Slurries for selective and non–selective polishing of SiC films

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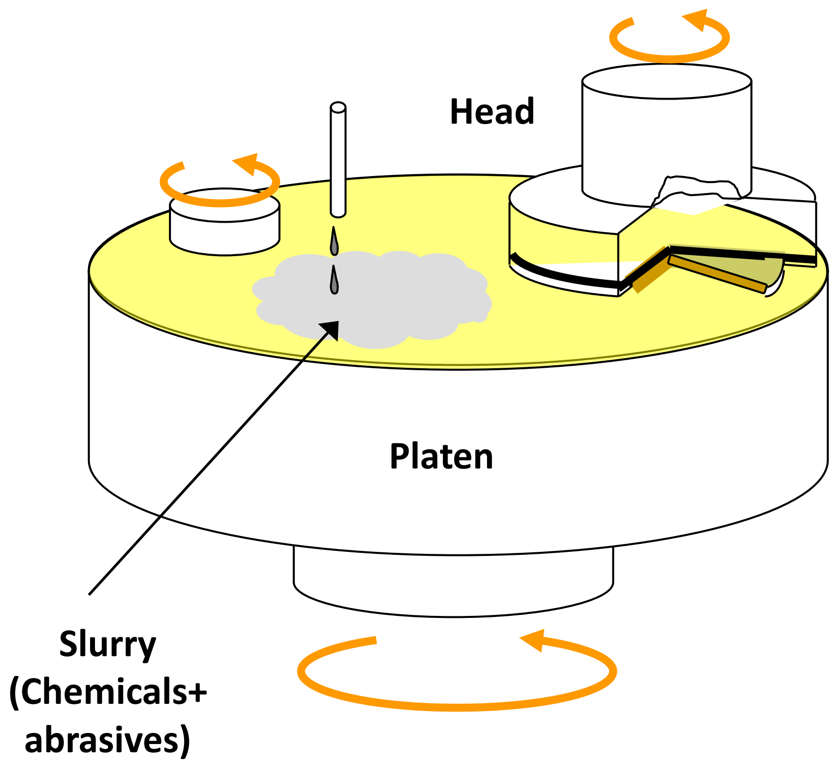
Outline

- Introduction
- Role of Ionic Strength
- Effects of salt addition on SiC RRs
- Zeta potential measurements of SiC and SiO_2 surfaces
- FTIR, contact angle and XPS analyses of SiC surfaces
- Polishing Mechanism
- Selective polishing of SiC
- Summary

SiC applications and CMP requirements

Applications	CMP requirements
• Hard mask for Low-K materials (amorphous/ poly-crystalline-SiC)	High RRs of SiC, low RRs of SiO_2
• Shallow Trench Isolation as a stop layer (amorphous/ poly-crystalline-SiC)	High RRs of SiO_2, Stop on SiC
• Semiconductor material for High Temperature devices (6H, 4H-SiC)	High RRs of SiC, epi-ready surface finish with good flatness and surface roughness
• MEMS/NEMS (3C-SiC) • LED's	

CMP setup and polishing conditions



Polisher	CETR bench top Polisher
Pressure	4 psi
Polishing time	1-5 min
Conditioning	Ex-situ
Slurry flow rate	120 ml/min
Platen/carrier Speed	90/90 rpm
Substrate	2″ a-SiC on Si (~1000 Å thick)
Pad	IC-1000 (K-Groove)
Thickness Measurement	Filmetrics (Interferometry)

Polish characteristics of SiC

- A very hard material (Mohs hardness : 9-10) and inert material -→ very low removal rates .

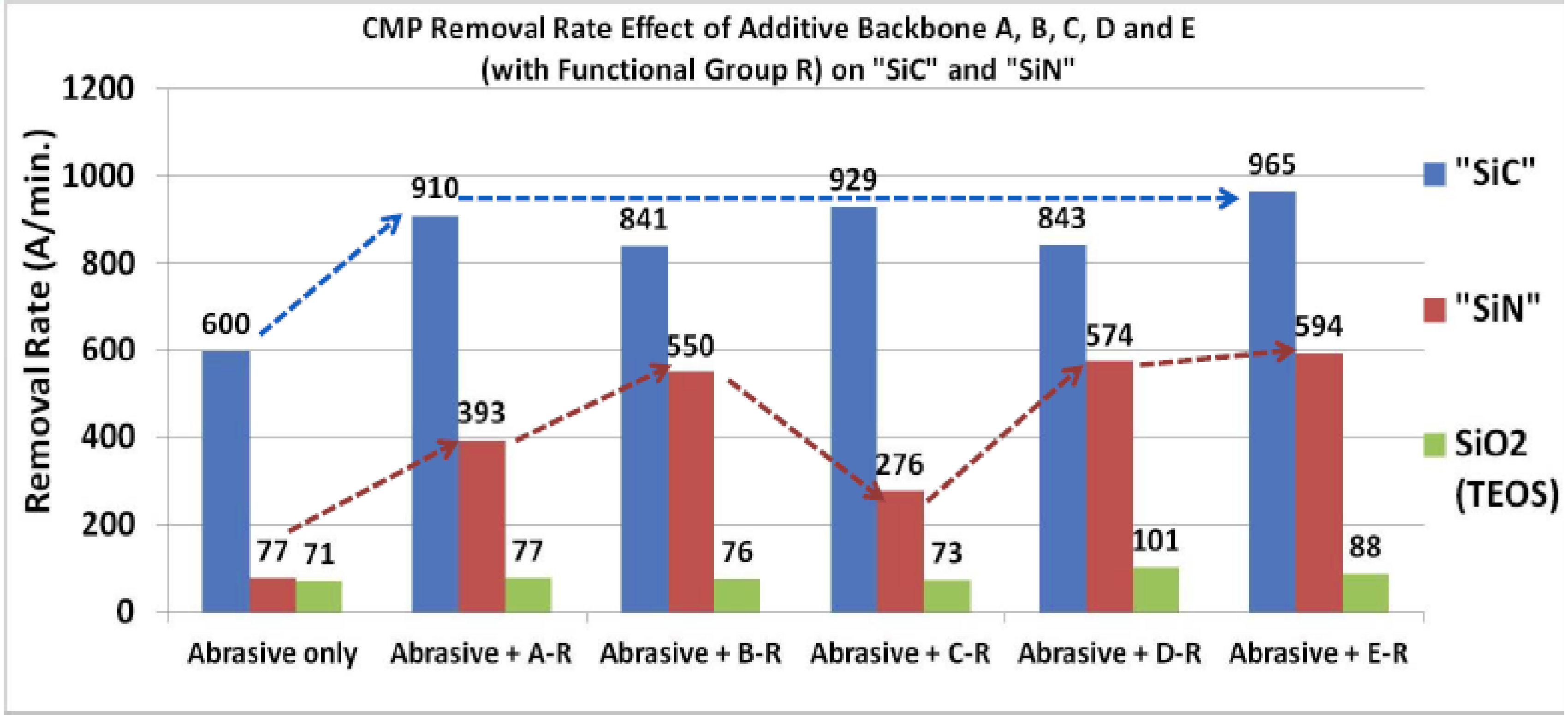
Different Polish rates on different faces*

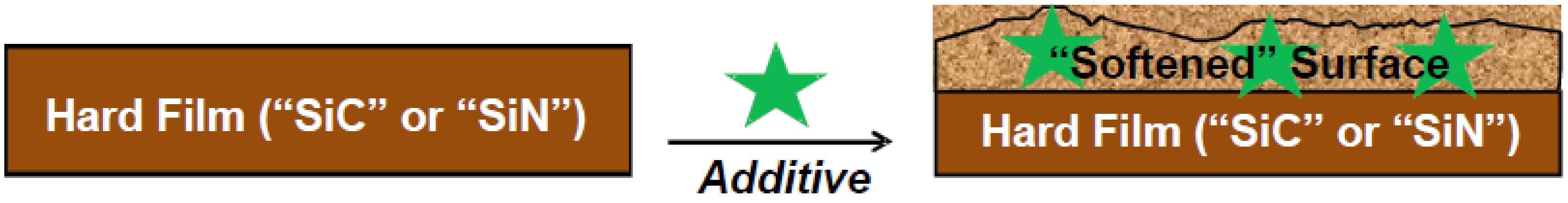
Polishing	Parameter	Si face	C face	m face	a face
Mechanical Polishing	MRR (nm/hr)	1040	698	799	795
	RMS (nm)	0.6	0.7	0.6	0.6
CMP	MRR (nm/hr)	153	6	108	104
	RMS (nm)	0.1	1.7	0.15	0.15

- No literature published on a-SiC CMP.

*Chen et al., *Materials Science and Engineering: B 142(1),* pp. 28-30. 2007

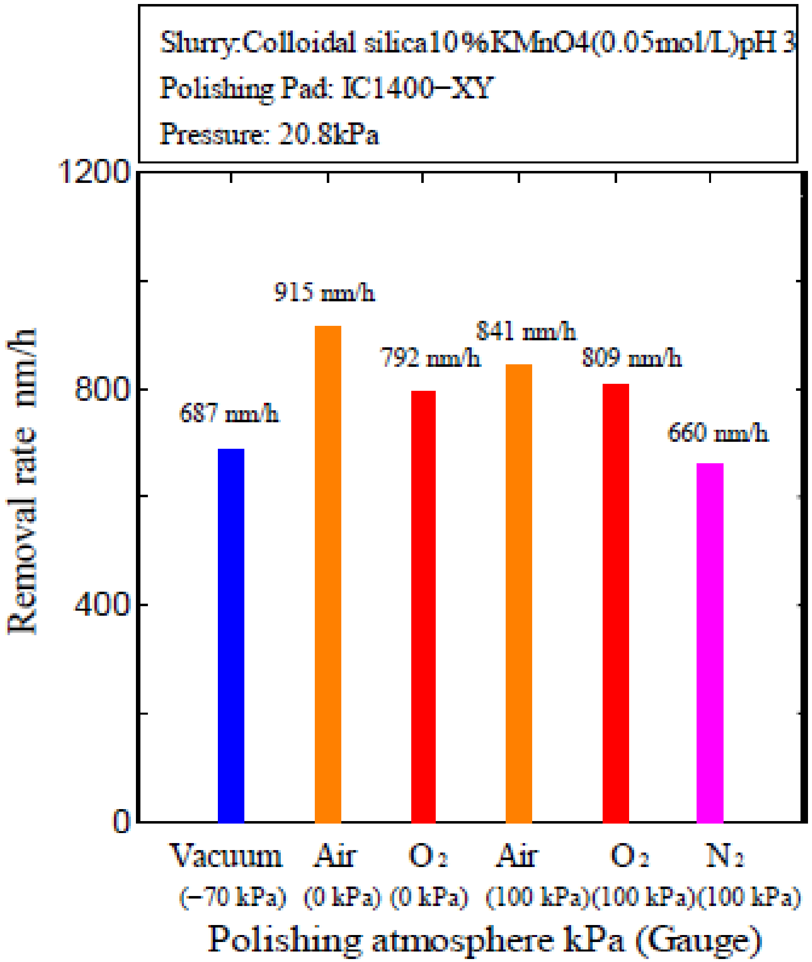
More recent data





James Schlueter, et al., DA Nanomaterials, ICPT-2012

More published data



Removal Rate in SiC-CMP under High and Low-Pressure Gases Atmosphere

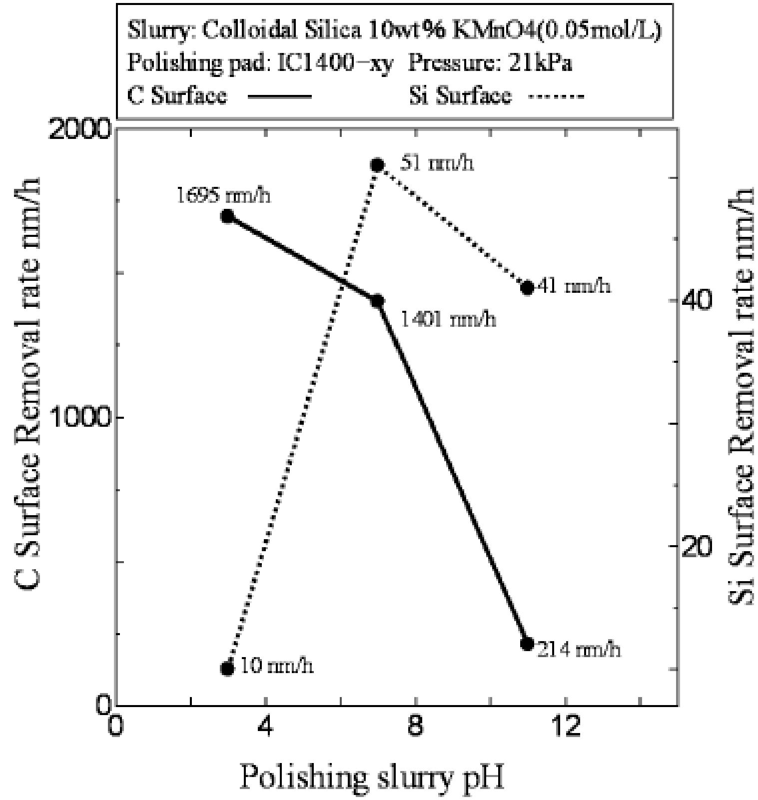
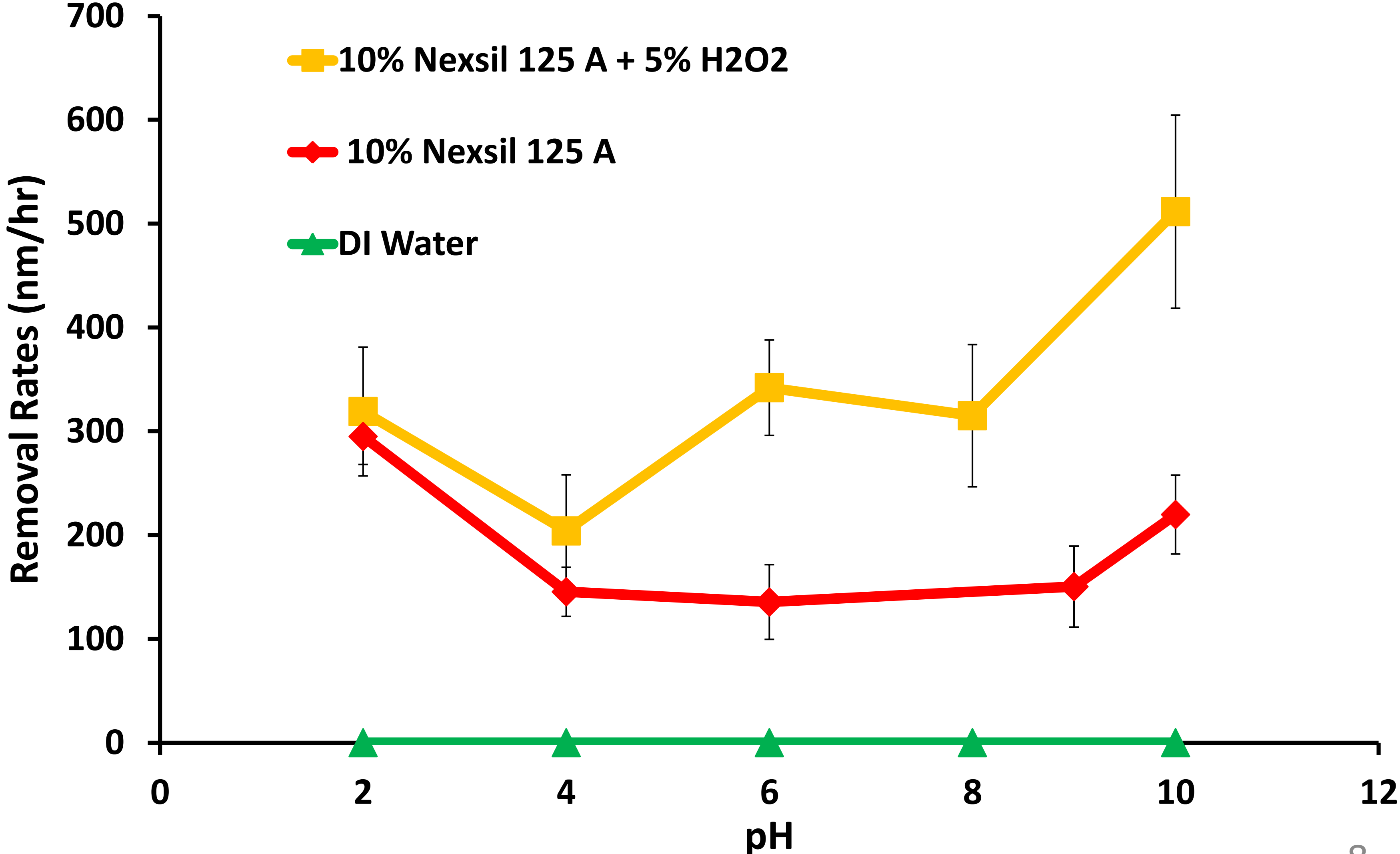


Fig.3 Removal Rate of SiC Wafer in Different pH s of Slurry

Removal Rate in SiC-CMP under High and Low-Pressure Gases Atmosphere

Tao Yin , et al., ICPT-2012

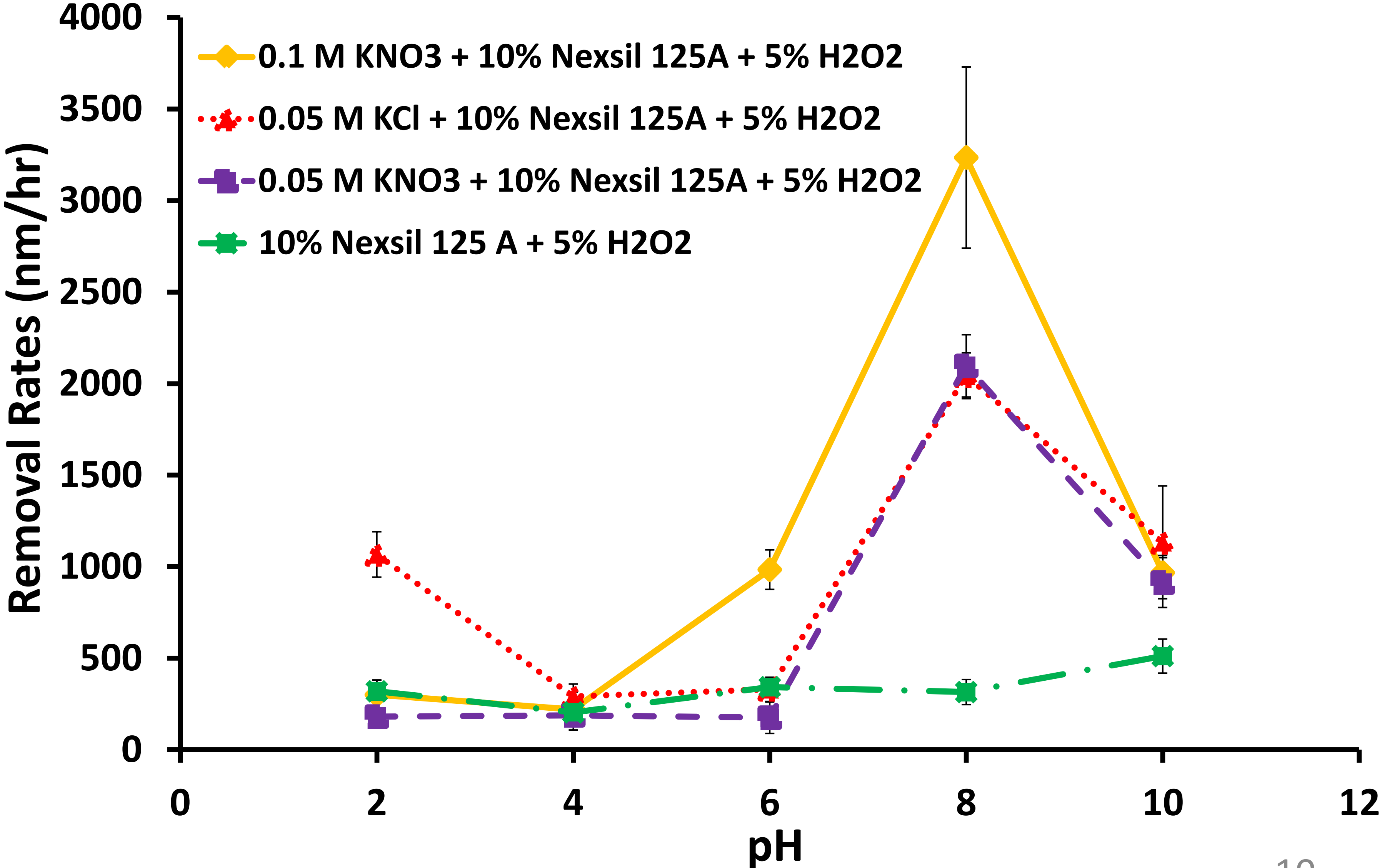
RRs of amorphous SiC with DI water, SiO_2, and SiO_2 + H_2O_2 slurries in the pH range 2-10



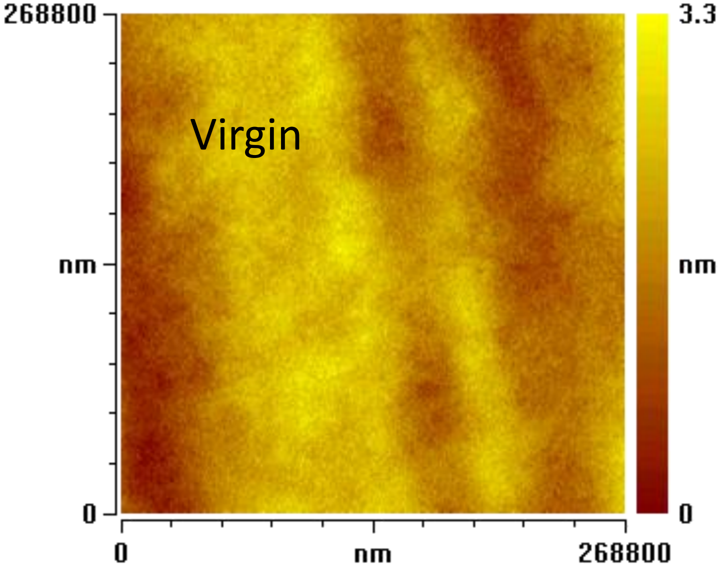
Lot of added KOH -Is ionic strength playing a role?

S. No	Slurry	Natural pH	Final pH	Conc. of KOH (mM)
1	10% Silica	3.2	8	2.85
2	10% Silica	3.2	10	10.85
3	10% Silica + 5% H_2O_2	2.9	8	7.50
4	10% Silica + 5% H_2O_2	2.9	10	137.5

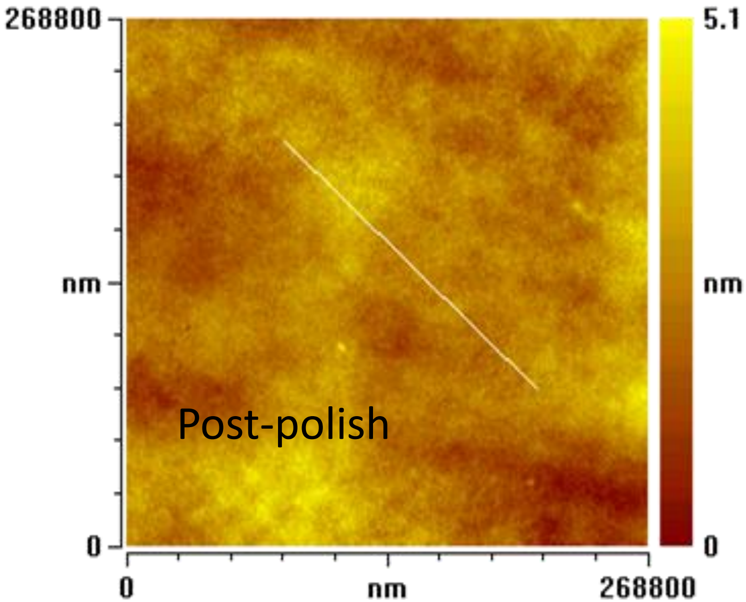
RRs of SiC in high ionic strength slurries

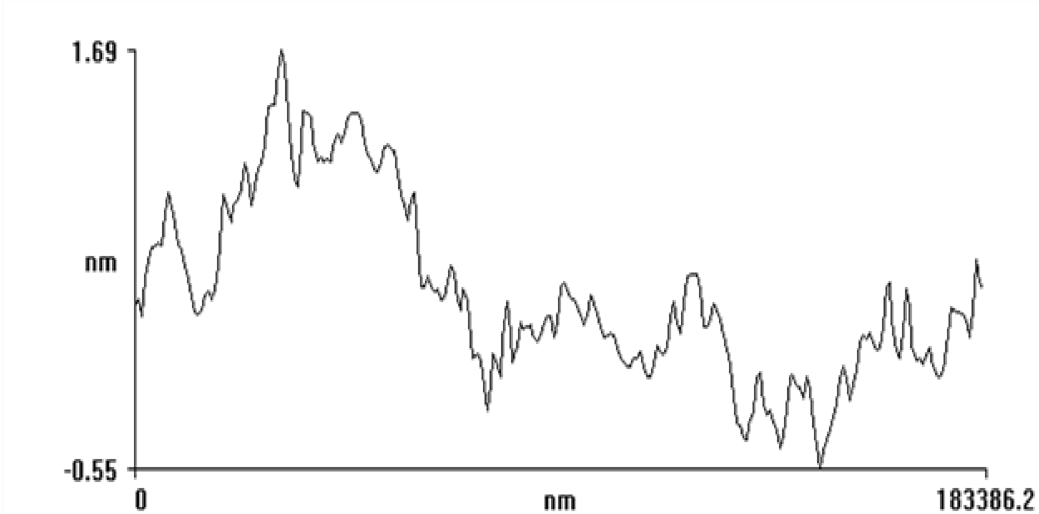


Surface images of virgin and post polish SiC wafers

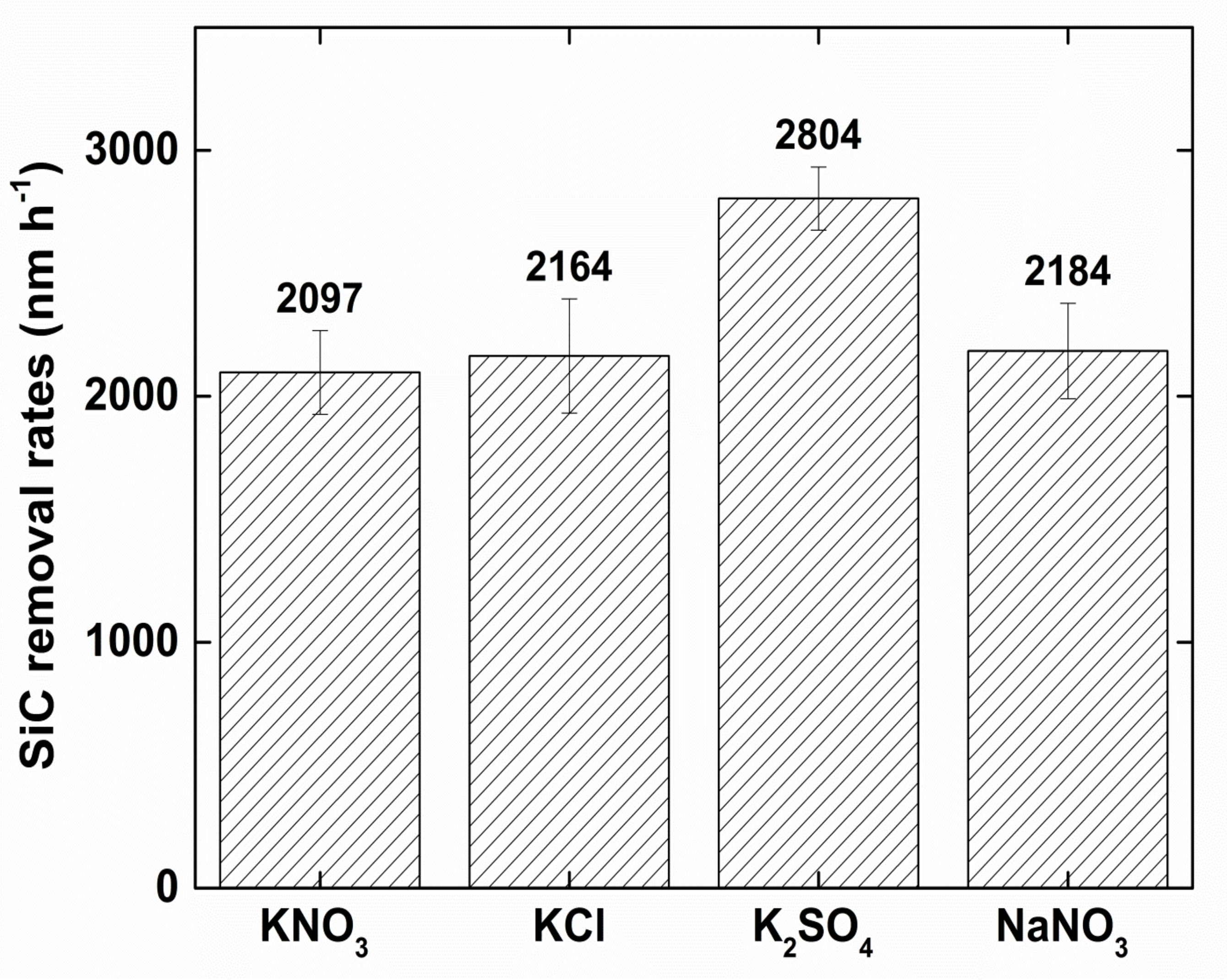


	Sq, nm	P/V, nm
Virgin	0.6	3.3
Post-polish	0.7	5.0



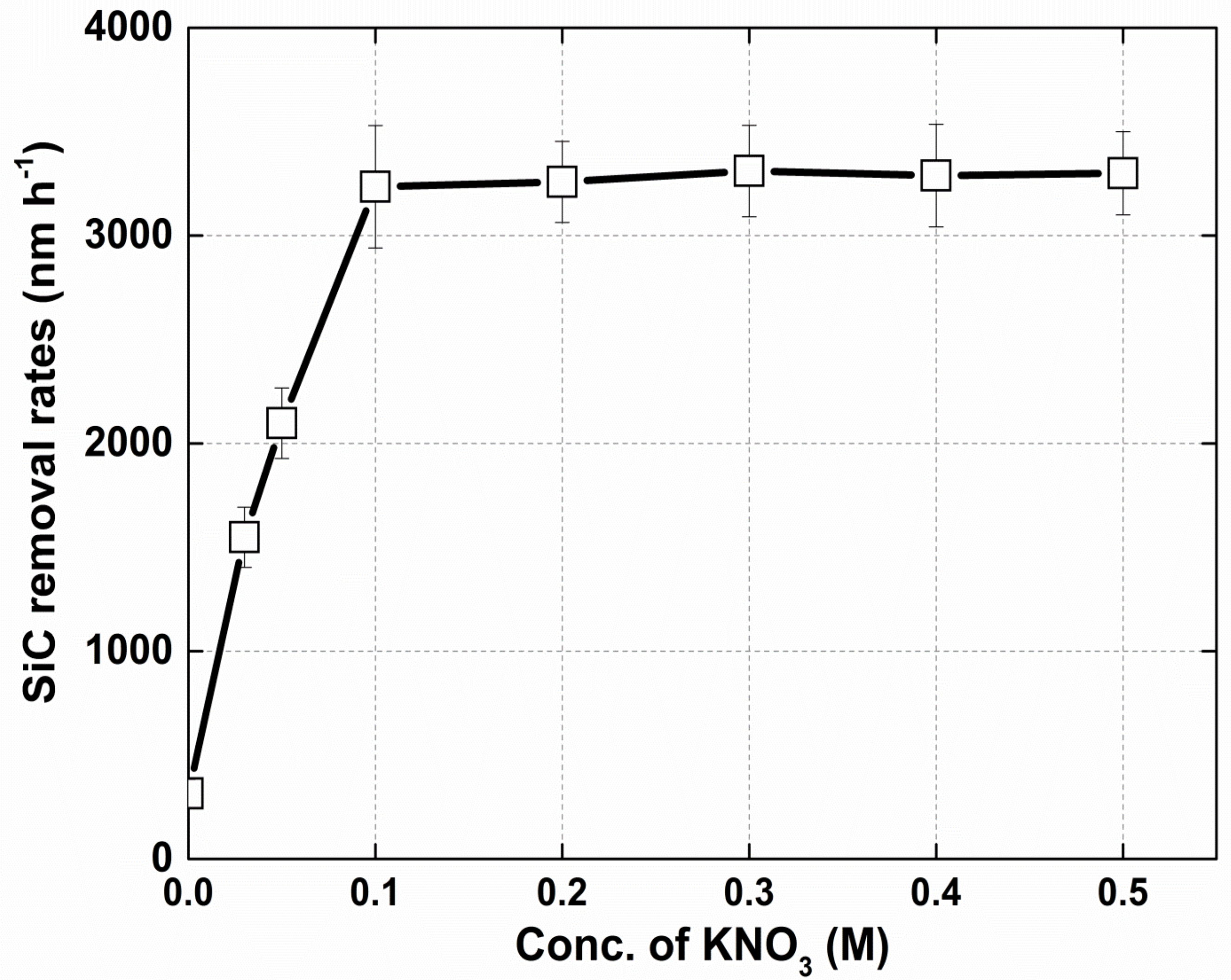


Effect of different salts on SiC RRs



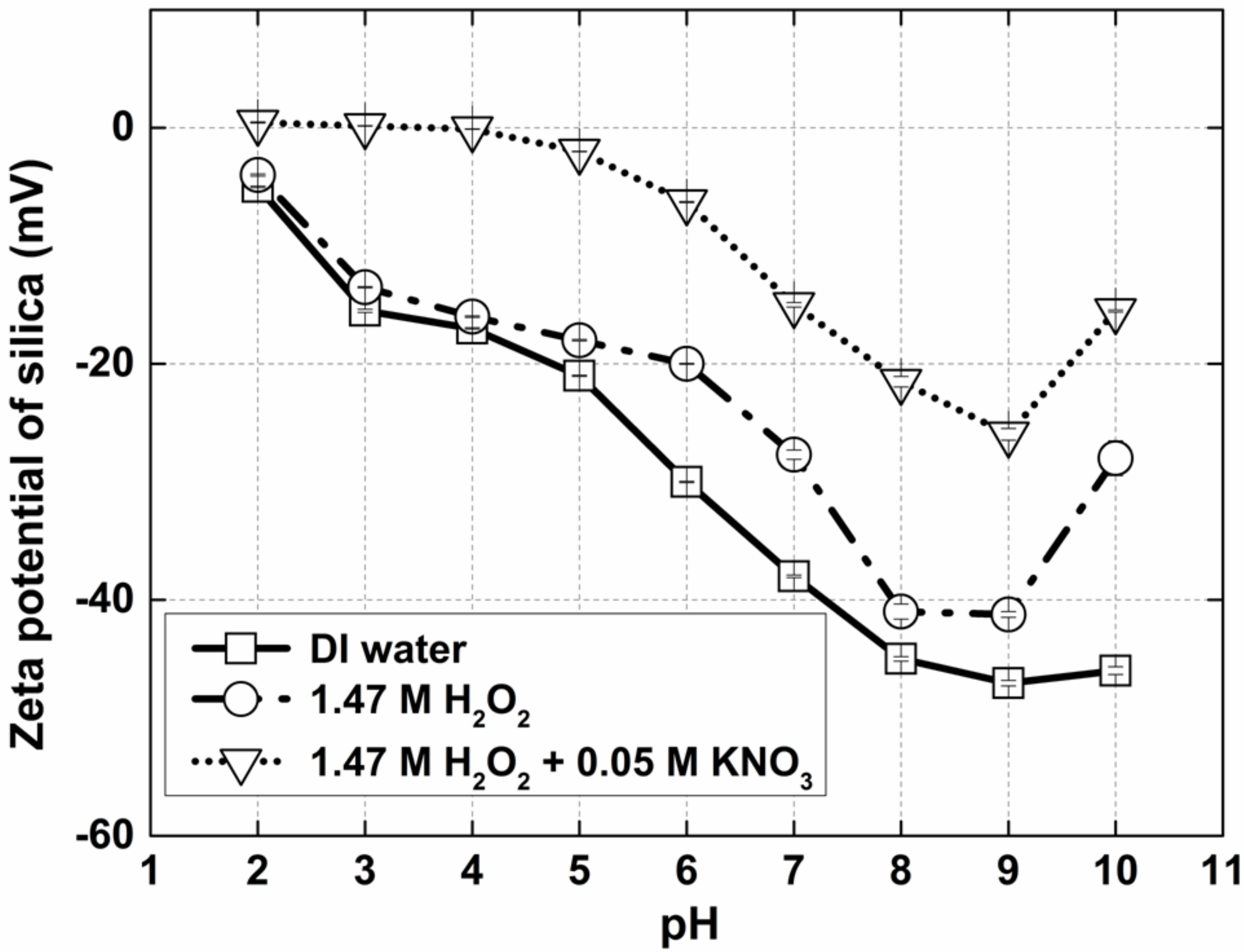
Slurry: 10 wt% silica + 1.47 M H_2O_2 + 0.05 M of different ionic salts at pH 8 and 4 psi.

SiC RRs as f(KNO_3 conc.)



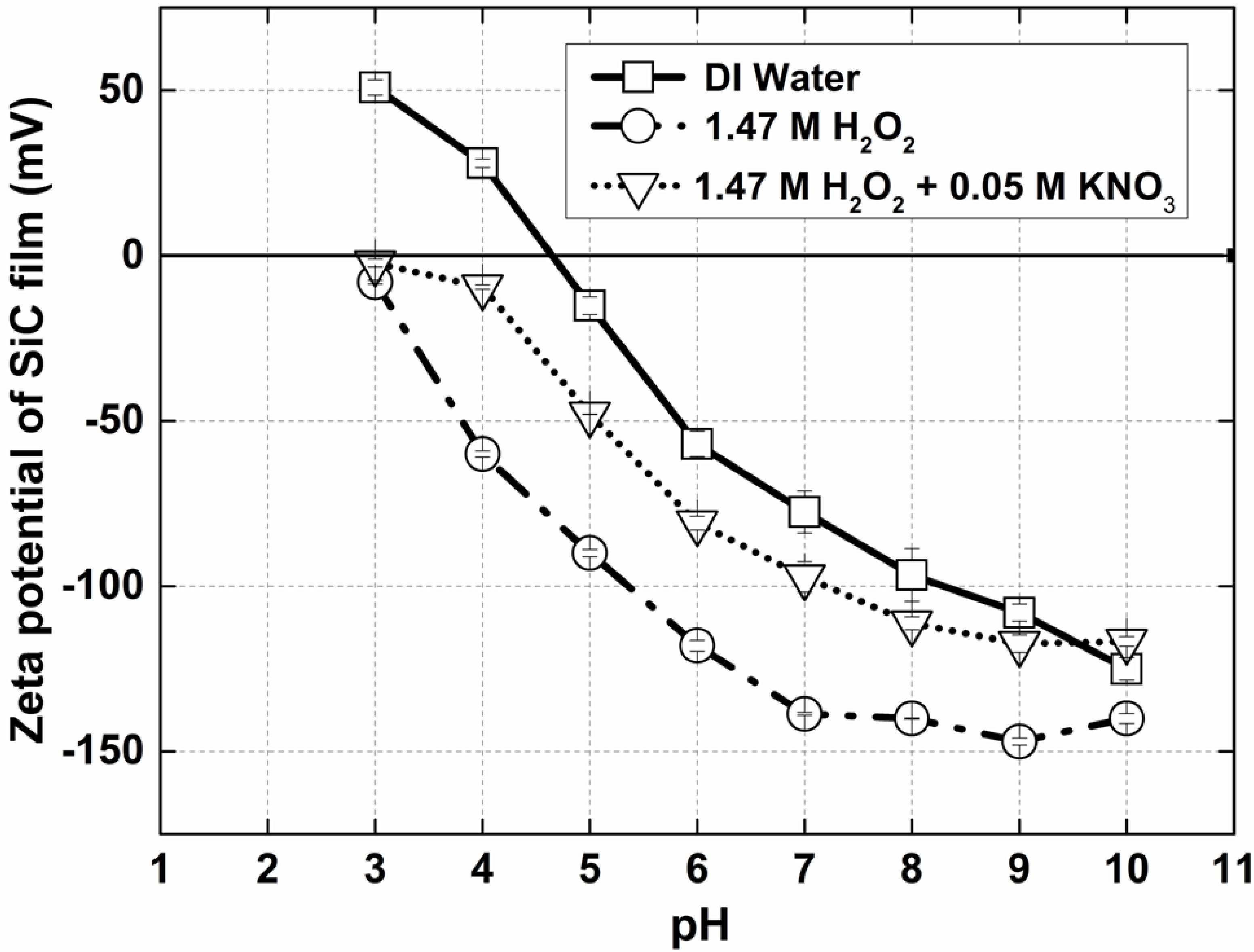
Slurry: 10 wt% silica + 1.47 M H_2O_2 + X M KNO_3 at pH 8 and 4 psi.

Zeta Potentials of 10 wt% SiO_2 particles with different additives

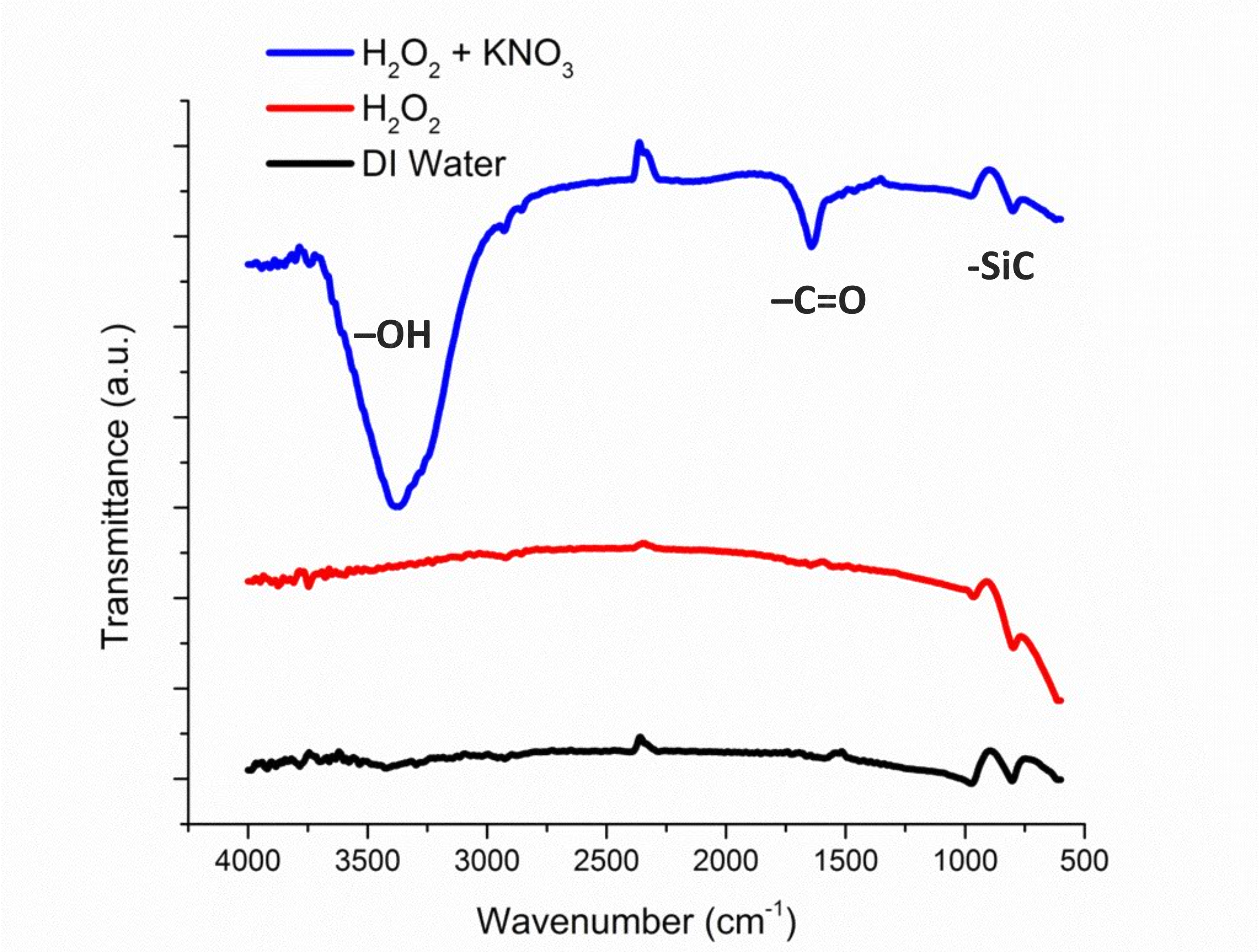


(a)DI water, (b) 1.47 M H_2O_2 and (c) 1.47 M H_2O_2 + 0.05M KNO_3

Zeta Potentials of SiC films with different additives



FTIR spectra of SiC powders exposed to different solutions at pH 8

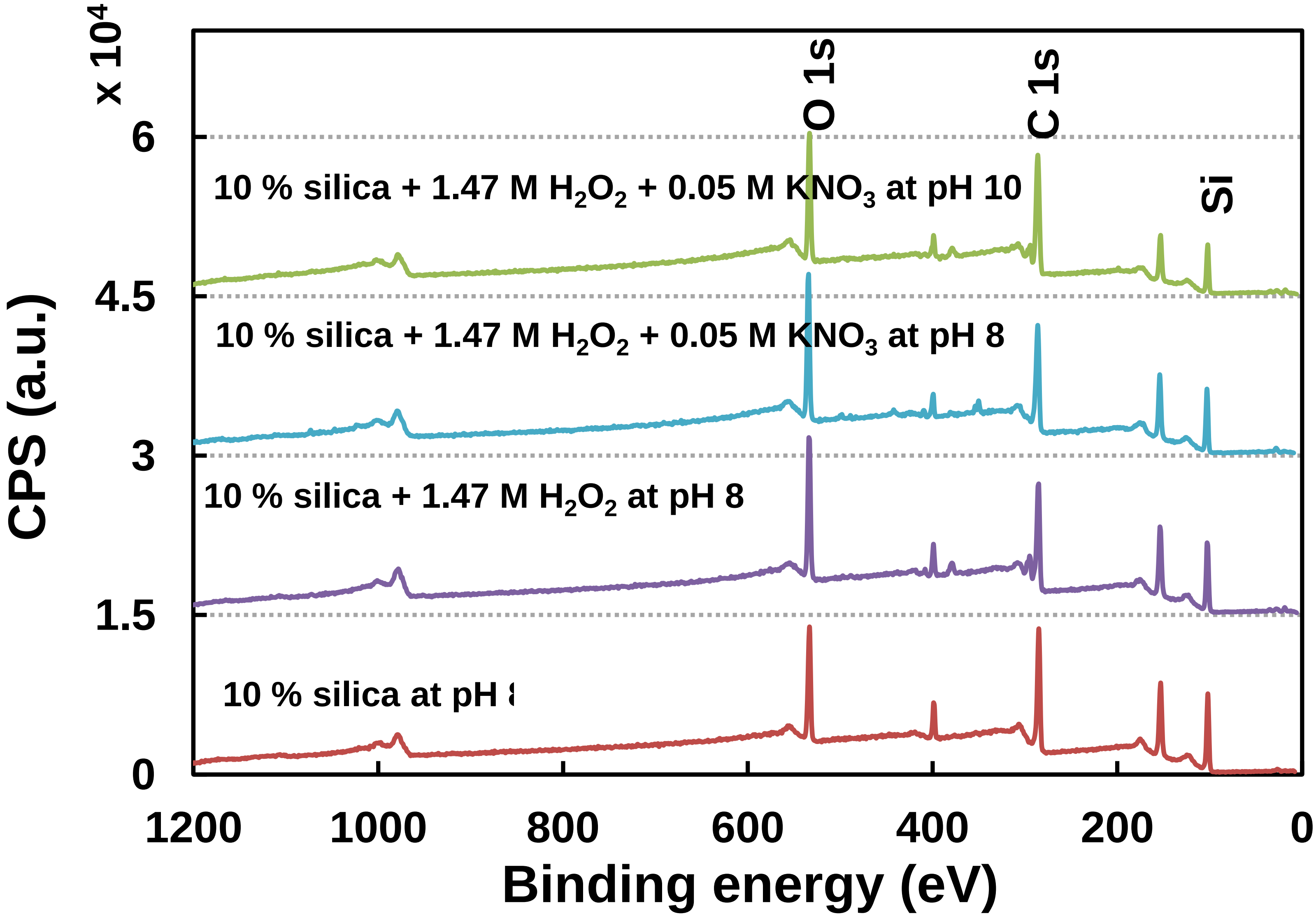


Surface compositions of SiC films dipped in different solutions for 5 minutes

	BE (eV)	A (At%)	B (At%)	C (At%)	D (At%)
C 1s	285	37.3	34.8	38.3	35.5
Si 2p	102	24.8	27.6	26.6	26.8
O 1s	534	30.7	29.8	27.9	30.0
N 1s	399	7.2	7.7	7.2	6.5
K 2s	380	-	-	-	1.0
C: Si ratio	-	1.5	1.3	1.4	1.3

A) none, (B) 1.47 M H_2O_2 at pH 8, (C) 1.47M H_2O_2 + 0.05M KNO_3 at PH 8 and (D) 1.47M H_2O_2 + 0.05M KNO_3 at PH 10.

XPS survey scan data of SiC films polished with different slurries



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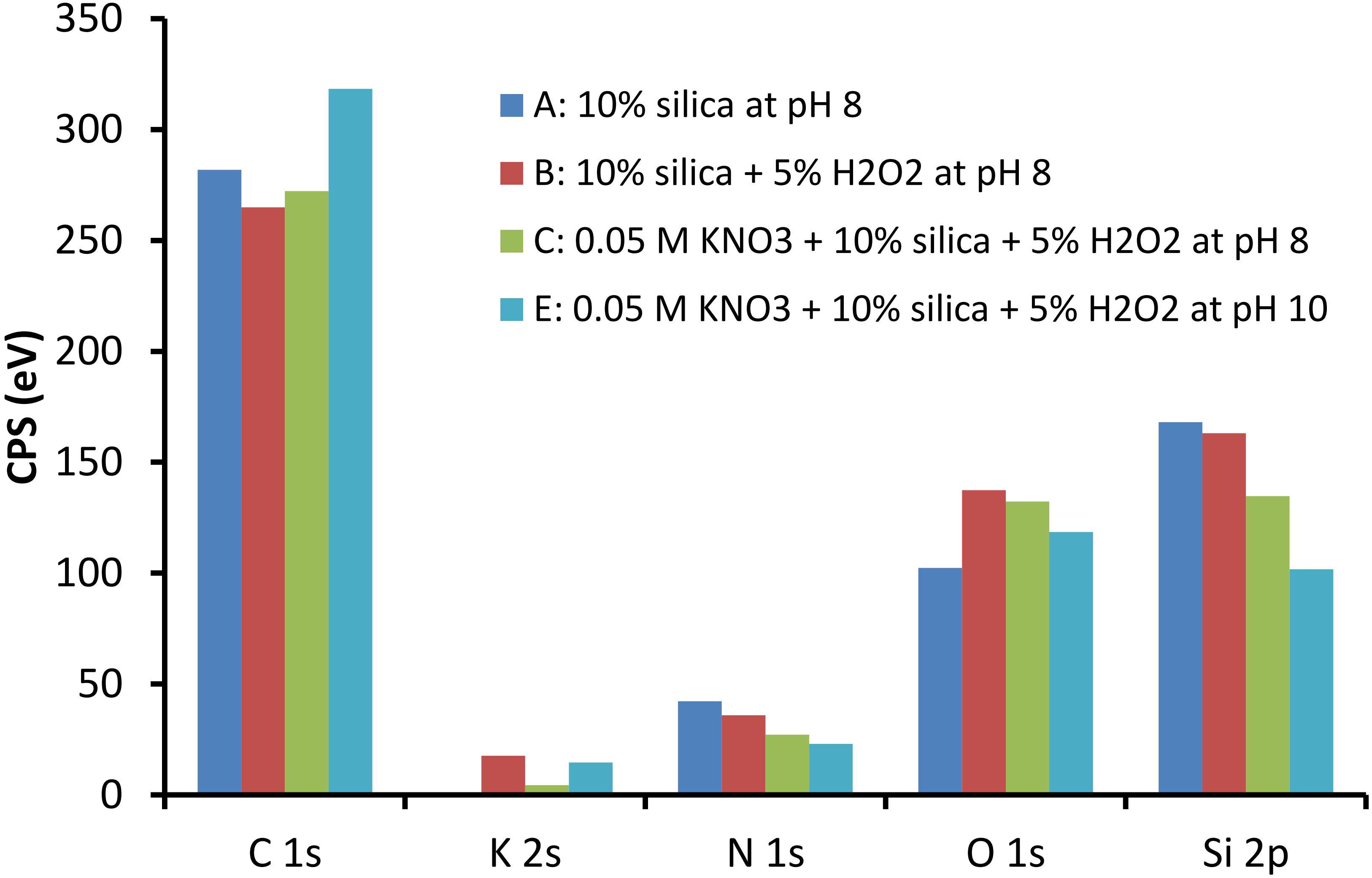
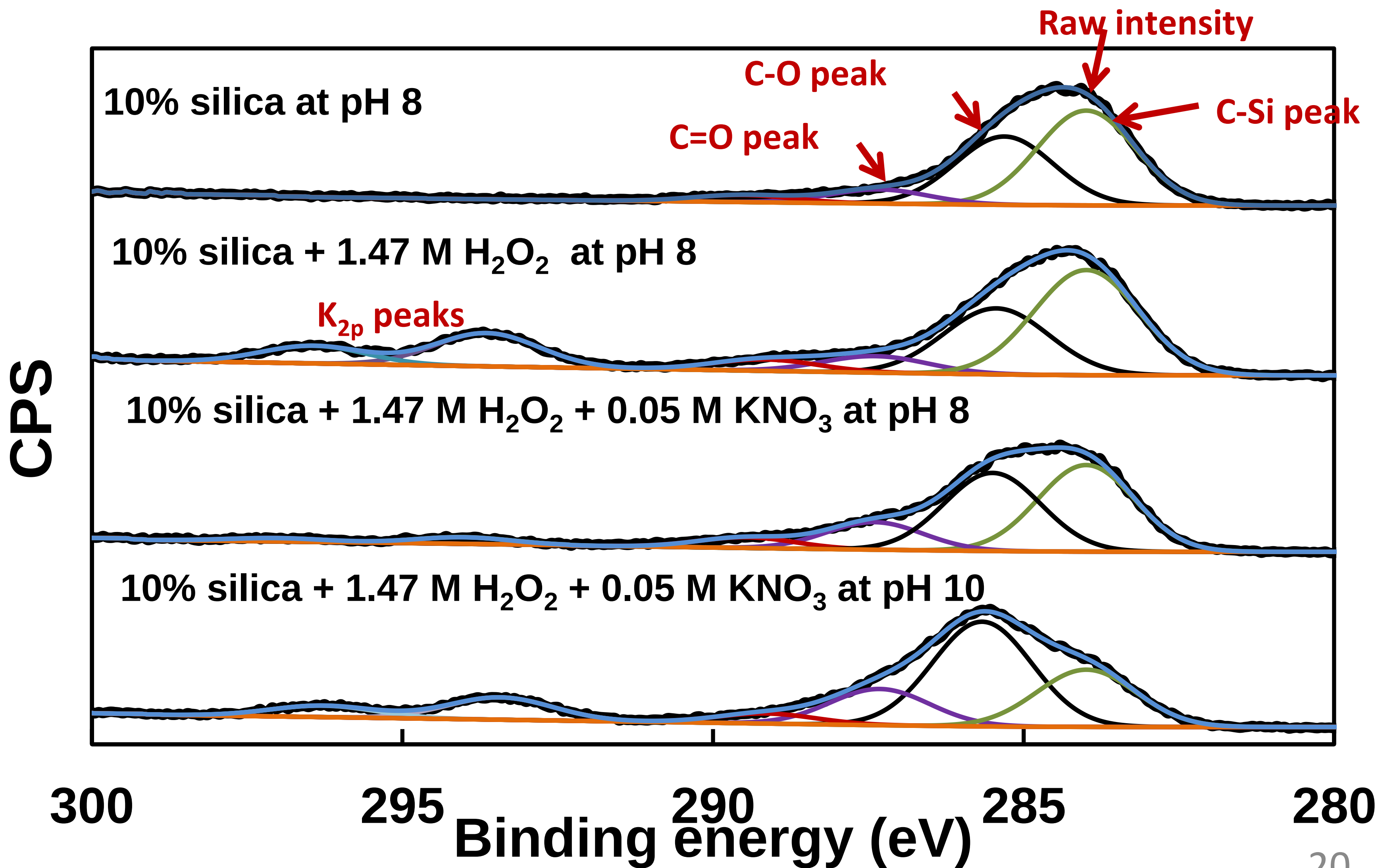


High resolution C1s spectra of SiC films polished with different slurries



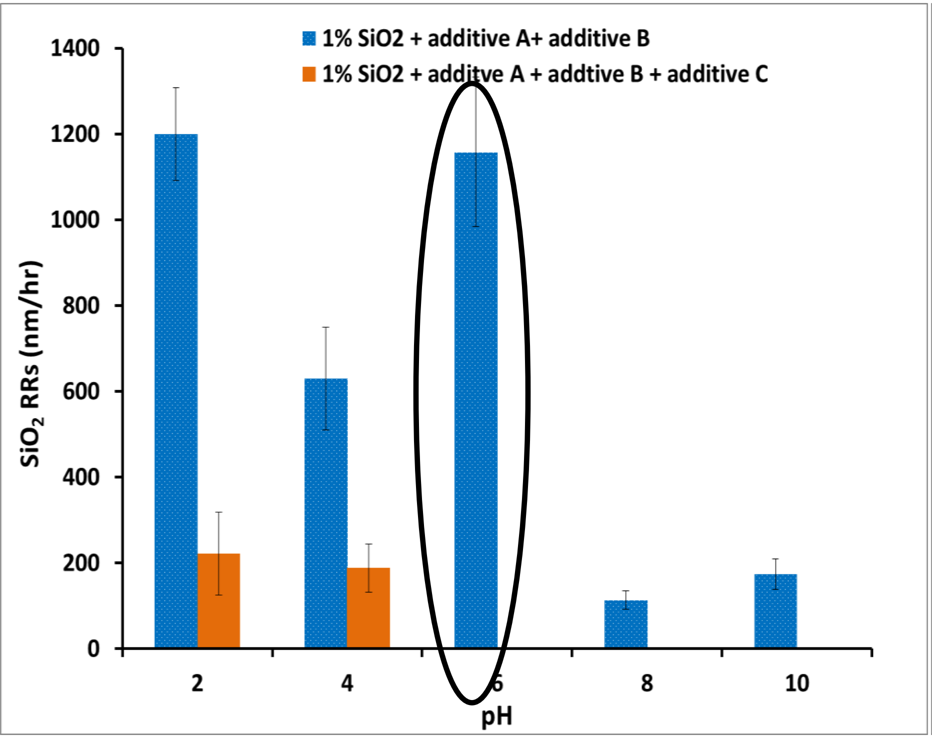
Contact angles of SiC coupons exposed to different solutions

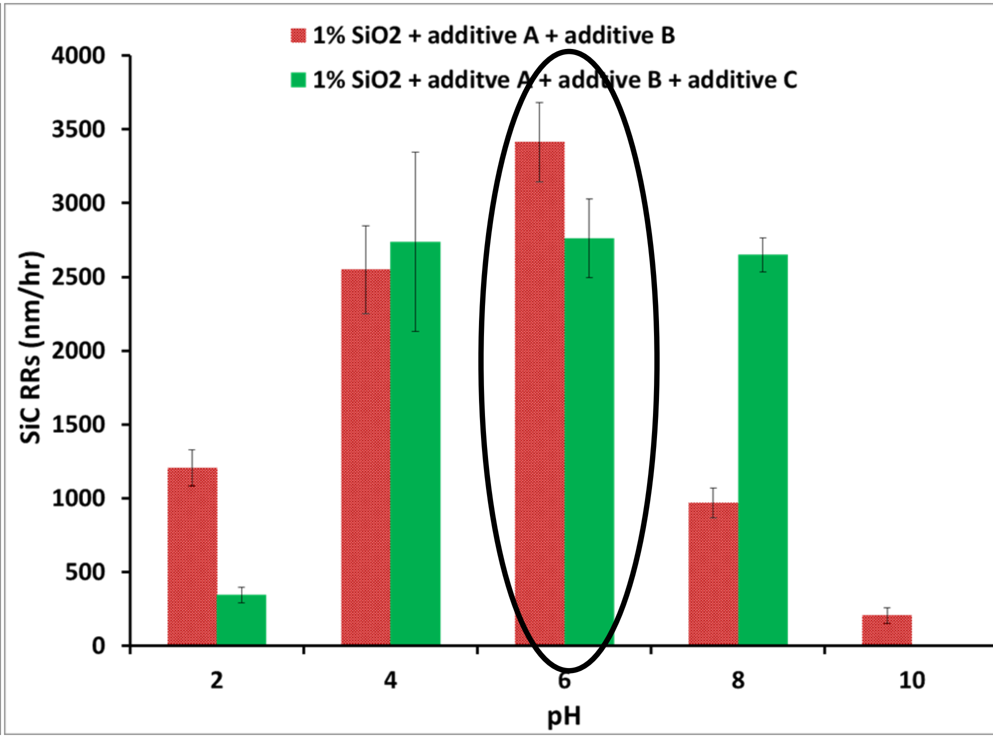
Solution	Average contact angle
Virgin	48^{o}
5% H_2O_2 at pH 8	31^{o}
5% H_2O_2 + 0.05M KNO_3 at pH 8	$<10^{o}$

Polishing Mechanism

- In the presence of H_2O_2:
  $SiC + 2H_2O_2 \longrightarrow Si_xO_yH_z + C_aH_bO_c$ (alcohol and acid)
- The formation of the oxidized species of Si and C (alcohol and carboxylic acid) is enhanced in alkaline pH region. It is well known that the conversion of carbon in the presence of an oxidizer is a 2 step process where an alcohol is formed initially followed by the conversion to a carboxylic acid.
- In the presence of KNO_3, K^+ from the salt will polarize the Si-O, C-O and C=O bonds and enhance the RRs.
  (**Electronegativity:** C = 2.44; Si=1.91; O= 3.44).
- The oxide formation is much less at pH 6. Although the formation of the oxidized species is highly enhanced at pH 10, the softening of the silica abrasives at this pH likely resulted in lower RRs.

Slurries for selective polishing of SiC





Summary

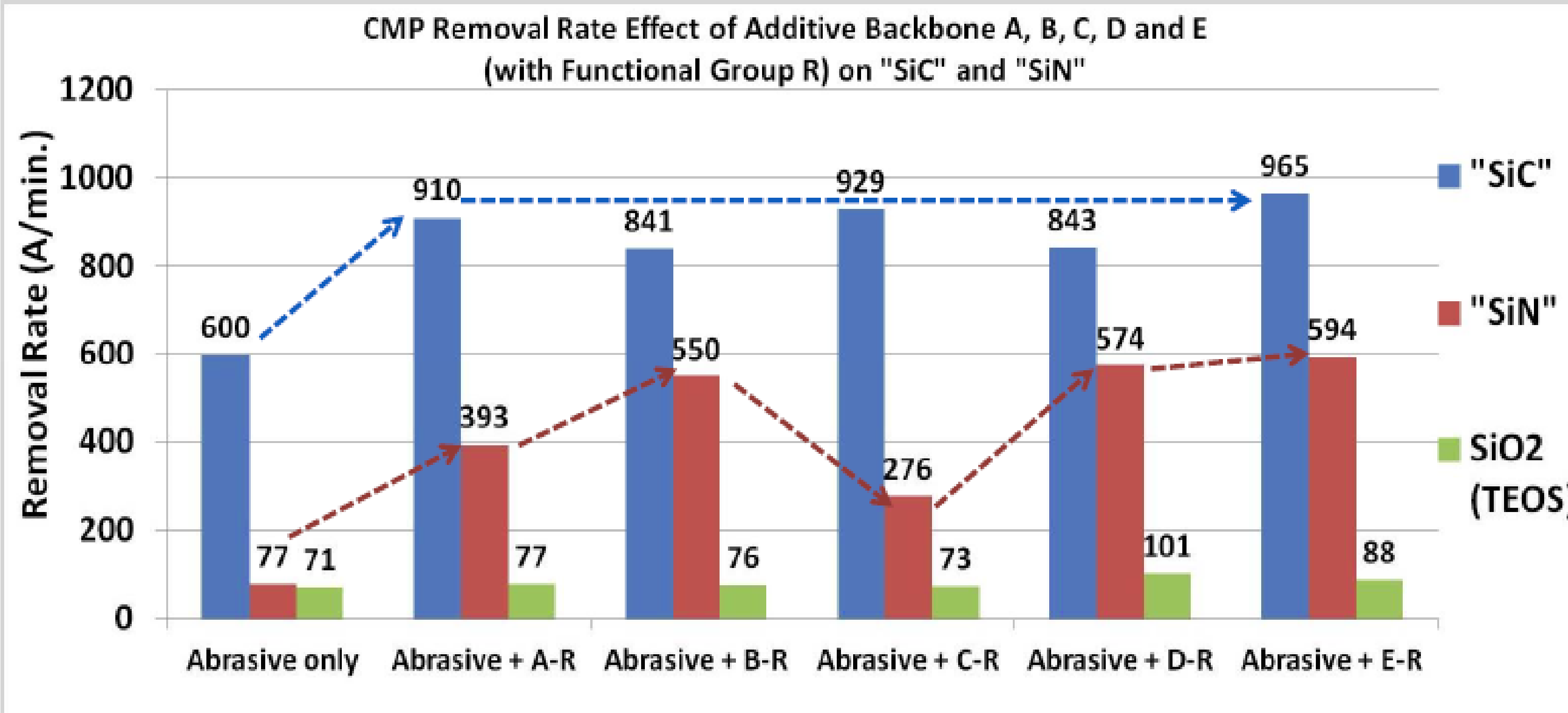
- Ionic Strength plays a major role in enhancing the SiC RRs by increasing the polarity between the bonds.
- 0.05 M KNO_3 + 10% silica + 5% H_2O_2 at pH 8 gave an SiC RR of ~2000 nm/hr. The post polish surface was excellent with an RMS surface roughness< 1nm.
- A mechanism for the high SiC removal rates observed with H_2O_2-based and salt containing slurries is proposed based on XPS, FTIR , contact angle and removal rate data.
- We developed low abrasive slurries that give high RRs of SiC and stop on Oxide.

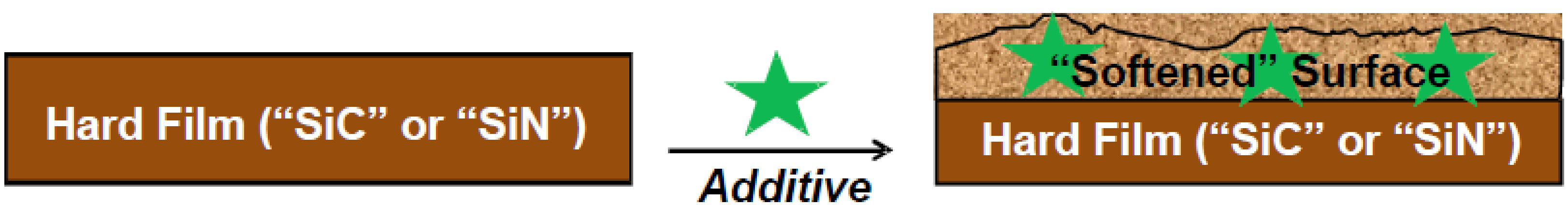
Acknowledgements

- DOW, 3M and Nyacol for supplying pads, conditioners, silica dispersions, respectively.
- Chris Plunket for CETR maintenance.

THANK YOU

Literature





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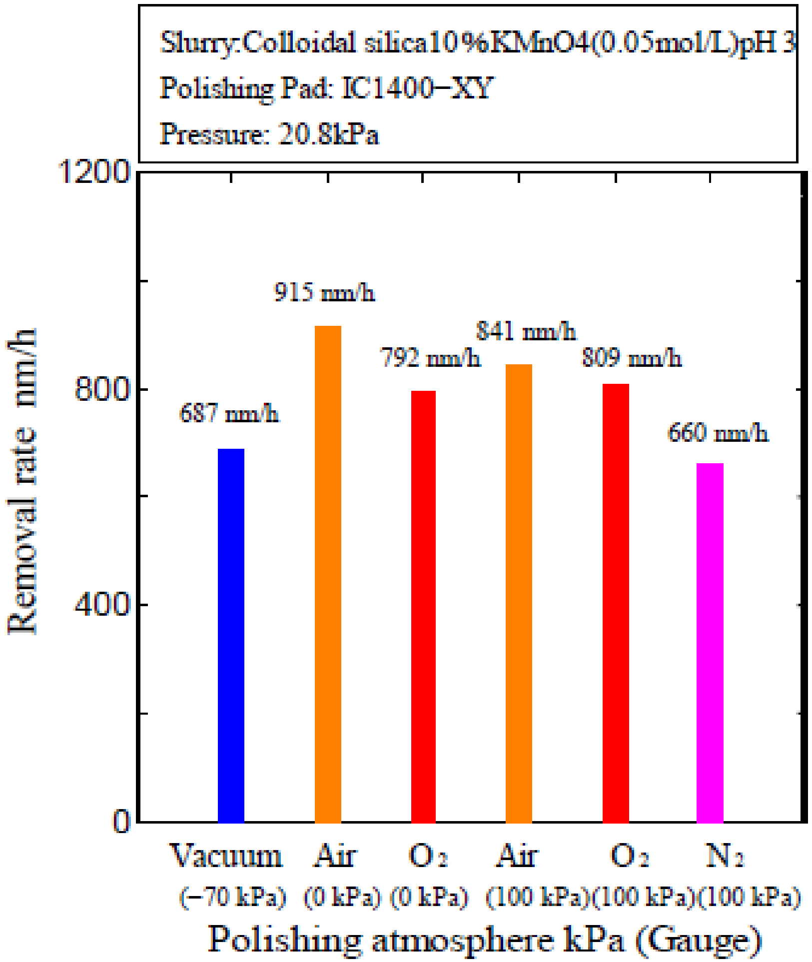
Literature



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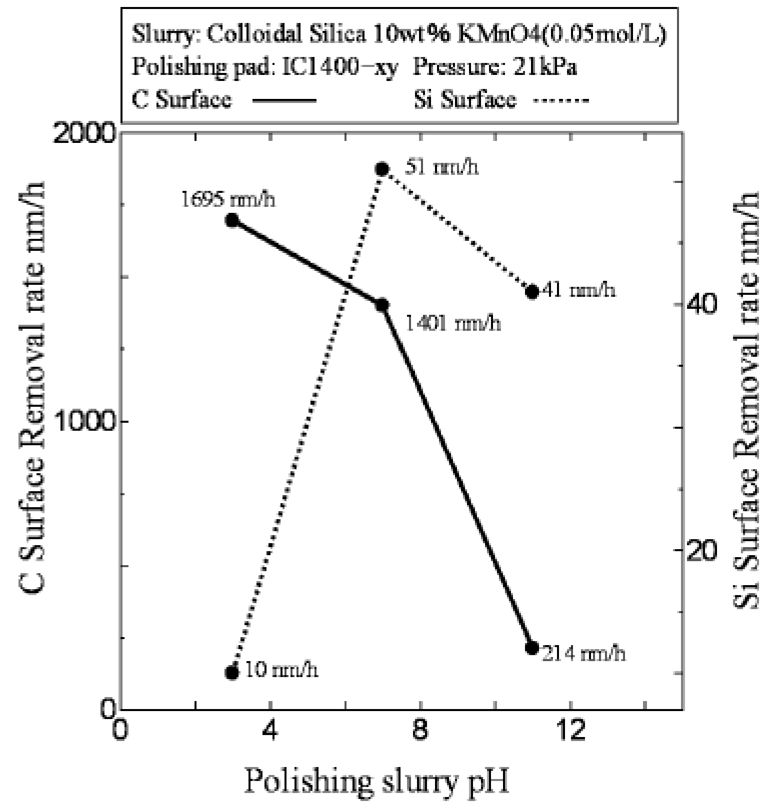

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