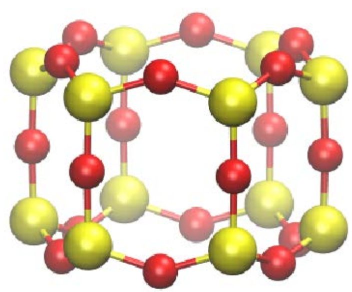
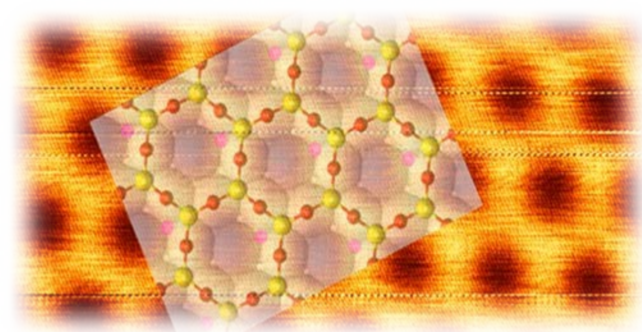
Ultra-thin two-dimensional crystalline nanoporous coatings
as cathode protection layers

J. ANIBAL BOSCOBOINIK Center for Functional Nanomaterials
JOHN SMEDLEY Instrumentation Division

Brookhaven National Laboratory





P3, 16th of November 2018

Center for Functional Nanomaterials
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The Model Zeolite
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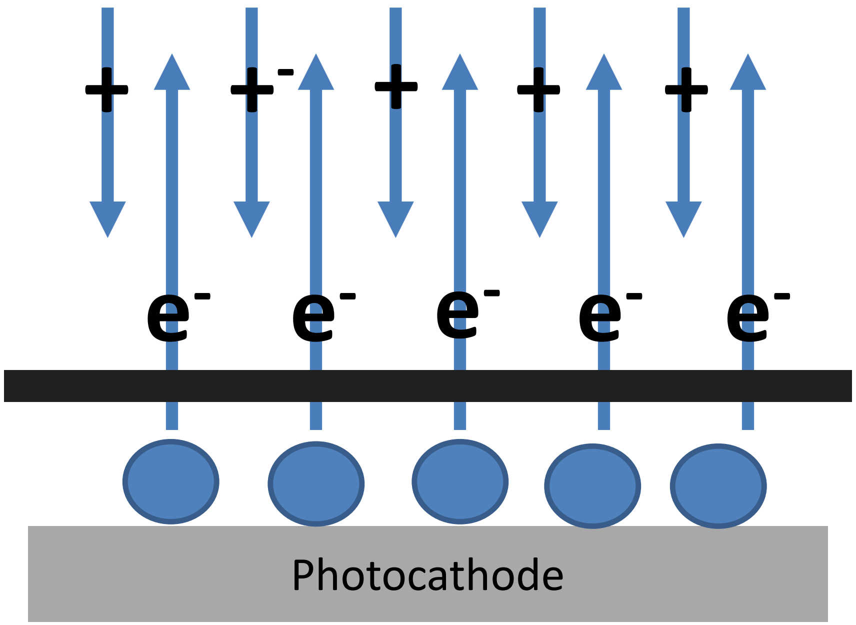
High Brightness Electron Sources

Factors affecting operational lifetime

– Ion bombardment of the cathode
– Chemical contamination
– Thermal decomposition



<u>2D-Material Requirements</u>

- Electron Transparent
- Thermally Stable

Wang, Yang, Moody, Batista, npj 2D Mater. Appl. 2, 17, **2018**

High Brightness Electron Sources

Factors affecting operational lifetime

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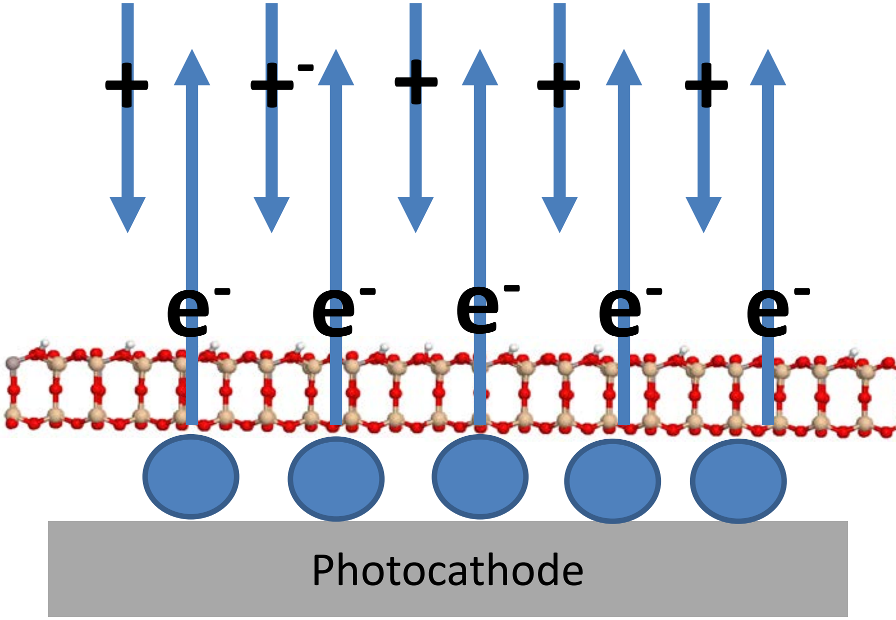
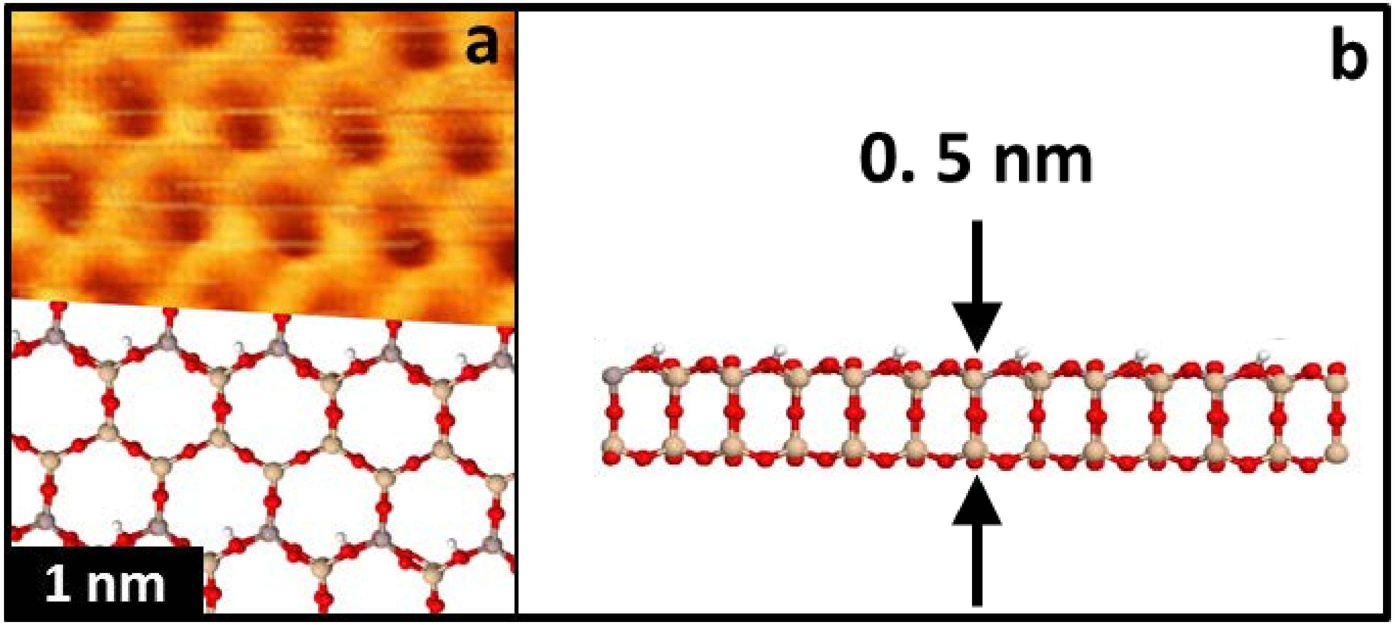


2D-Material Requirements

- Electron Transparent
- Thermally Stable

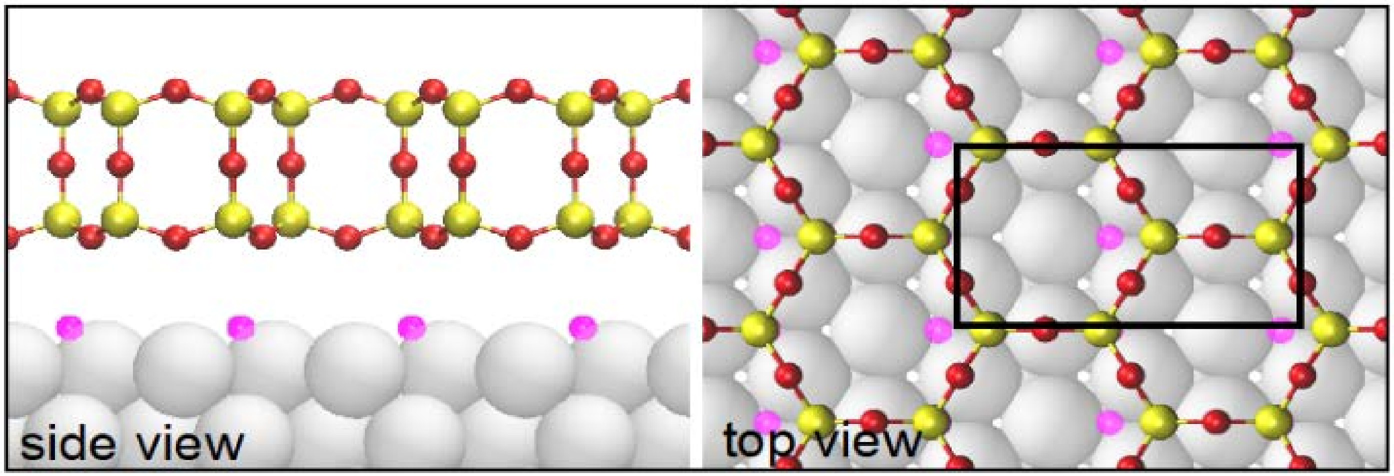
2D-Silicates and Aluminosilicates



Boscoboinik, Shaikhutdinov, Catal. Lett. **2014** DOI: 10.1007/s10562-014-1369-3

Composition

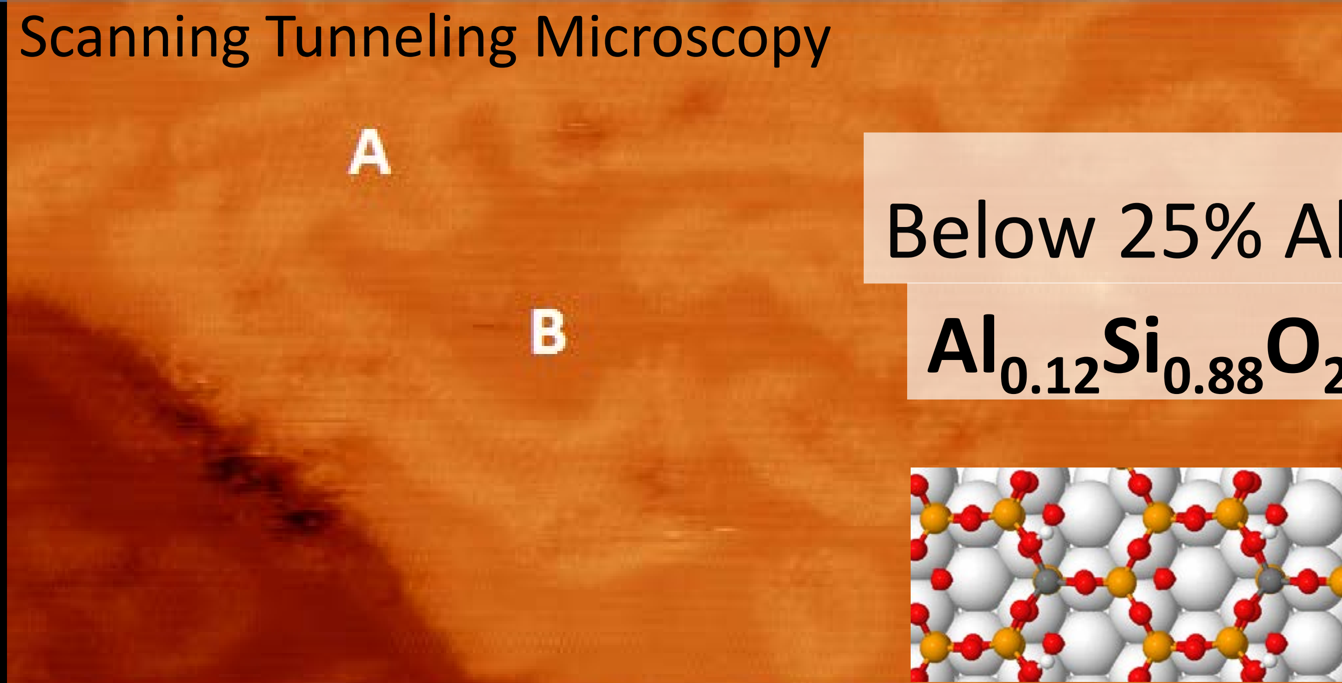
$Al_xSi_{1-x}O_2$ $(0 \leq x \leq 0.5)$

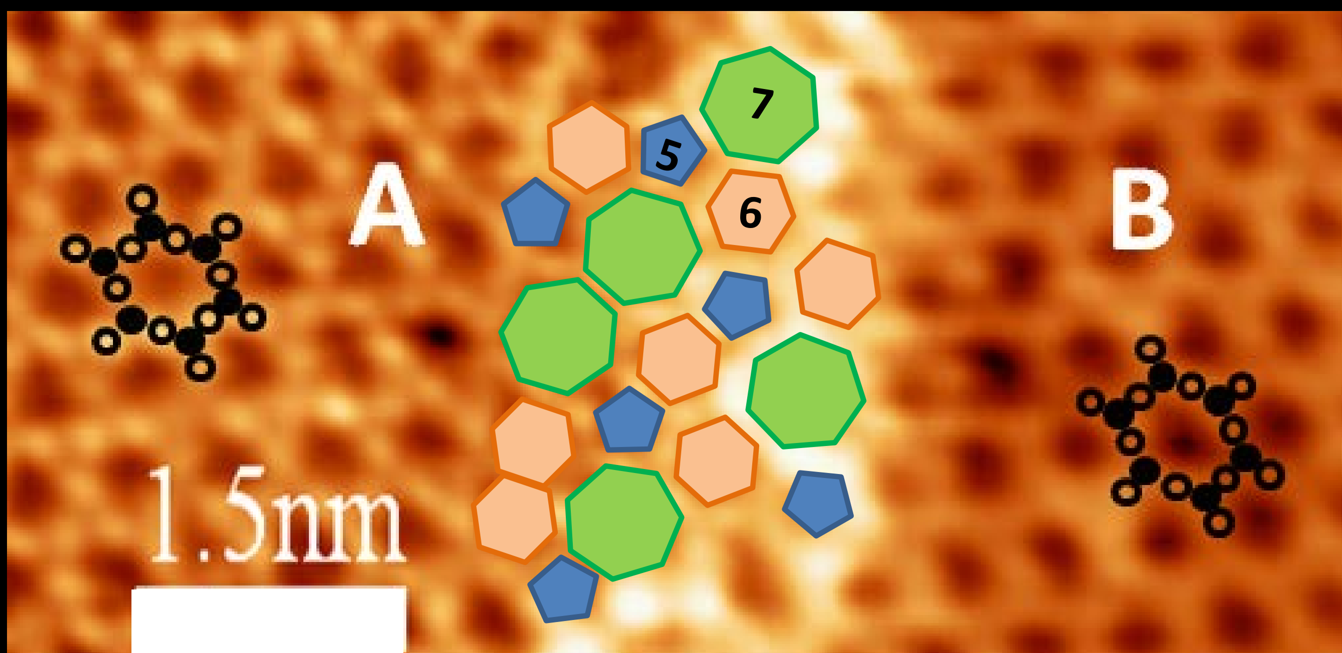


Ru(0001), Pt(111), Pd(100), Pd(111)

Supports

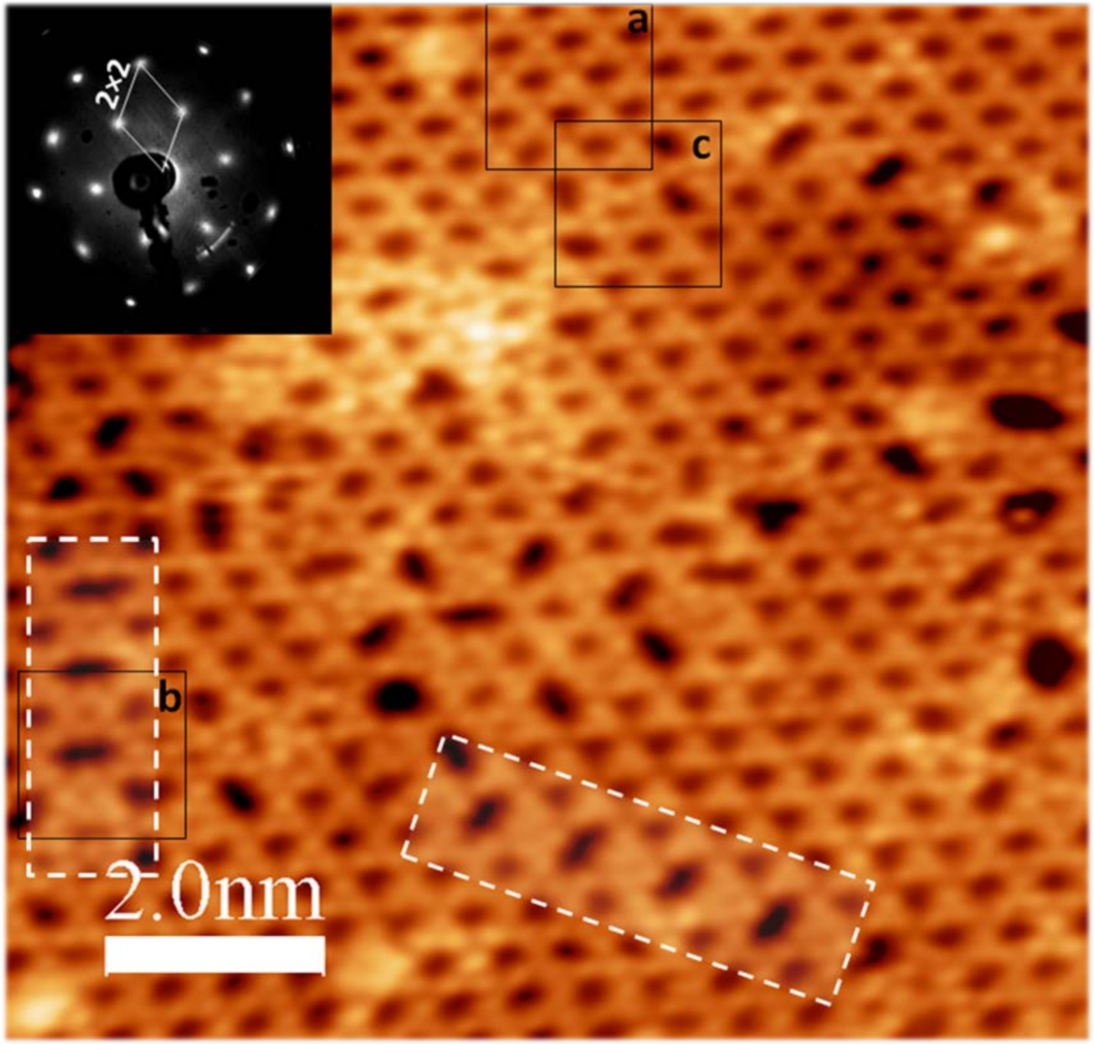
Scanning Tunneling Microscopy



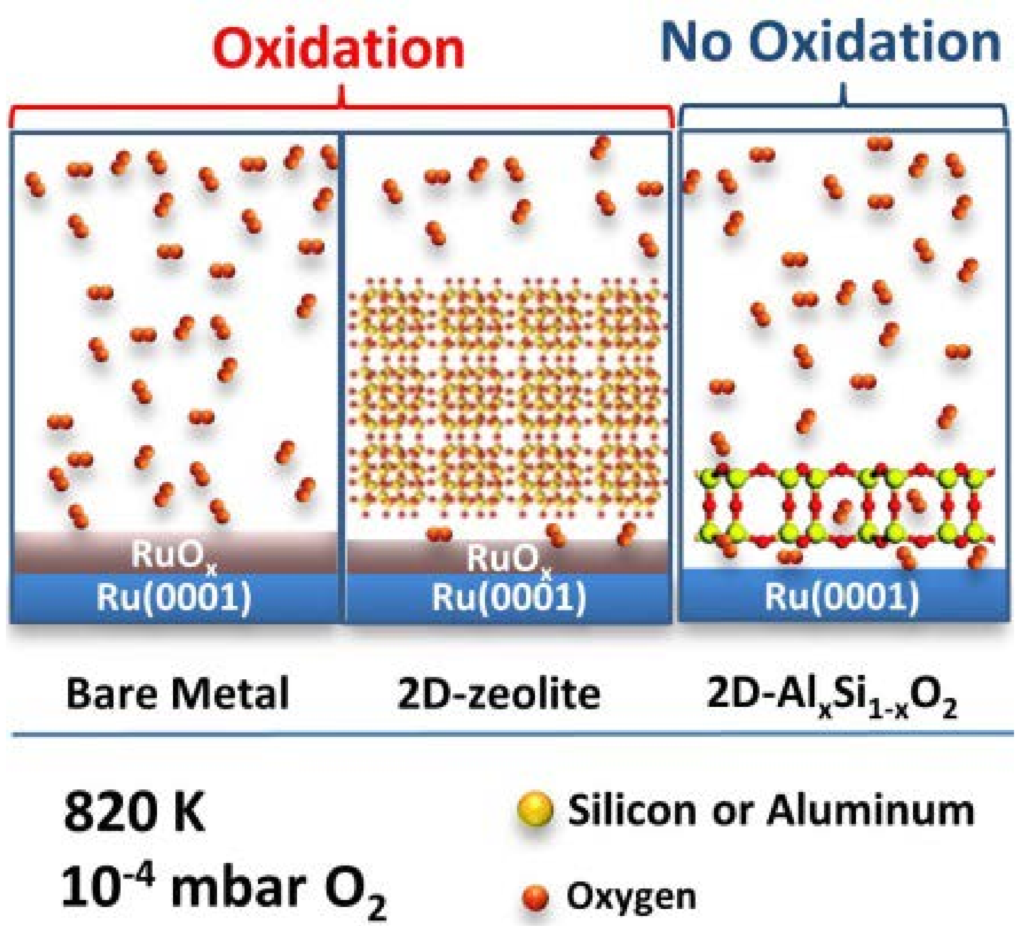


Boscoboinik et al. *Angew. Chem. Int. Ed.* 2012, 51, 6005.

$Al_xSi_{1-x}O_2$ (x > 0.25)

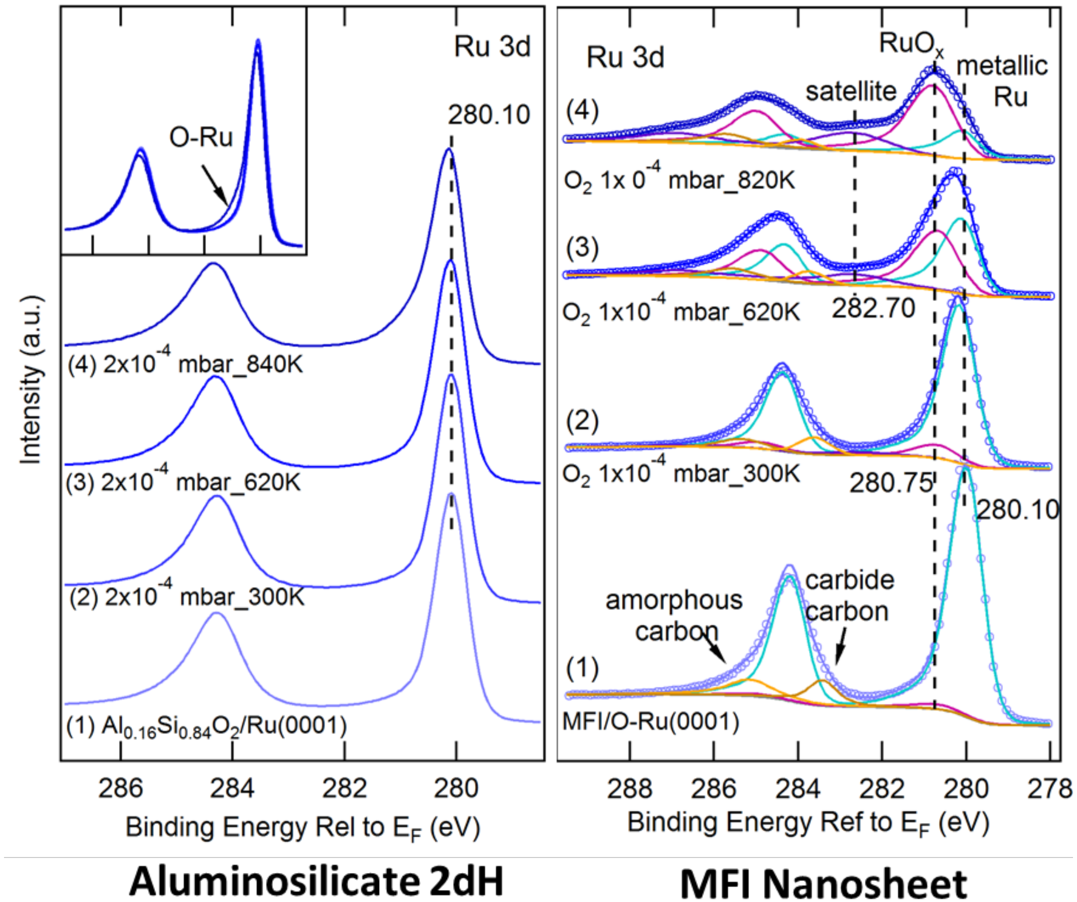


Corrosion Resistance



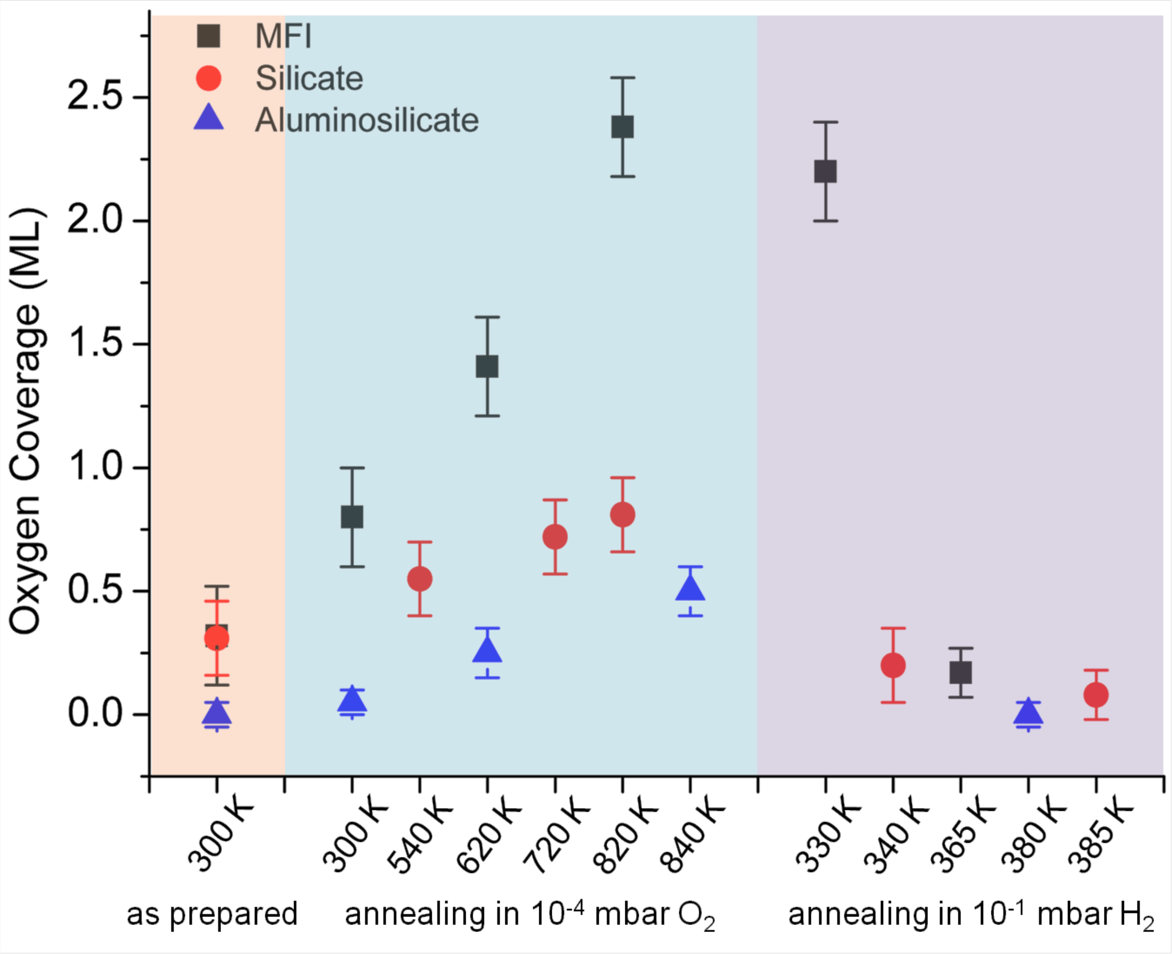
Zhong, Boscoboinik et al. *J. Phys. Chem. C*, **2016**, 120, 8240.

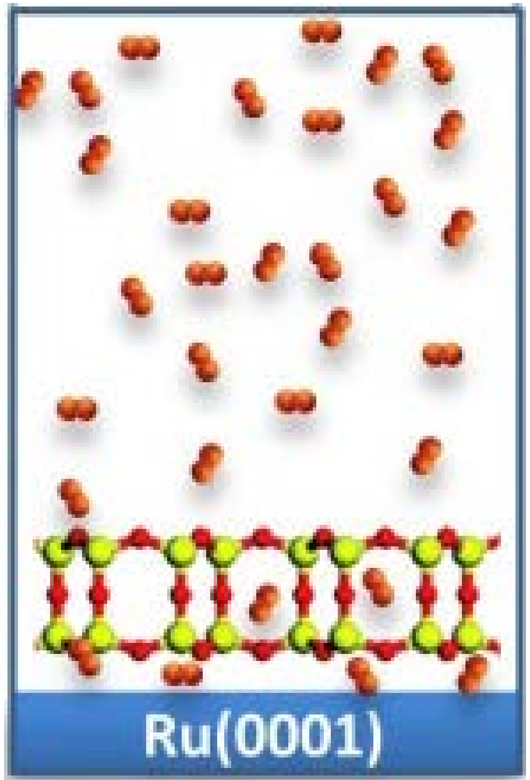
Corrosion Resistance



Zhong, Boscoboinik et al. *J. Phys. Chem. C*, **2016**, 120, 8240.

Corrosion Resistance



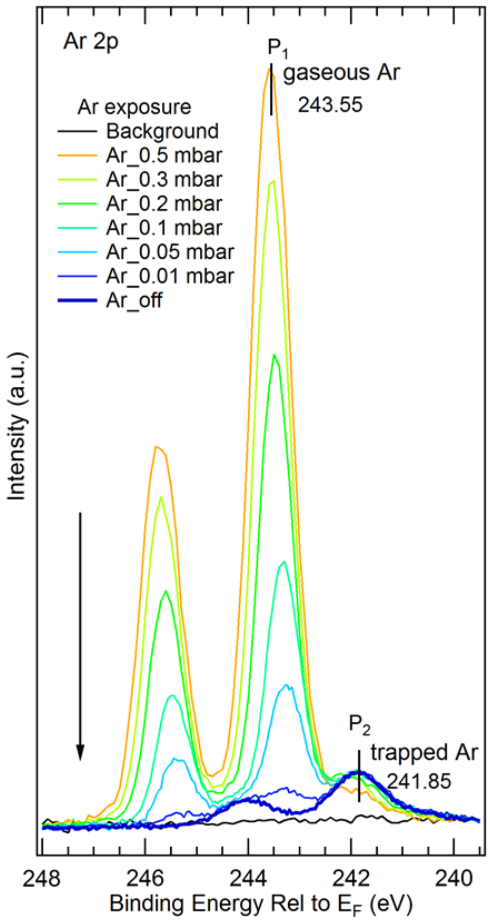


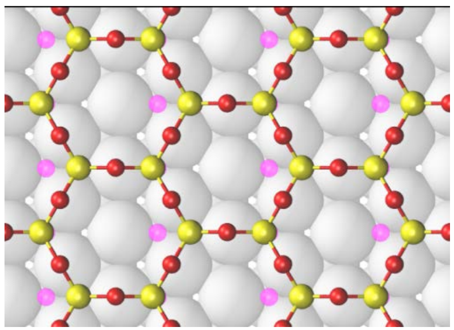
2D-$Al_xSi_{1-x}O_2$

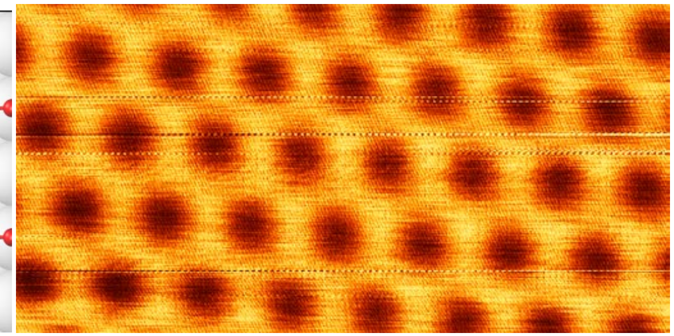
Zhong, Boscoboinik et al. *J. Phys. Chem. C*, **2016**, 120, 8240.

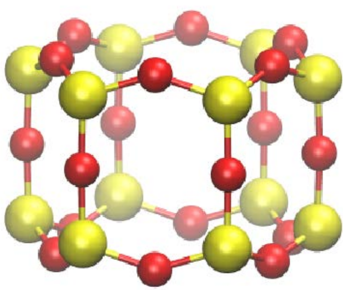
Gas trapping

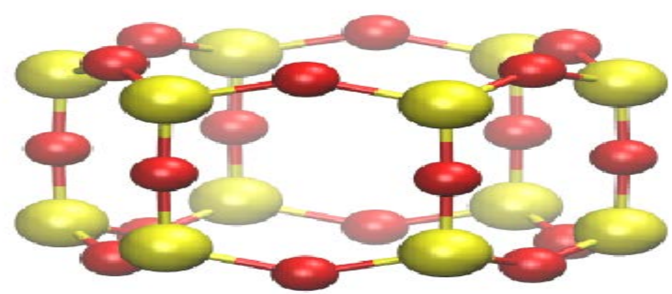
- **Exposure to Argon gas**







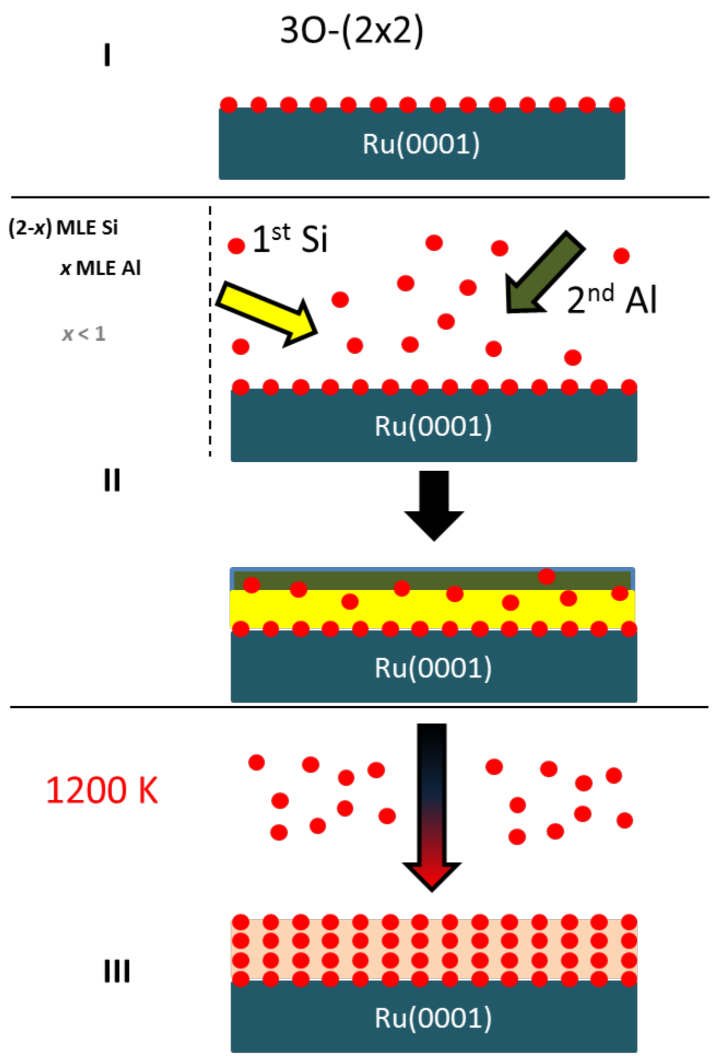




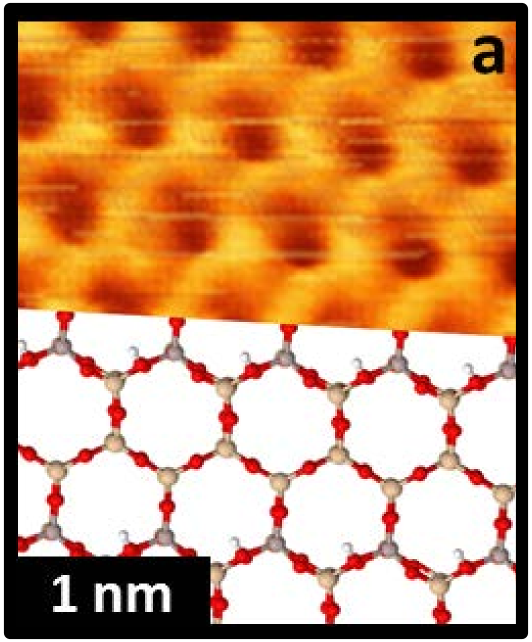
Zhong, Boscoboinik et al., *Nat. Commun.* 8, 16118 (**2017**)

Synthesis
and
Alternatives

Current Synthesis Method (UHV conditions)



Base pressure 10^{-9} mbar
E-beam evaporation



Resulting film stable in air

Alternative #1.1: Exfoliation

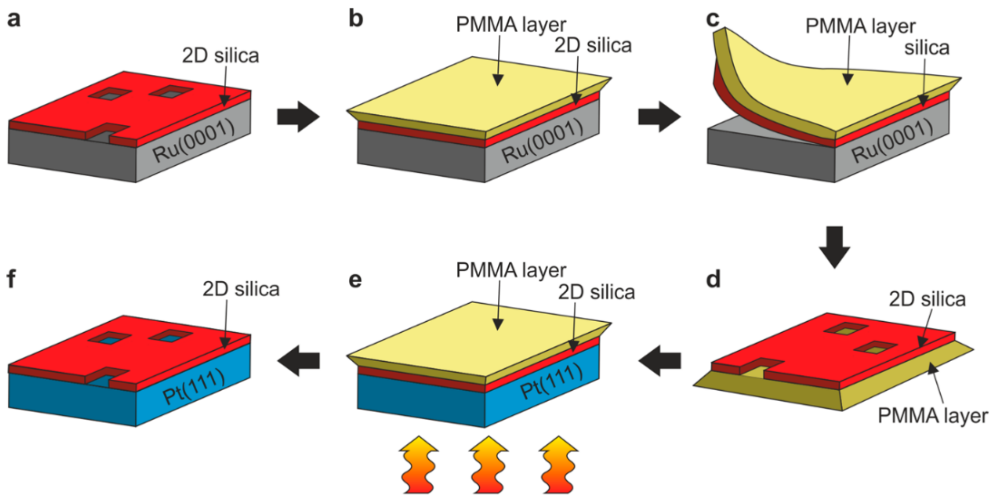
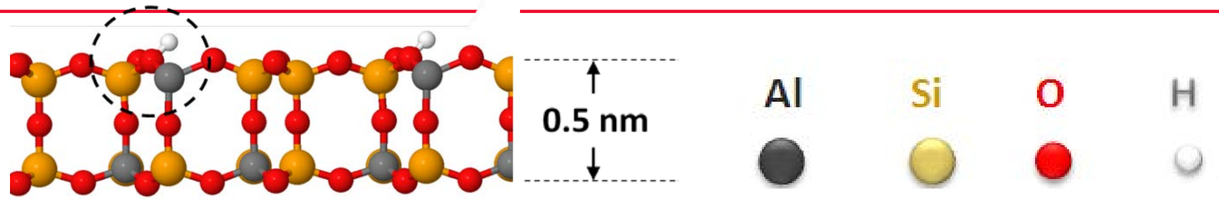


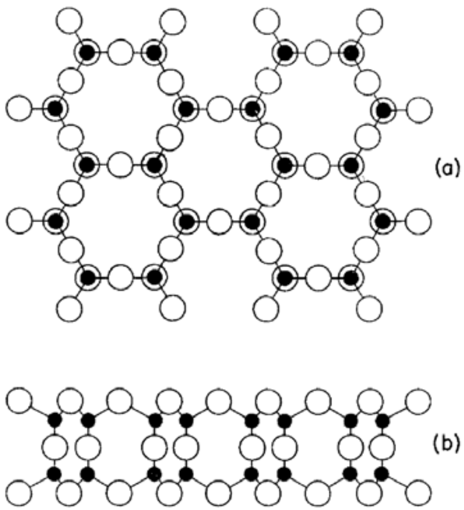
Figure 3. Schematic of the transfer procedure. (a) Silica bilayer on ruthenium substrate. (b) Spin coating of system with PMMA layer. (c) Mechanical exfoliation of PMMA; silica adheres to PMMA layer. (d) Silica supported on PMMA layer. (e) Placing the PMMA-supported silica layer on clean Pt(111) substrate, subsequent heat treatment. (f) After PMMA removal, silica is supported on Pt(111) substrate.

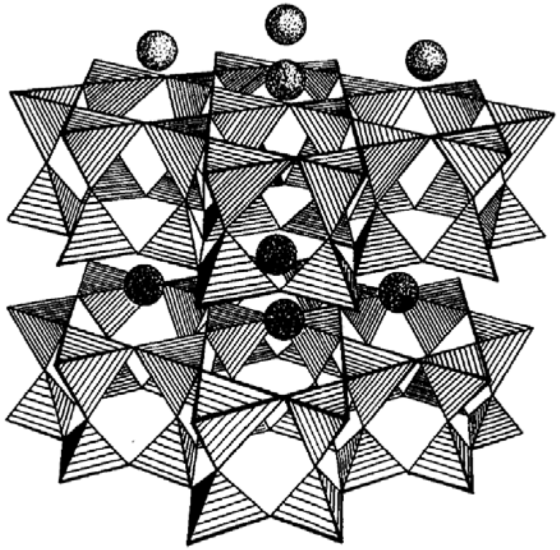
https://pubs.acs.org/doi/pdf/10.1021/acsnano.6b03929

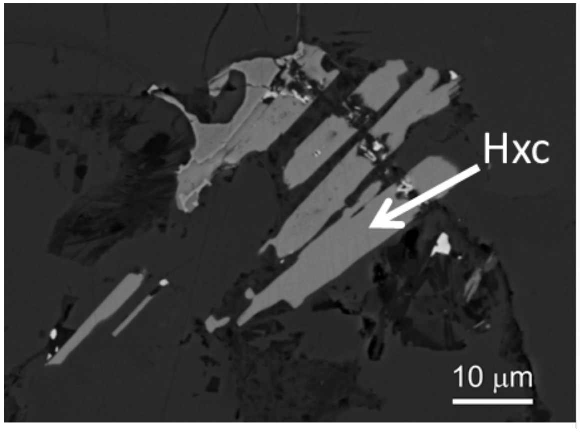
Alternative #2: Exfoliation



Hexacelsian (a multilayered version)



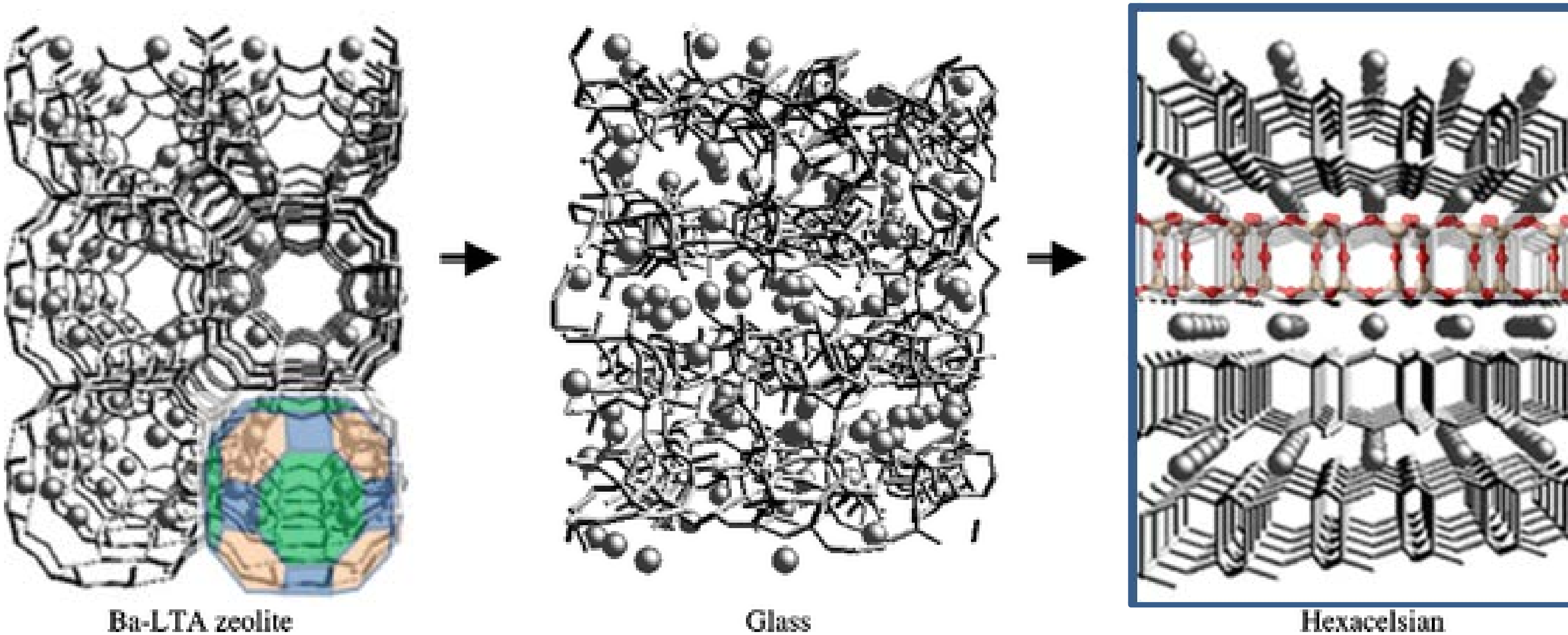




Irina Galuskina

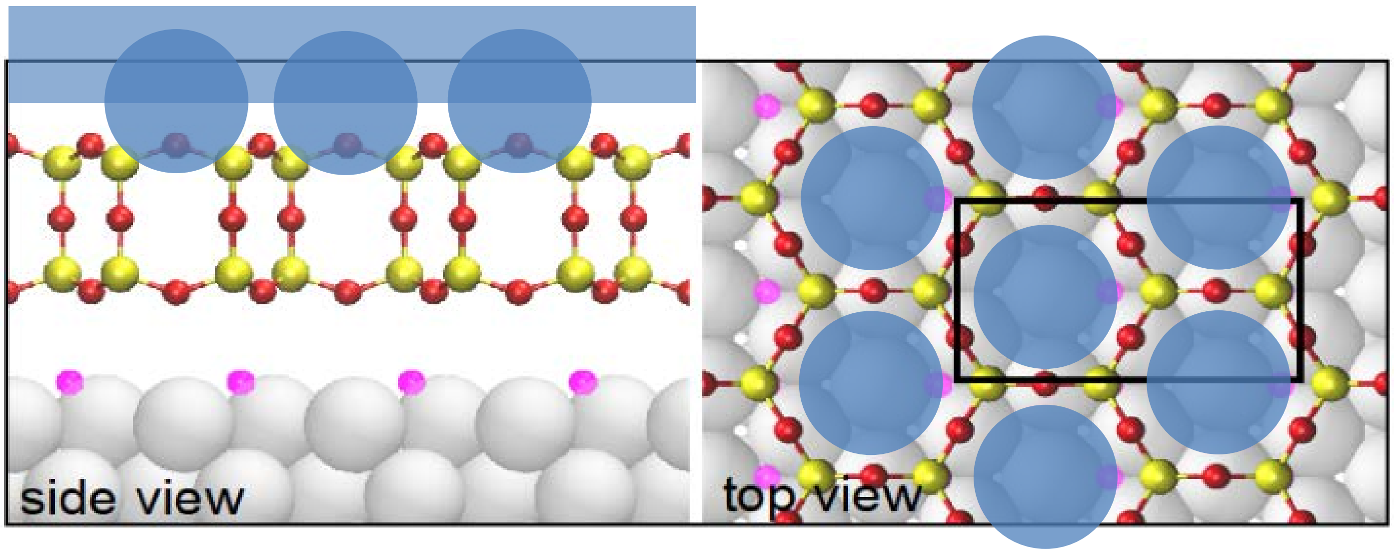
B. Yoshiki, K. Matsumoto
J. Am. Ceram. Soc., 34 (1951), pp. 283–286

Can be synthesized from Zeolite A!

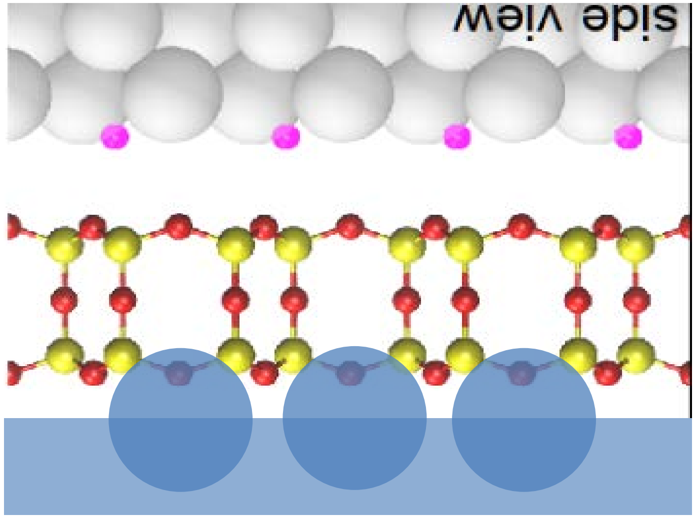


Djordjevic et al. *Phys. Chem. Chem. Phys.*, 2001, **3**, 1560-1565

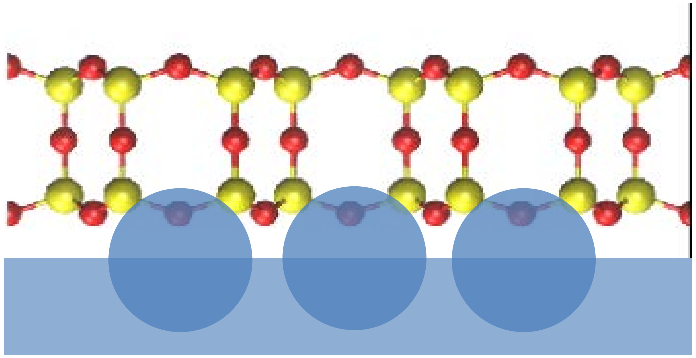
Alternative #1.2: Grow cathode on silicate



Alternative #1.2: Grow cathode on silicate



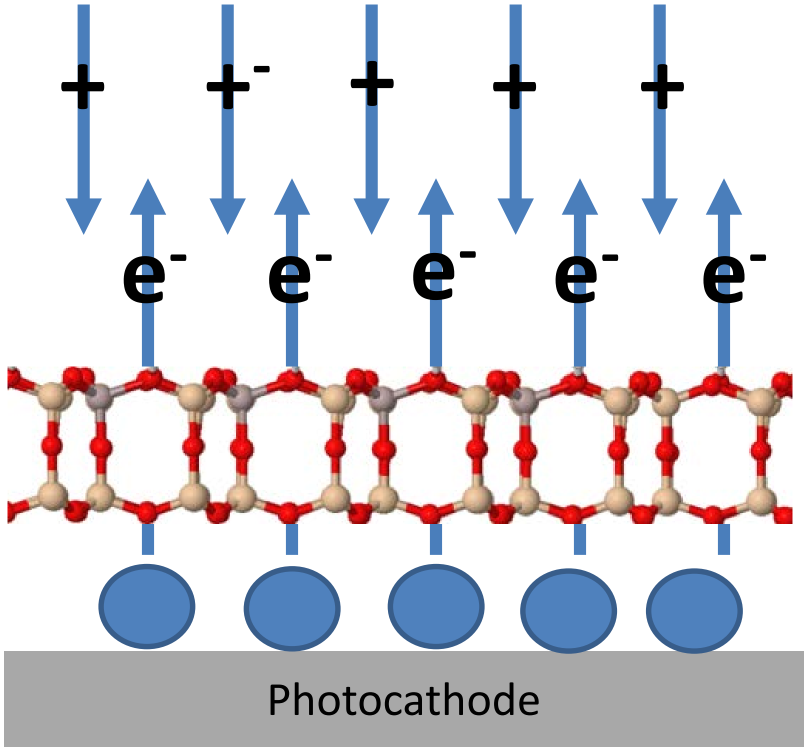
Alternative #1.2: Grow cathode on silicate



Summary

- Stable ultra-thin silicates
- Potentially reducing:
  - Ion bombardment of the cathode
  - Chemical contamination
  - Thermal decomposition
- Directional electron emission
- Tunability of work function

- **Challenging preparation or deposition on photocathodes – alternatives are being explored**



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Center for Functional Nanomaterials at Brookhaven National Laboratory

A DOE Office of Science User Facility for Nanoscience Research

About the CFN:

A national user facility

A portfolio of world-class instruments and expertise under one roof

All facilities and staff expertise available to Users ***for free***

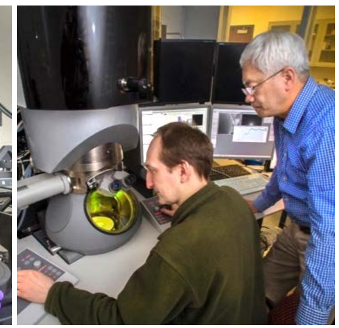
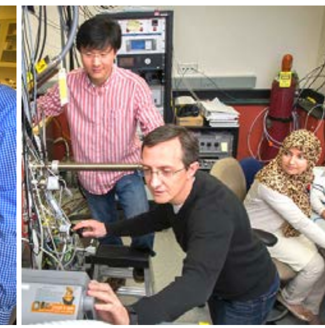
Proprietary rate available

Strategic Themes:

Self-Assembled Nanomaterials by Design

Nano-Architectures for Energy Solutions

Nanomaterials in Operando Conditions

Facilities for creating, characterizing, and understanding nanomaterials:

- Materials Synthesis
- Nanofabrication
- Proximal Probes
- Electron Microscopy
- Advanced Optical Spectroscopy and Microscopy
- Advanced X-ray and UV Probes
- Theory and Computation

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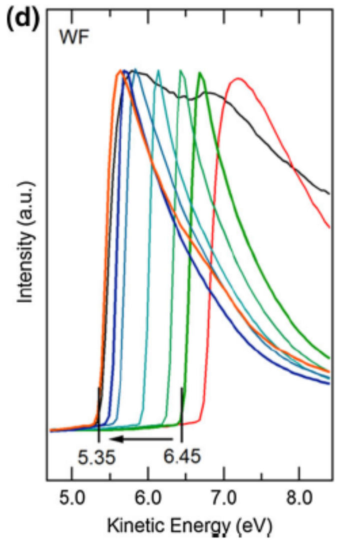
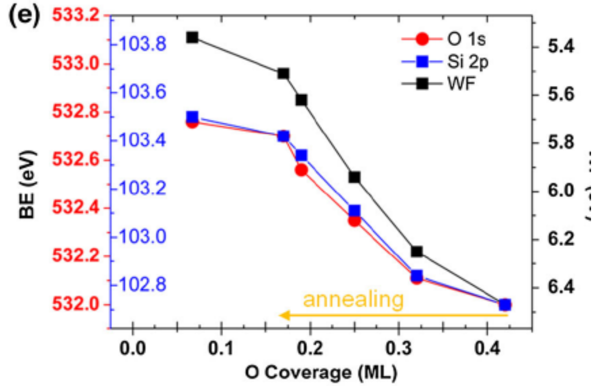
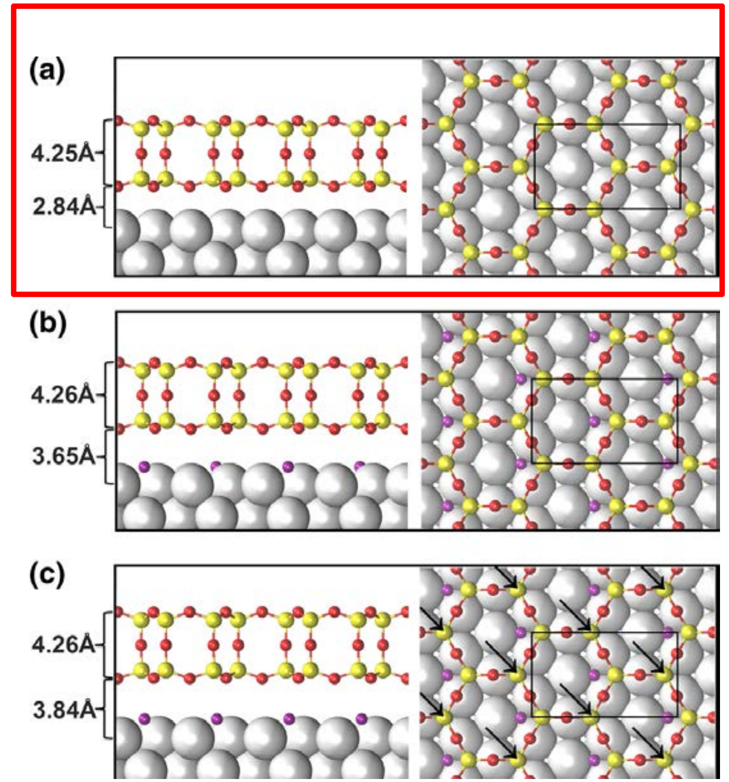
Booth 616

Thank you

2D-silica on Ru(0001)







	Ru(0001)	$(SiO_2)_8$/0O/Ru(0001)		$(SiO_2)_8$/2O/Ru(0001)		$(SiO_2)_8$/4O/Ru(0001)	
	Ru	Ru	Ru/(SiO_2)	Ru/O	Ru/O/(SiO_2)	Ru/O	Ru/O/(SiO_2)
p	0.02	0.02	0.38	−0.03	0.03	−0.18	−0.18
Φ	5.12† (5.37)	5.12	3.88	5.32	5.16	5.89	5.93

The number in parenthesis is the experimental value

† The work function of the clean Ru(0001) with top two layers allowed to relax. Φ = 5.03 eV was reported by Kim et al. [42]

Wang, Boscoboinik et al. Top. Catal., **2017**, DOI: 10.1007/s11244-016-0704-x

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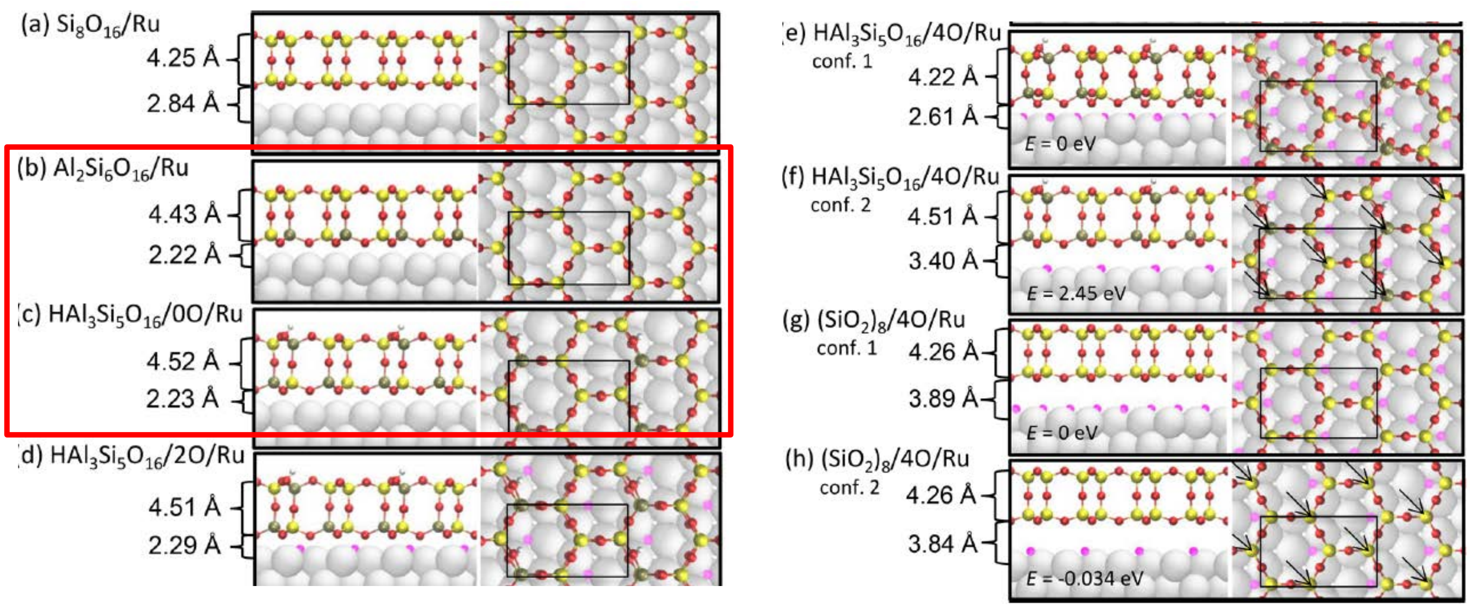
2D-aluminosilicate on Ru(0001)

Table 1. Dipole Moment (p in eÅ) and the Work Function (Φ in eV) of nO/Ru(0001), (H)$Al_xSi_{8-x}O_{16}$ (bilayer) and (H)$Al_xSi_{8-x}O_{16}$/nO/Ru(0001) (total) for n = 0, 2, and 4

	dipole moment (p in eÅ)				work function (Φ in eV)		
	nO/Ru	bilayer	interface	total	nO/Ru	bilayer	total
$Al_2Si_6O_{16}$/Ru(0001)	0.02	0.21	−0.28	−0.05	5.15	8.10	5.50
$HAl_3Si_5O_{16}$/Ru(0001)	0.03	0.42	−0.25	0.20	5.15	7.39	4.61
$HAl_3Si_5O_{16}$/2O/Ru(0001)	0.01	0.41	−0.40	0.02	5.24	7.42	5.24
$HAl_3Si_5O_{16}$/4O/Ru(0001)	−0.10	0.46	−0.74	−0.38	5.66	7.11	6.69



Wang, Boscoboinik et al. J. Phys. Chem. C 2018, DOI: 10.1021/acs.jpcc.8b05853

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Permeability of single atoms (or ions)