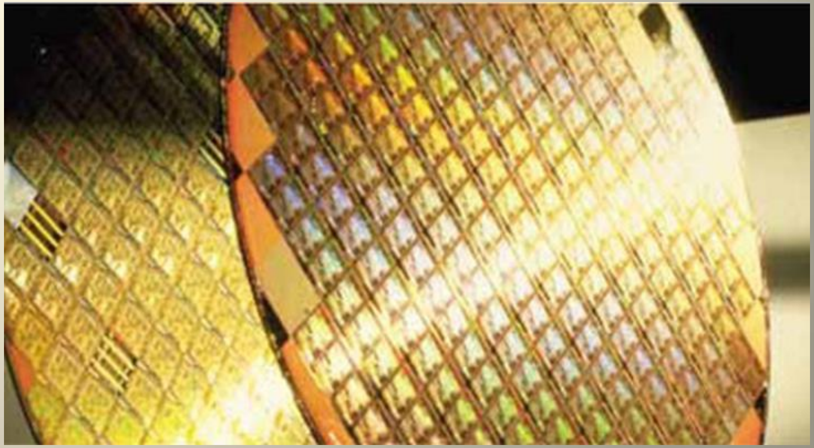
- Devoted team of CMP experts
- Complete evaluation done by Scientists and well trained CMP Engineers
- Excellent feedback to improvise/improve and deliver competitive products
- Elaborate facility and equipment

Current Materials/Projects

<u>All substratres from 25mm-300mm</u>

- BEOL
- FEOL
- HDD/Glass
- LED
- Magnetic

- Post-CMP Cleaning
- Slurry Evaluation and Characterization
- Fundamental Slurry Investigation



LASP/CAST Group

Current Members:
Yan Li
Rithu Bhonsle
Vincent Schade
Xiangyu Niu
Zhenyu Bao
Kaushik Mohan
Dinusha Karunaratne

Recently Departed Members:
Yongqing Lan
Mingjie Zhong
Shyam Vankataraman
Changxue Wang
Yan Mu
Yuanfang Lu

Hard Drive Disk

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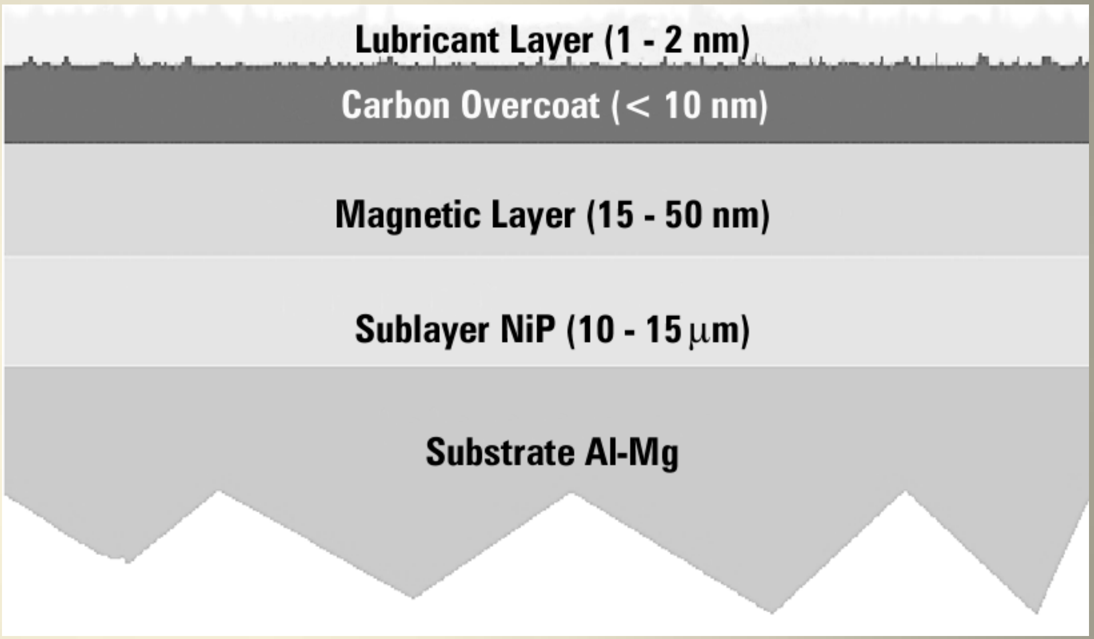
➢Platter

- Rigid
- Lightweight
- Stable
- Inexpensive



NiP Layer

Ni-P alloys are deposited via an auto catalytic nickel plating process
Composition contains upwards of 9% to 15% phosphorous
CMP is primary method of achieving necessary flatness

Proposed method of NiP CMP

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Single Step
SiO_2 slurry

~Tunable MRR
~Excellent Surface Quality
~Advancement through Chemistry

Post CMP

Allied High Tech Bench-top Polisher

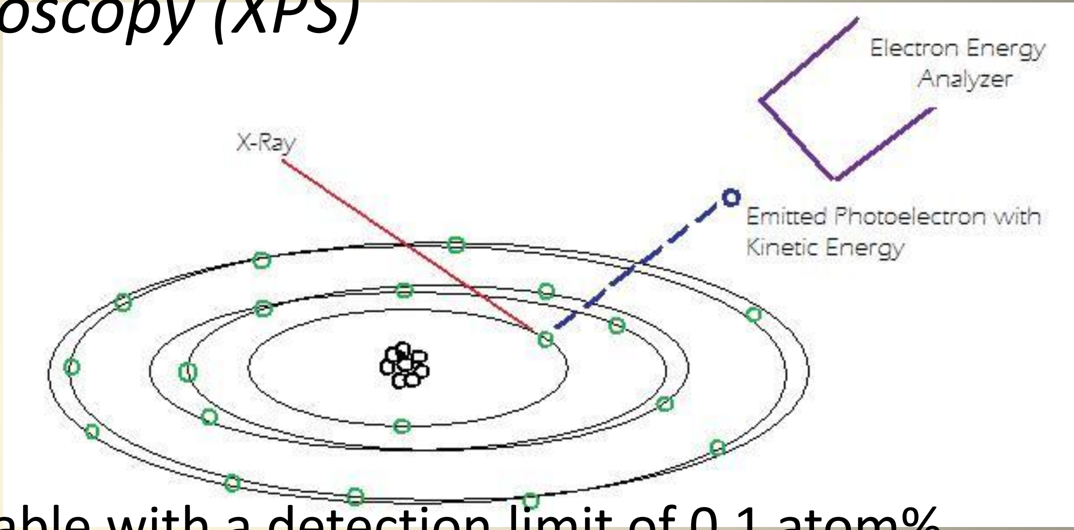
--Designed carrier for 95mm HDD disk
--Correlated results to larger machines

Customer Target

MRR: ≥ 300nm/min
$R_{a:}$ ≤ 0.1nm (5*5 µm)

NiP Surface Evaluation

X-ray photoelectron spectroscopy (XPS)



- *Elemental Identification*

All elements except H are detectable with a detection limit of 0.1 atom% or less.

- *Chemical State Identification*

Binding energy, peak shape and Auger parameter measurements are used to determine surface chemistry

- *Depth Profiles*

Sputter depth profiles are used to examine a sample as a function of depth.

Surface Evaluation

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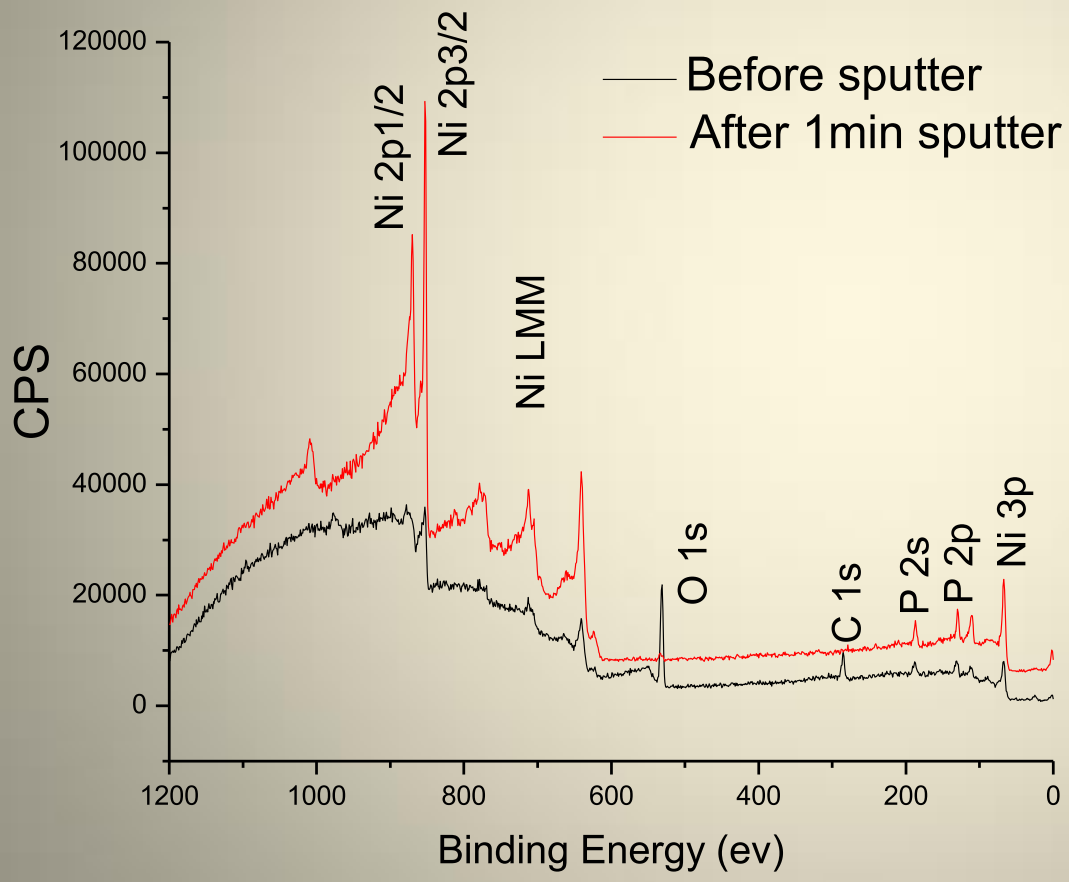
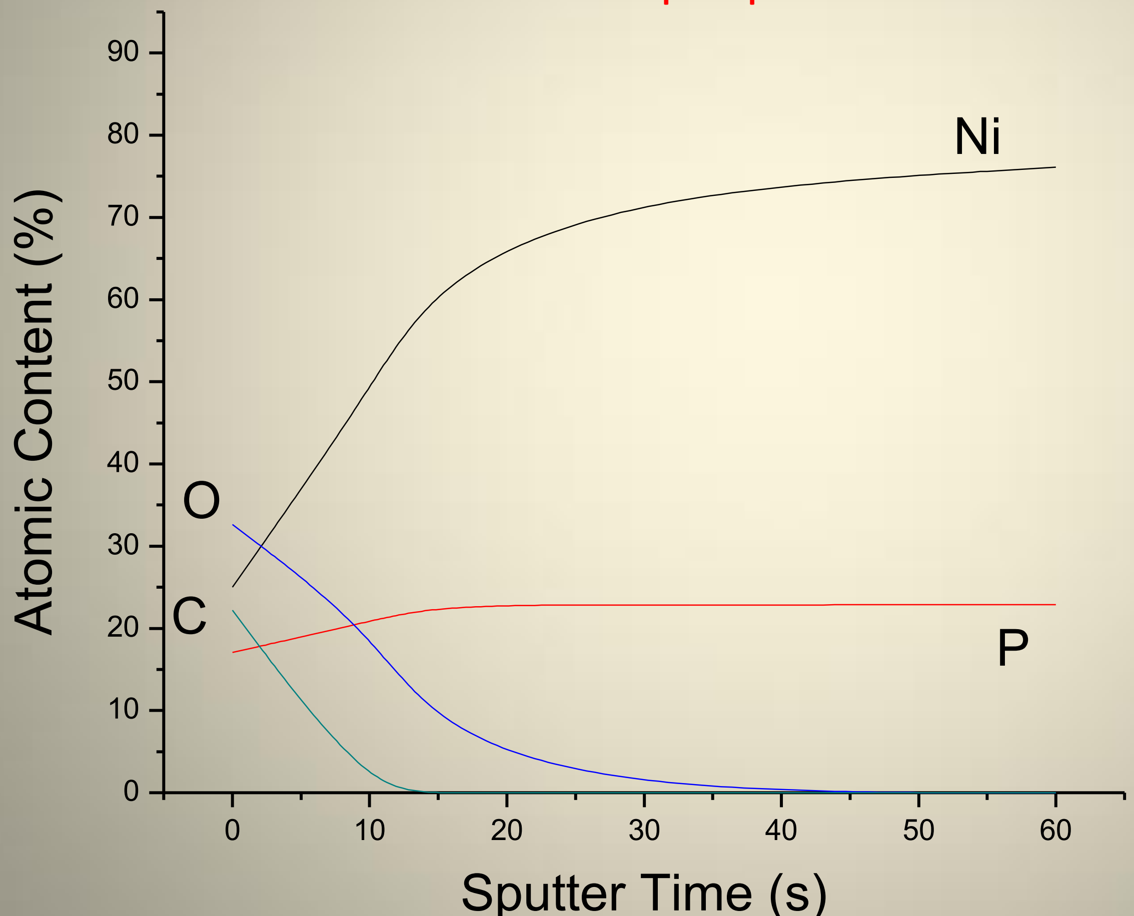
XPS full scan spectra of a disk surface



- Before sputter, elements on the polished surface consist of Ni, P, O, and C
- After sputter 1 min, Only Ni and P were detected.
- Modified surface from CMP process/formulation is relatively thin

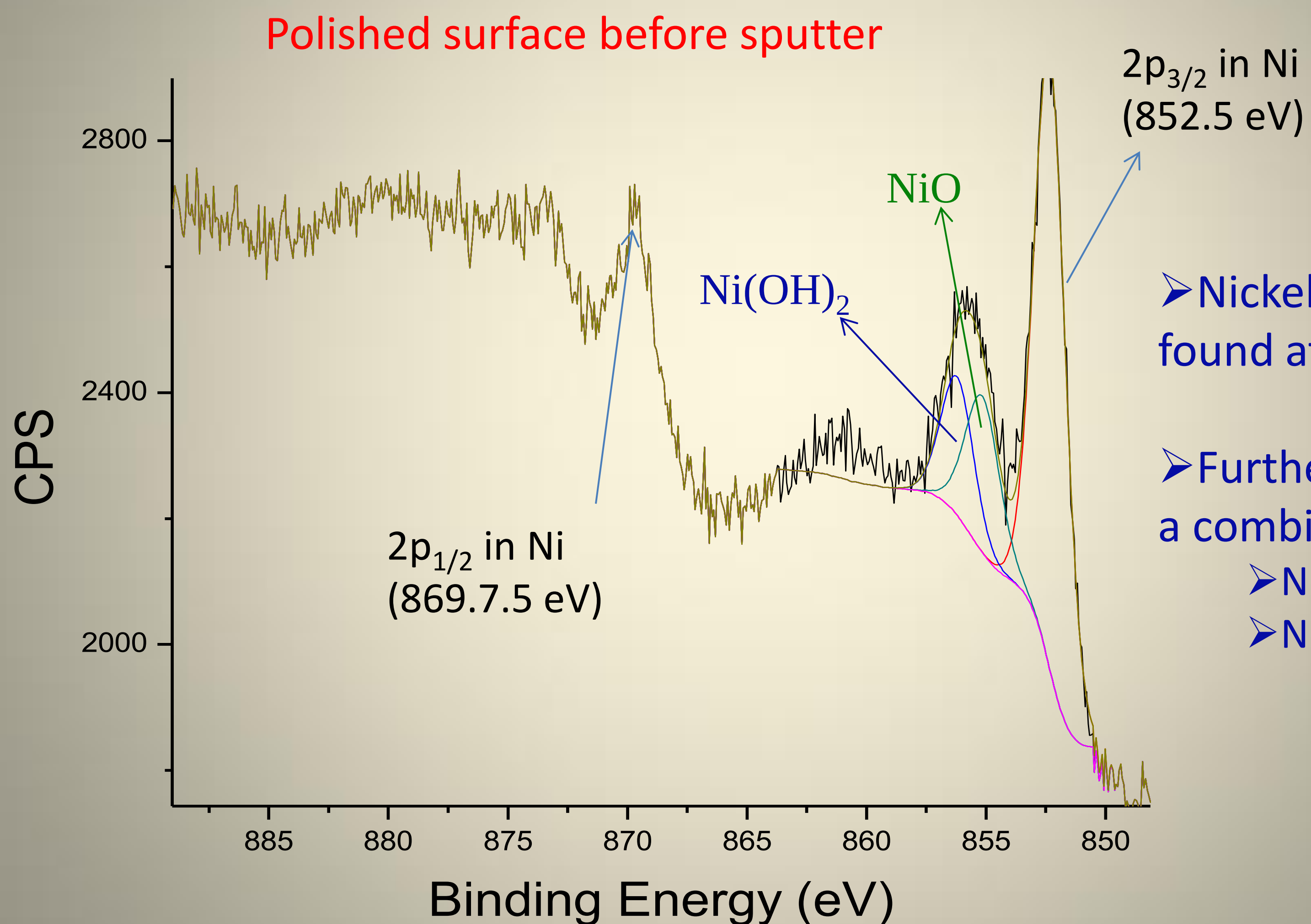
Surface Evaluation

Elemental depth profile



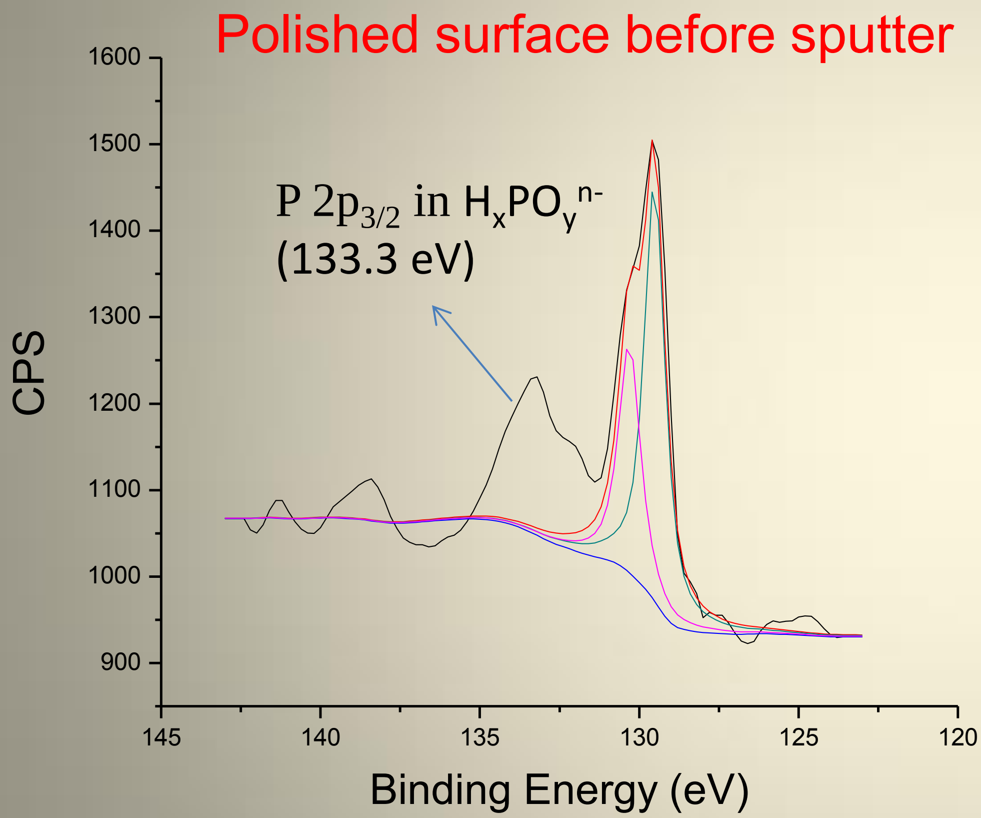
- Result analysis suggest thin layer containing 'carbon' and 'oxygen'
- Does not highlight exact composition on surface
- Evaluate each element and Angle Resolved XPS

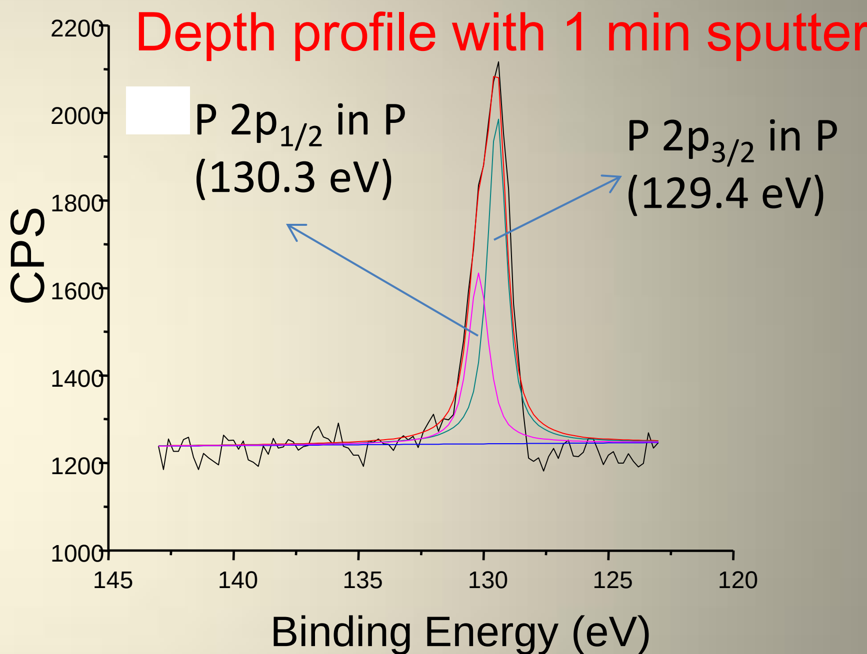
XPS — Ni (2p)



- Nickel oxide peak found at 855.7 eV
- Further identified as a combination of:
  - NiO (854.2 eV),
  - $Ni(OH)_2$ (856.4eV).

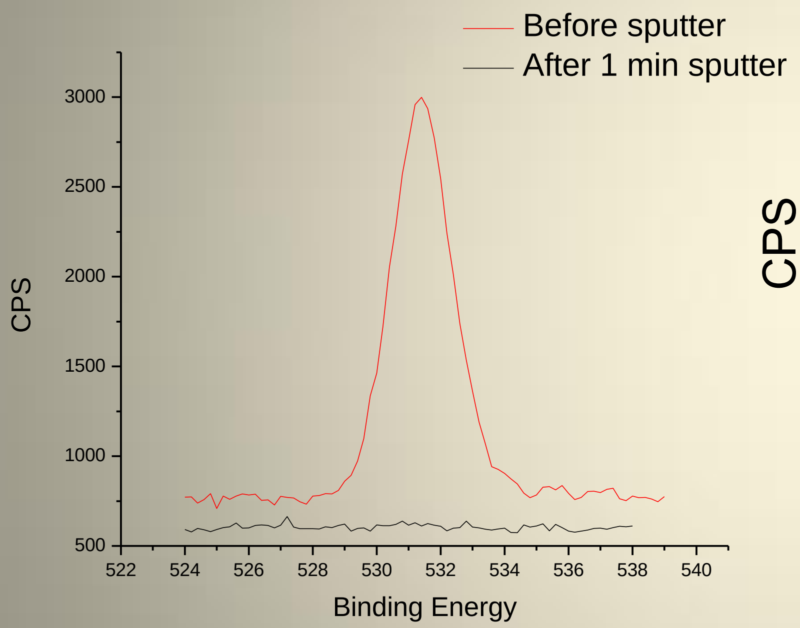
XPS — P (2p)

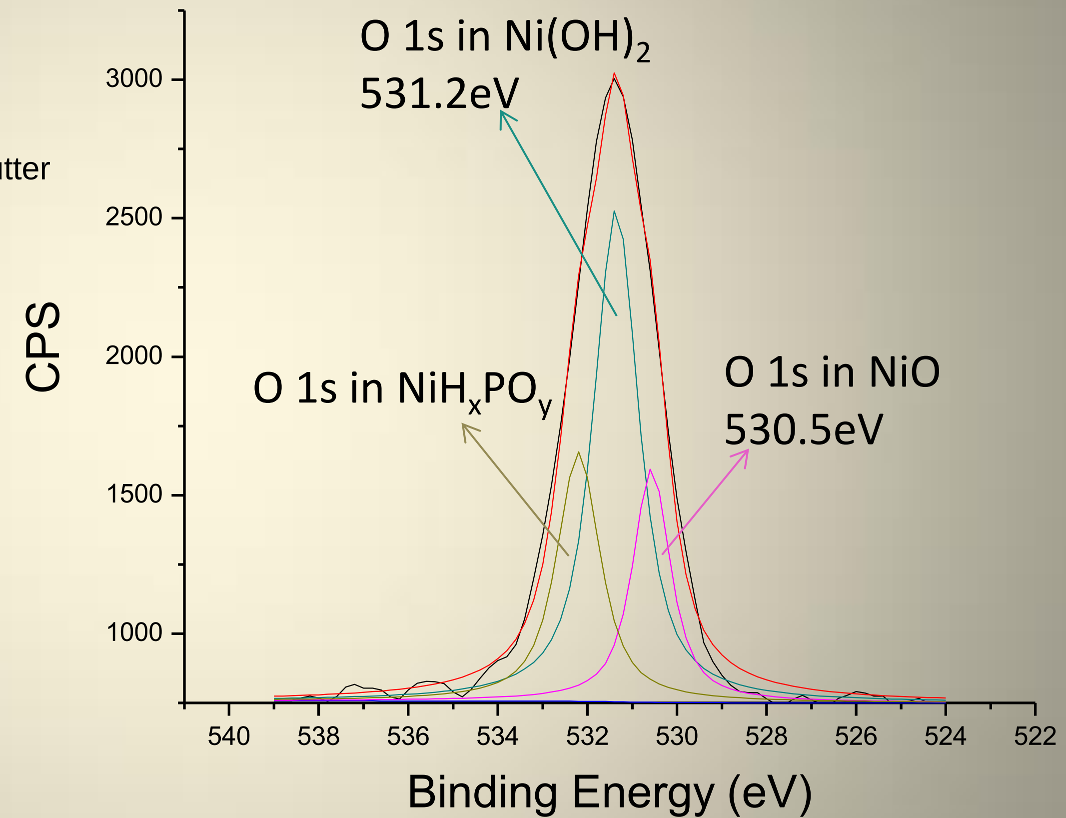




C. Zhang et al.	133.0 eV	P_2O_3
Z. Qi et al.	133.1 eV	NiH_xPO_y
Z. Ma et al.	133.7 eV	$NiHPO_3$

XPS — O (1s)

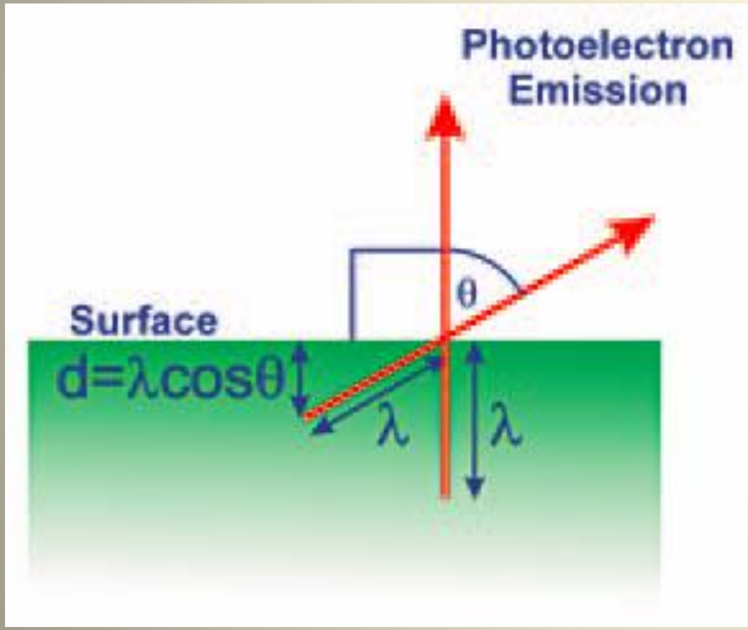


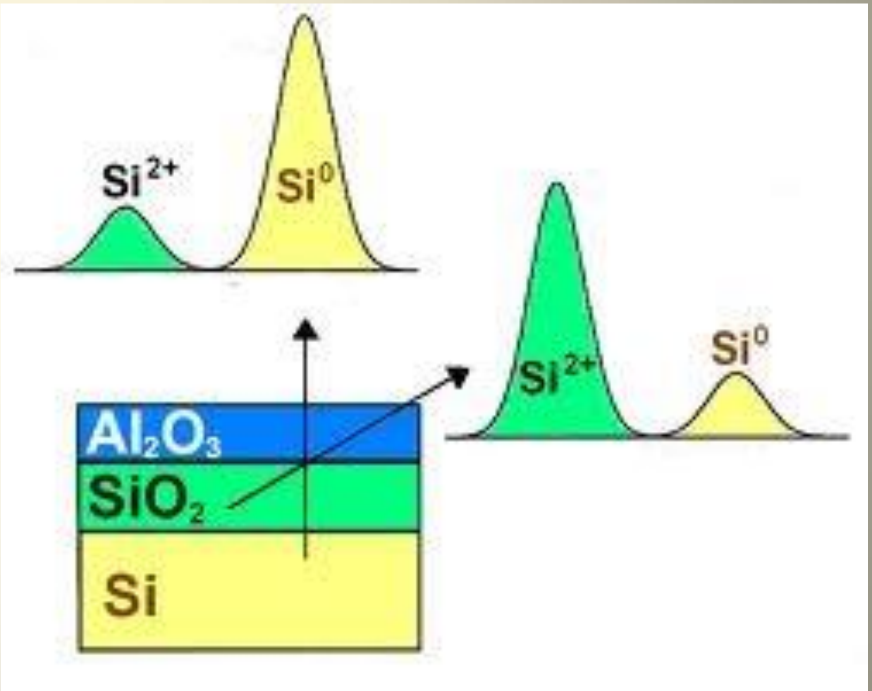


➢XPS results demonstrate that the NiP surface has been oxidized into NiO, $Ni(OH)_2$ and NiH_xPO_y during/after polishing

Principle of Angle Resolved XPS (ARXPS)

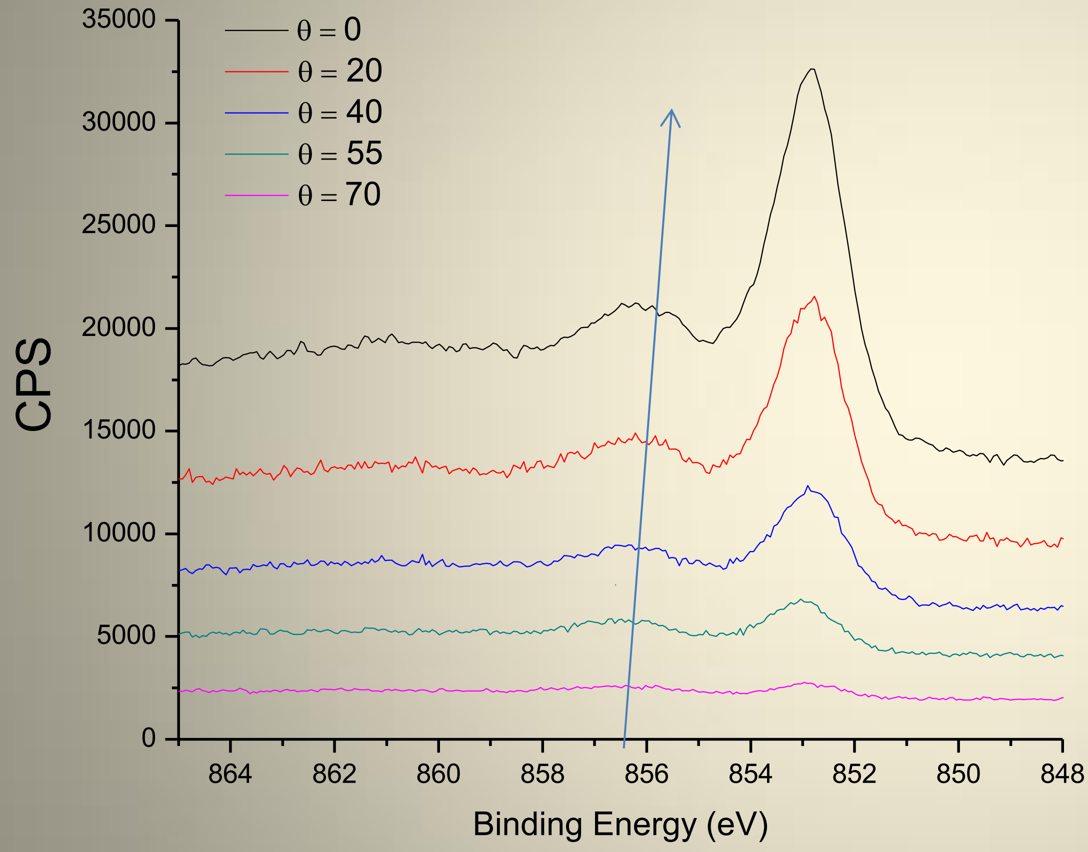
ARXPS is widely used for thin film analysis

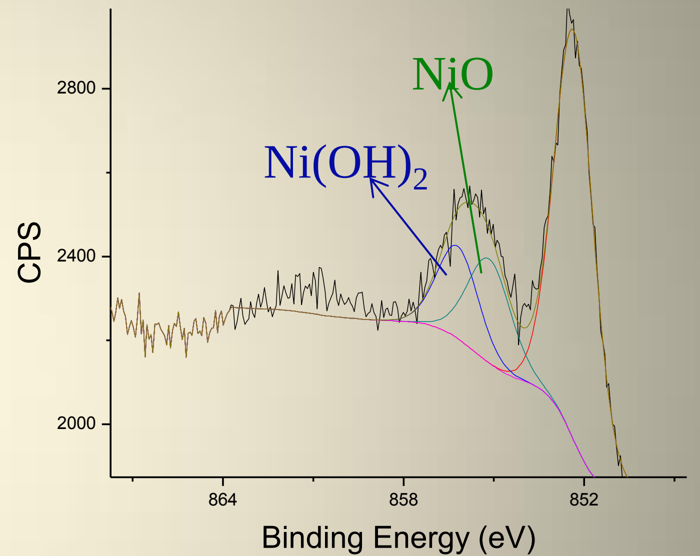




Large ϴ: surface analysis
Small ϴ: deeper analysis

ARXPS—Ni ($2p_{3/2}$)

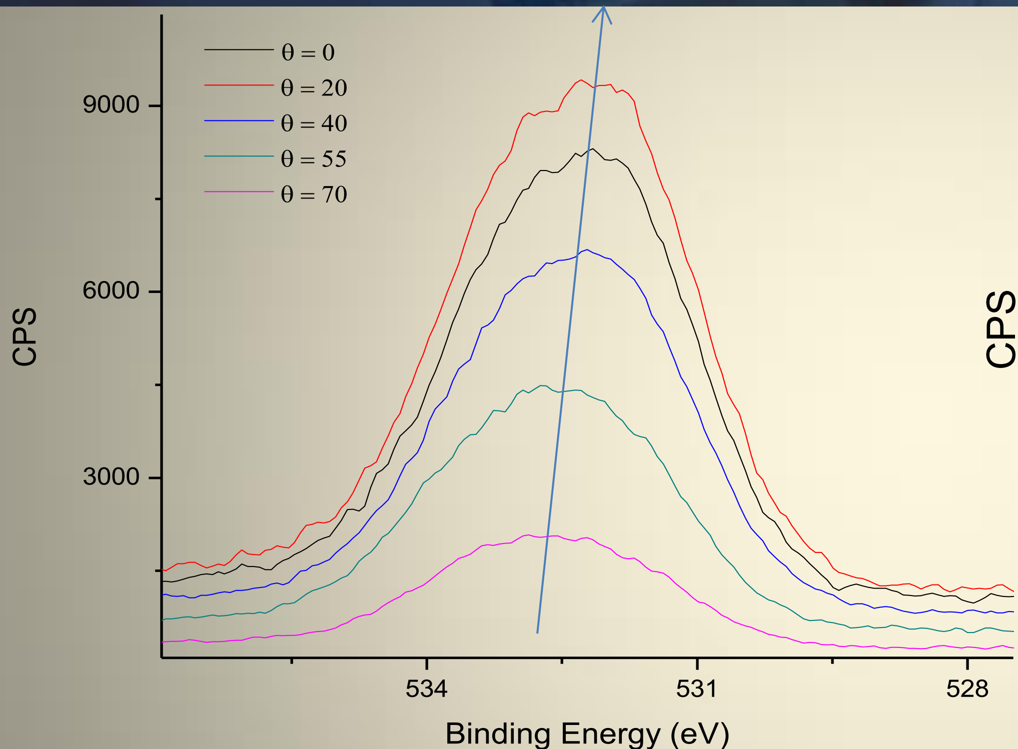


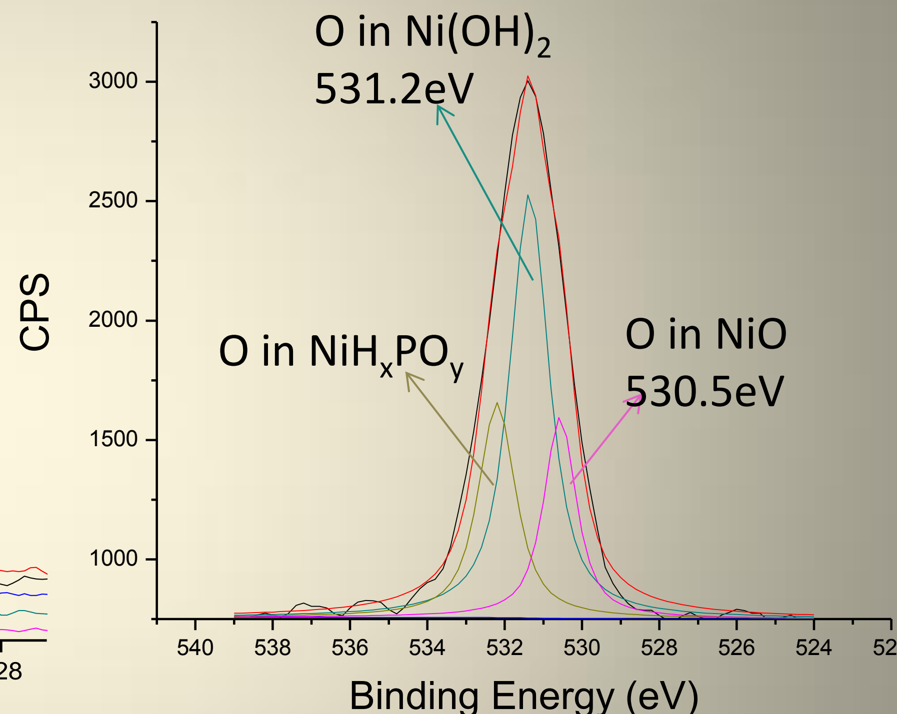


θ (°)	Peak position (eV)
55 (surface)	856.32
40	856.14
20	856.07
0 (deeper)	855.95

- Peak shift towards NiO with increased angle

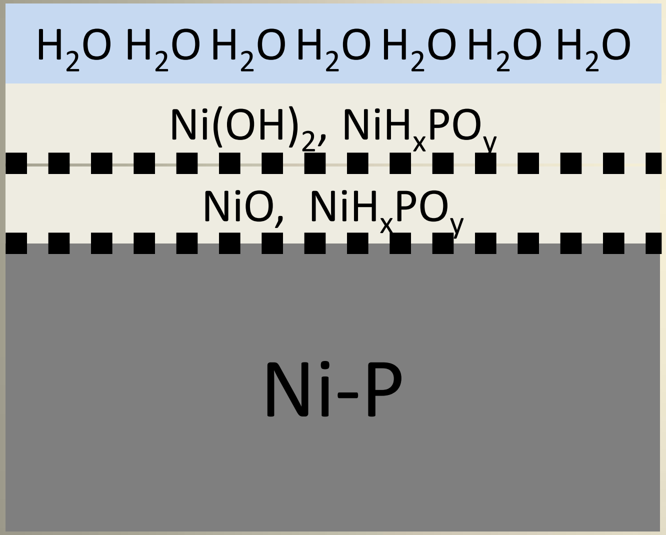
ARXPS—O (1s)





ϴ (°)	Peak position(eV)	$A_{Ni(OH)2}/A_{NiO}$
55 (surface analysis)	532.74	2.381
40	532.16	1.811
20 (deeper analysis)	531.90	0.879

NiP Oxidation Layers

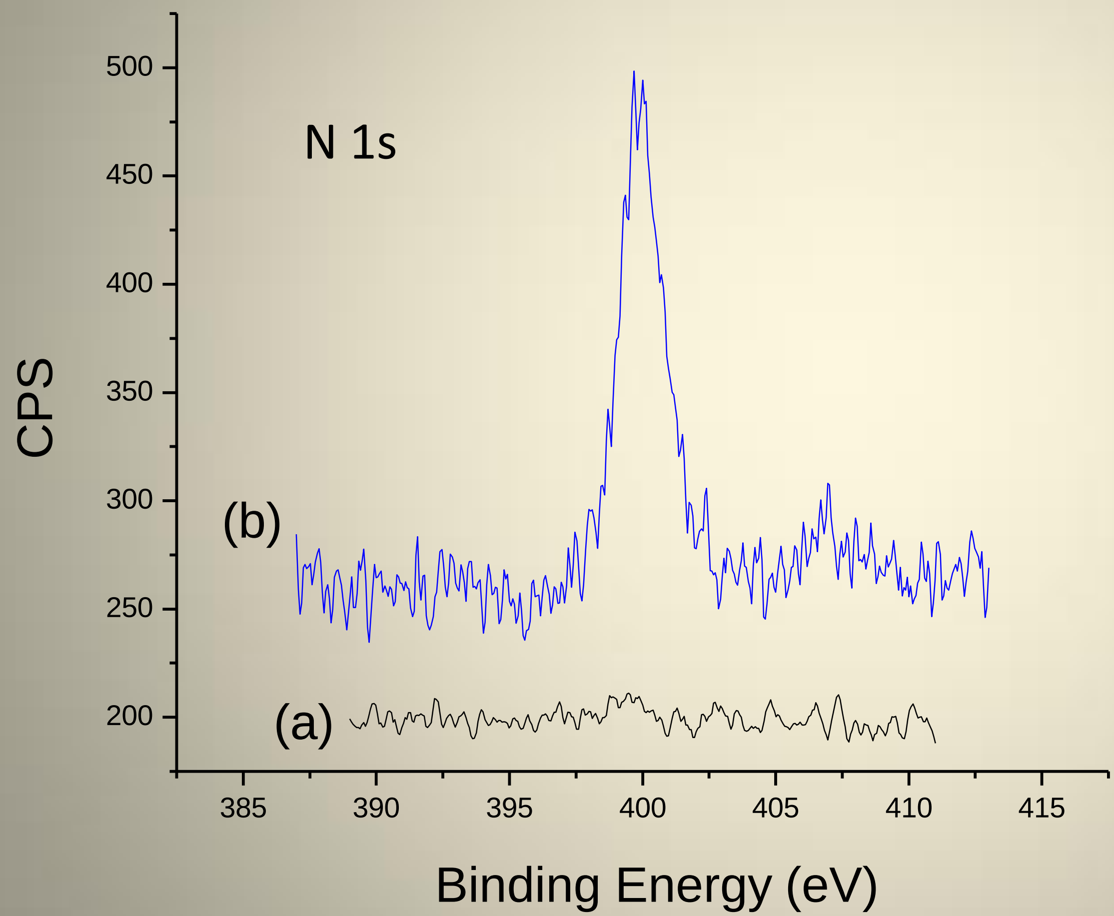


During/After Polishing:

◆The disk surface contains a thin $Ni(OH)_2$ layer followed by a thin NiO layer

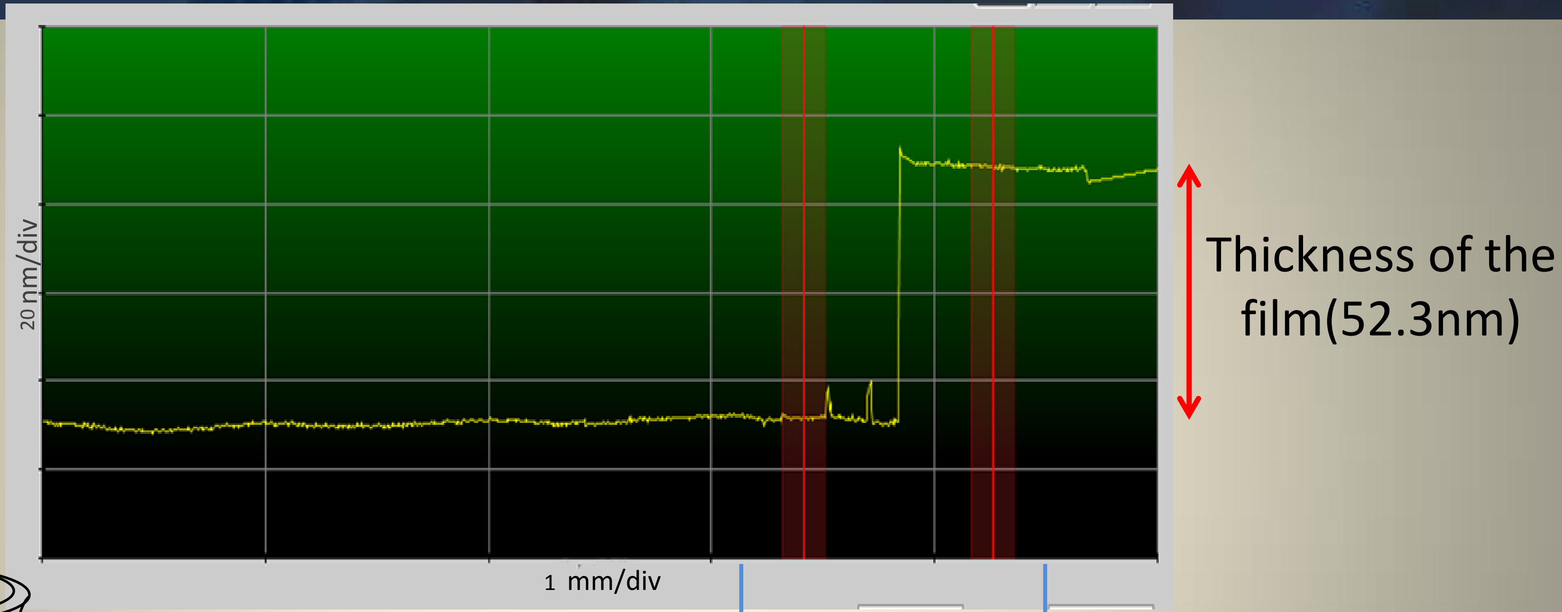
◆Utilize chemical to interact with NiP oxidation layers to promote removal and corrosion protection

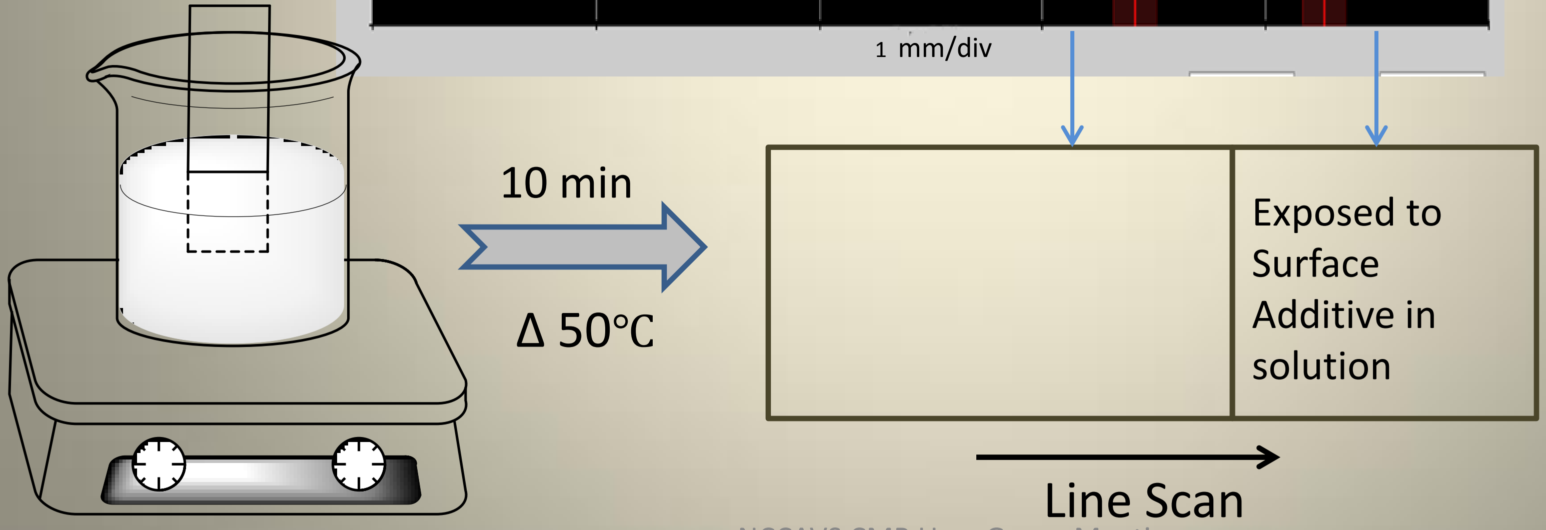
Surface Analysis (XPS)



- Peak not present with baseline formulation (a)
- Evidence of the Nitrogen based film forming compound (b)
  - Peak at 399.7 eV
- Tailored chemistry for effective film formation and surface protection

Surface Film Formation





Polishing Performance

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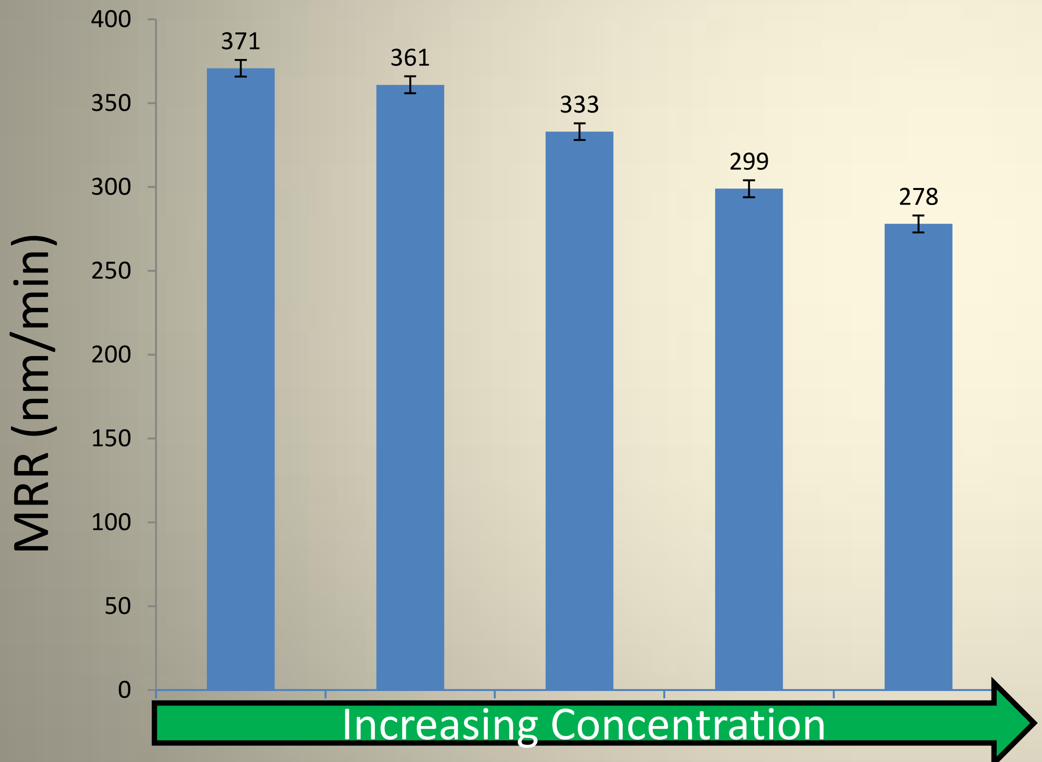
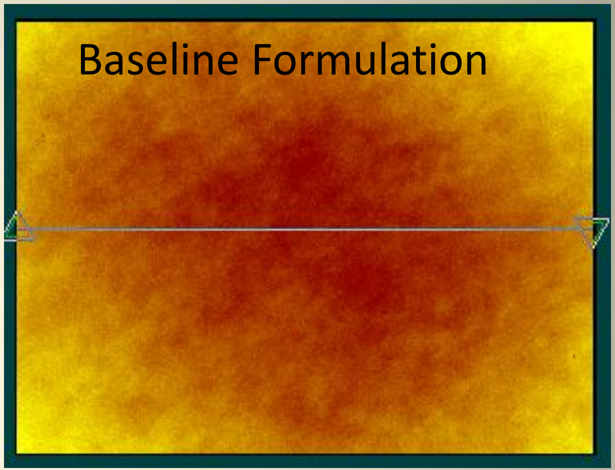
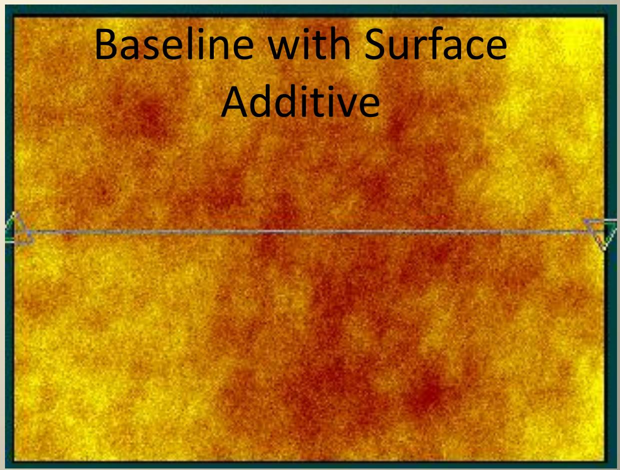
Baseline Formulation with [X] Surface Additive





R_a = 1.280 nm

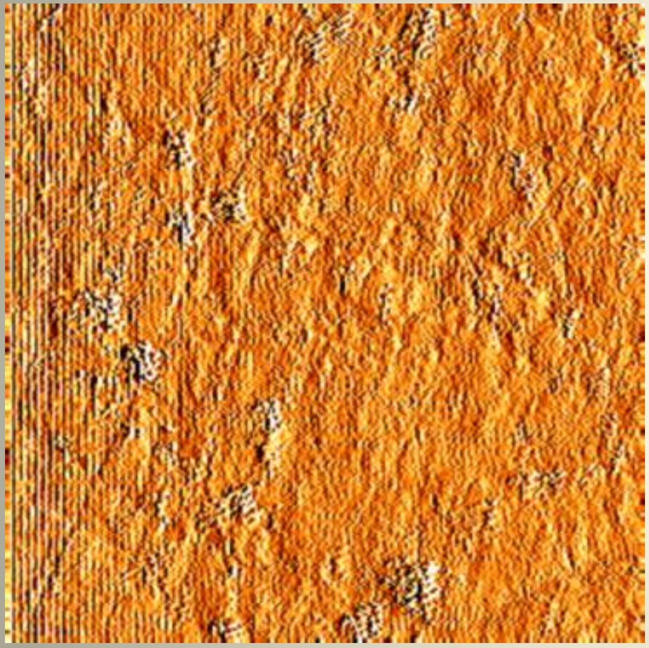


R_a = 0.509 nm

Zygo images of 0.7 * 0.53 mm area

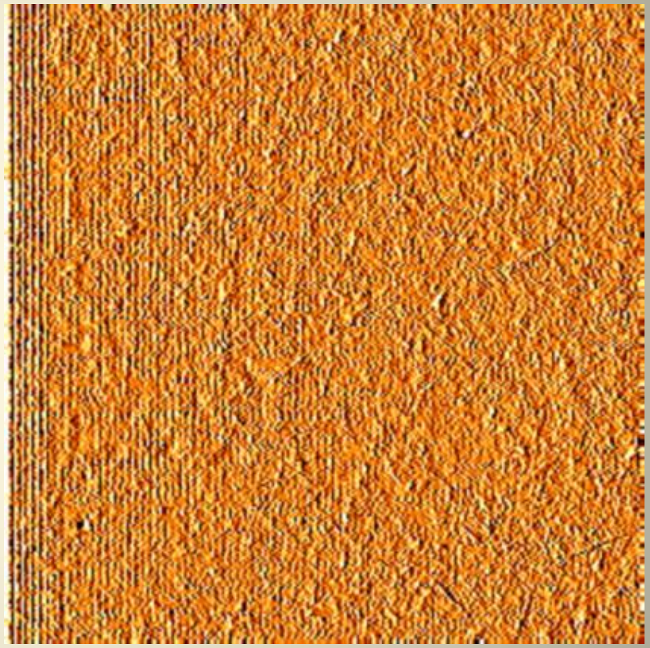
Surface Quality (AFM)

Baseline Formulation



R_a = 0.507 nm

Baseline with Surface Additive



R_a = 0.277 nm

Scan area: 5*5 µm

Conclusions

- XPS evaluation aided in understanding the oxidation and the layer composition
- Determined that during/after polishing, the disk surface contains a thin $Ni(OH)_2$ layer followed by a thin NiO layer
- Use of additives specifically tailored to interact with oxide species to improve surface quality
- Achieved the desired MRR approximately 350nm/min
- Surface Quality is improved but still being evaluated as the R_a is as low as 0.27nm but not yet the desired 0.1nm

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Acknowledgments

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ABRASIVES

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