Georgia Tech School of Civil and Environmental Engineering
College of Engineering

Can we increase concrete durability with nanoparticles?

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Special Thanks to Dr. Yuanzhi Tang

National Nanotechnology Coordinated Infrastructure
SENIC Southeastern Nanotechnology Infrastructure Corridor
Georgia Tech Institute for Electronics and Nanotechnology
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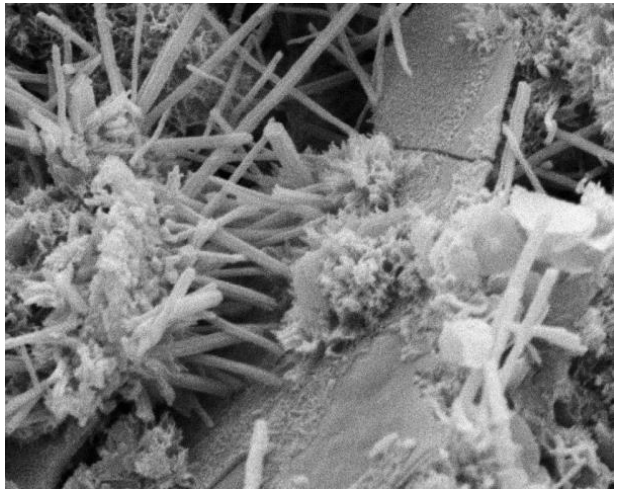
Concrete is incredibly complex

- Pre-hydration it has at least 5 components
- Post hydration, has at least 5 new components



http://www.cementlab.com/cement-art.htm

Before Hydration	
Compound	% by weight
$Ca_3Al_2O_6$	10
$Ca_4Al_2Fe_2O_{10}$	8
Ca_2SiO_5	20
Ca_3SiO_4	55
Na_2O	Up to 2
K_2O	
$CaSO_4.2H_2O$	5

http://www.engr.psu.edu/ce/courses/ce584/concrete/library/construction/curing/Composition%20of%20cement.htm

Corrosion is a major source of durability loss in concrete

https://theconstructor.org/concrete/durability-of-reinforced-concrete-to-environment/8894/

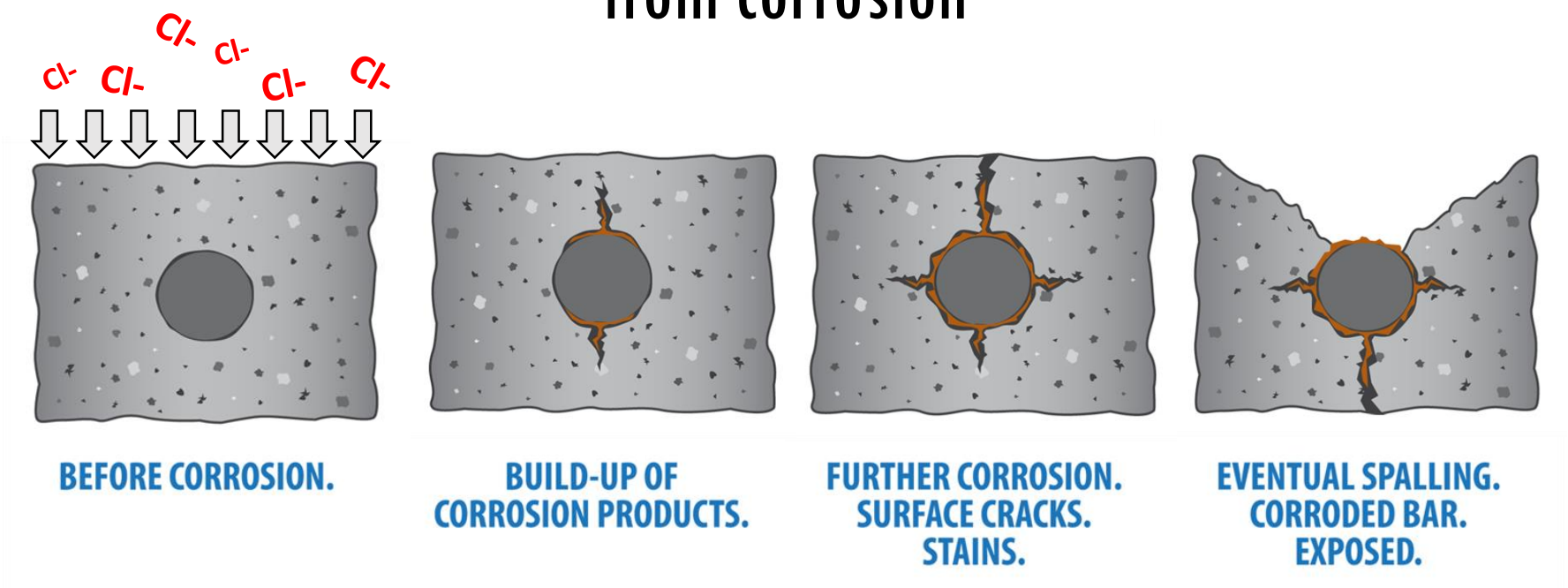
Image from Dr David Scott

But it's more costly than just loss of durability

- ~5% of an industrialized nation's income is spent on it
- In the U.S., 3.2% of the GDP
- Average bridge in the U.S. is 43 years old
- 9.1% of U.S. bridges structurally deficient

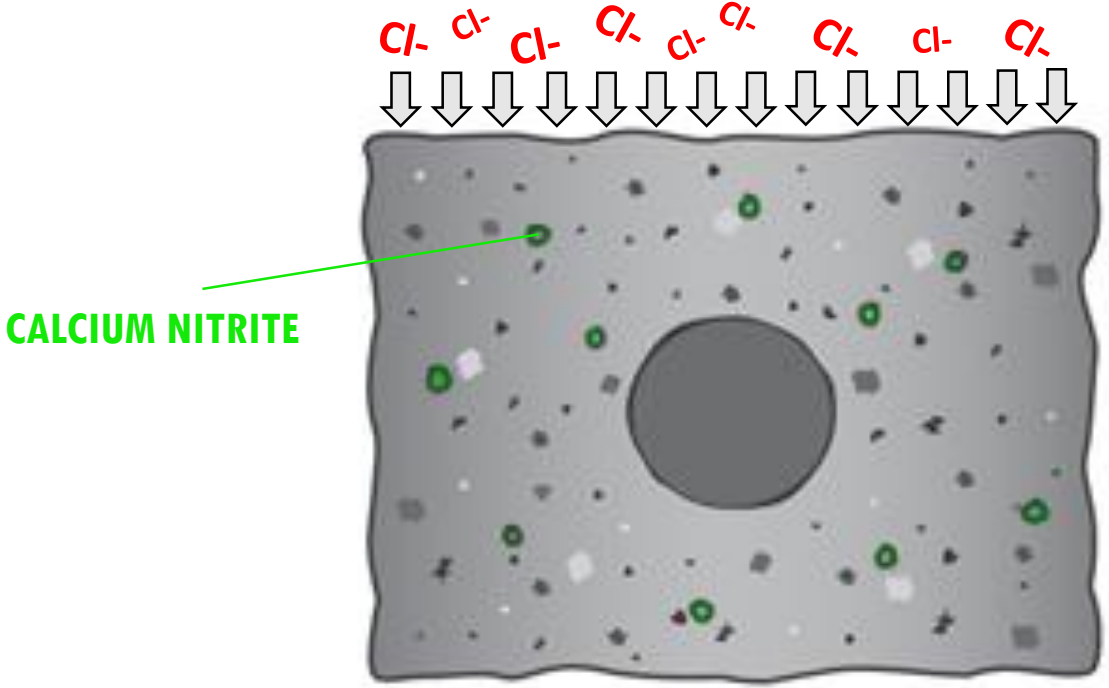
Image from Dr. David Scott

Chloride ions destroy the passive layer that protects concrete from corrosion



https://theconstructor.org/concrete/corrosion-steel-reinforcement-concrete/6179/

Previous solutions have involved calcium nitrite or nitrate



CALCIUM NITRATE BECOMES CALCIUM CHLORIDE AND NITRITE

$$Fe^{2+} + 2\,OH^- + 2NO_2^- \longrightarrow Fe_2O_3 + 2NO + H_2O$$

HELPS REGENERATE PASSIVE LAYER

Why can't we use what we already have: NO_x

http://www.icopal-noxite.co.uk/nox-problem/nox-pollution.aspx

NO_x is one the components needed to create smog

http://www.huffingtonpost.com/2013/12/09/china-smog-benefits-advantages-state-media_n_4413043.html

- NO_x
- VOCs
- UV light

Our plan: use TiO_2's photocatalytic properties in cement to bring in NO_x from the air

http://www.european-coatings.com/Homepage-news/Permanent-changes-to-titanium-dioxide-industry

Sample Preparation

First, cement plates had to be crushed

- Plates are 5% TiO_2 by mass
- Final particle size was between 0.6 and 1 mm

The crushed particles were then exposed to NO gas and UV light

Samples were exposed to the UV light for 5 hours

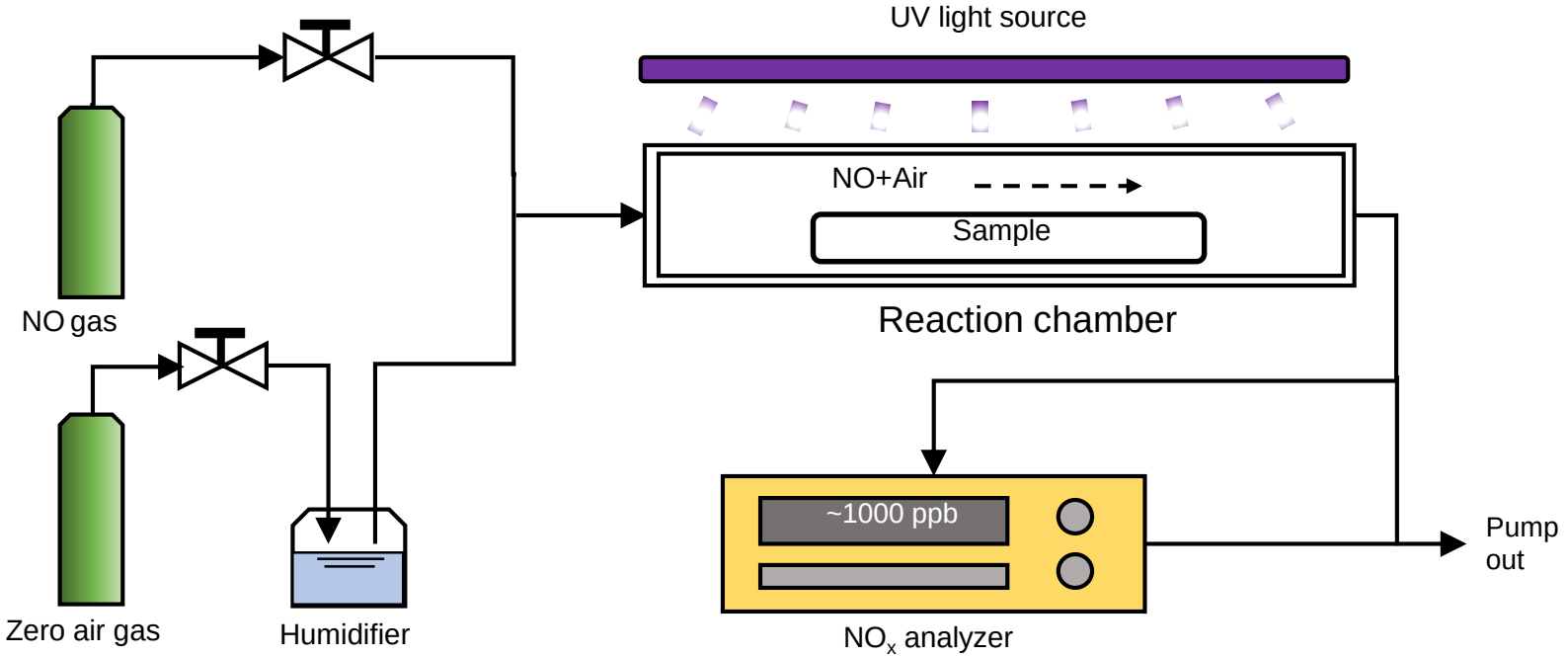
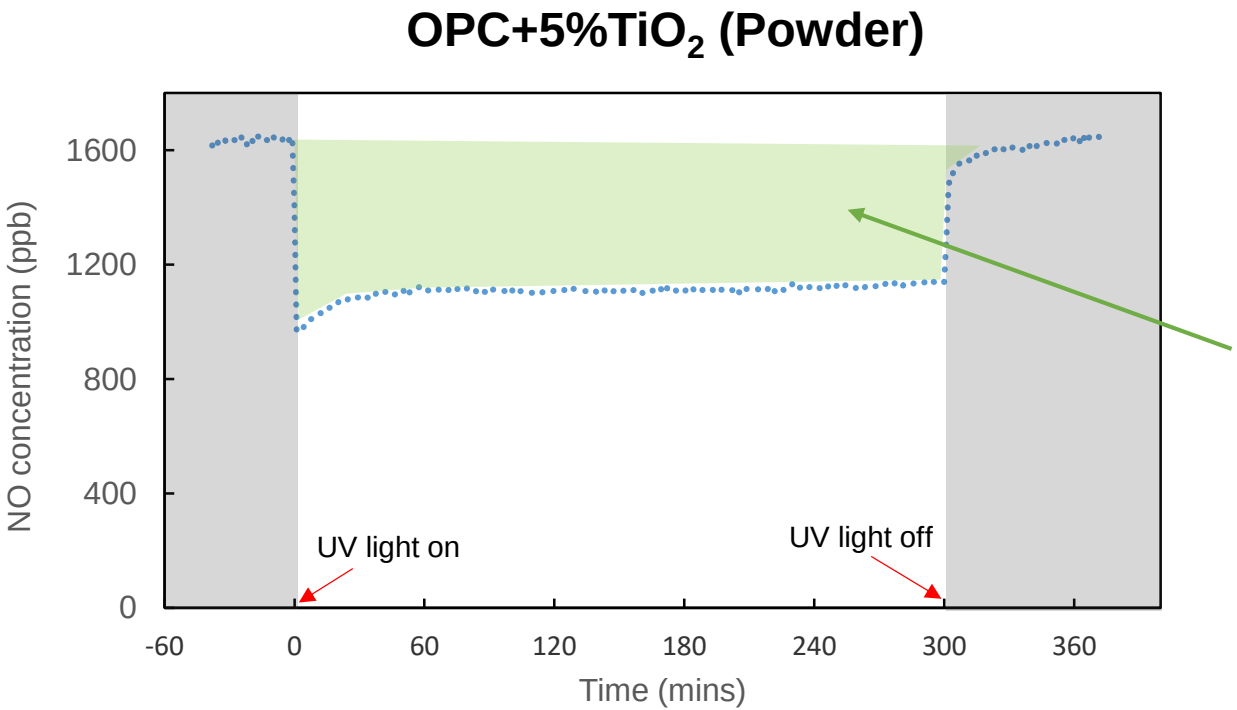


Image by Bill Jin

We can estimate NO_x taken in by the concrete



0.29mg NO_2^- or 0.39mg NO_3^-

Testing

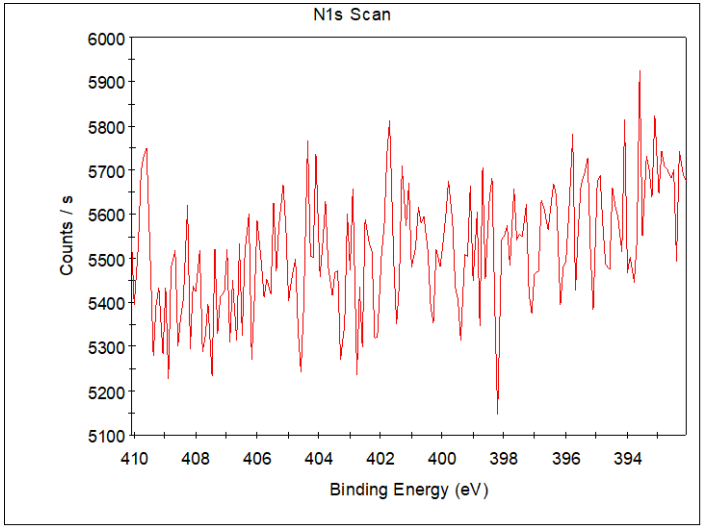
X-Ray Diffraction (XRD) works best for crystalline samples

- Could not detect nitrogen species

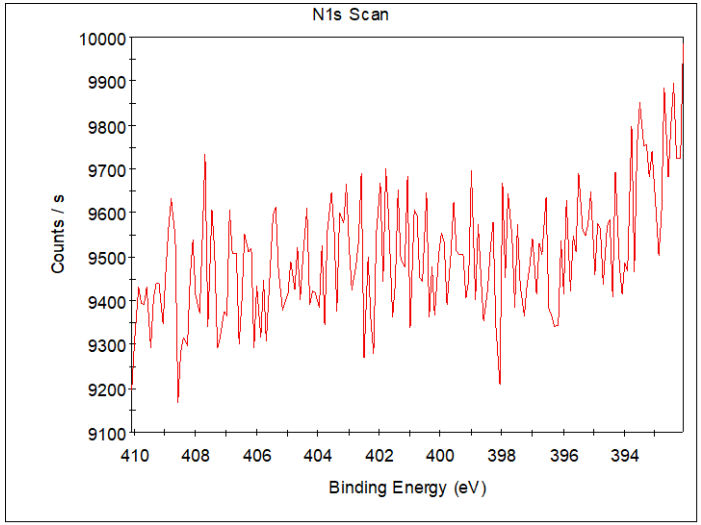
http://mcf.gatech.edu/capabilities/x-ray-diffraction/

Nitrogen was not detectable through x-ray photoelectron spectroscopy (XPS), either

Before UV

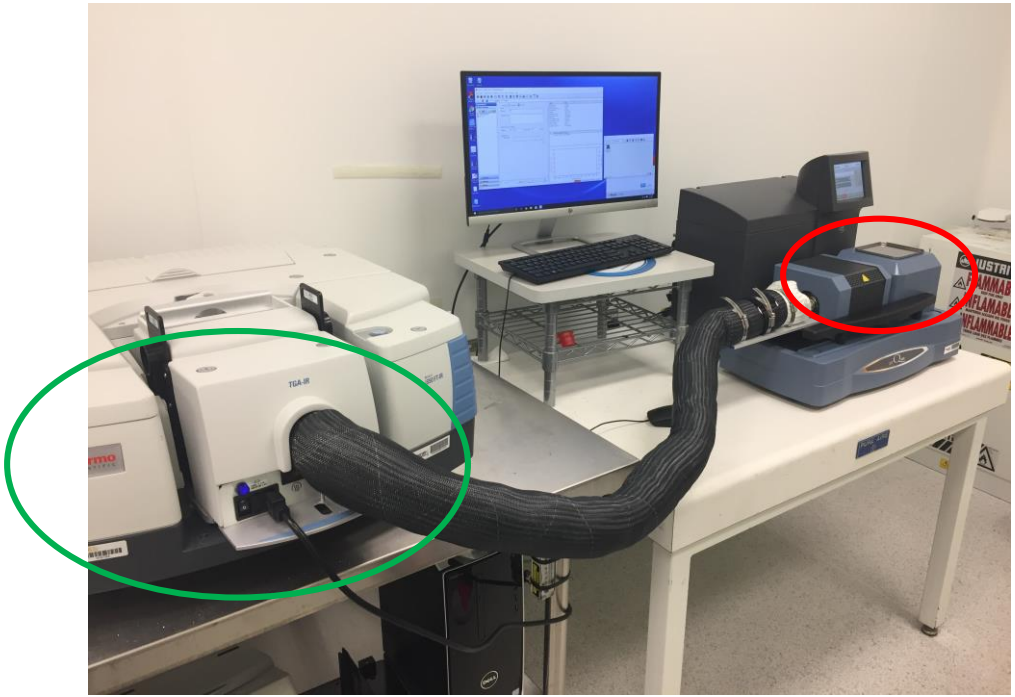


After UV



We used TGA/FT-IR to look at gas release under decomposition

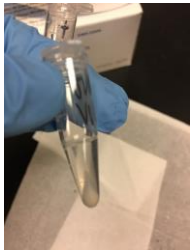
FTIR: to detect released gas

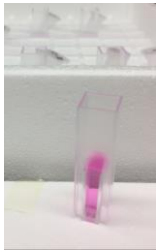


TGA: to heat the sample

- There was no detectable nitrogen gas or any sort of nitrogen compound

We used UV-Vis and wet chemical extraction to look at nitrite concentration

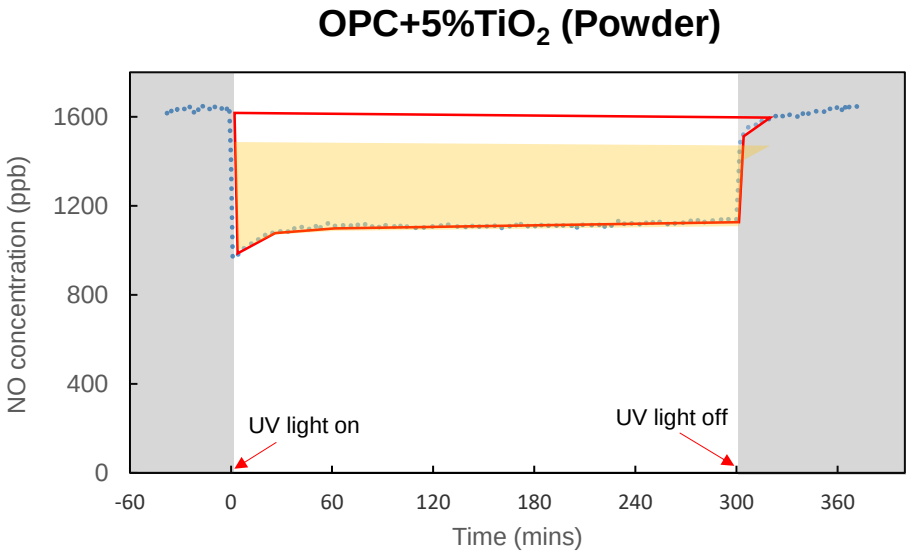




- Compared to calculated mass

Images by Bill Jin

Good news: found nitrites



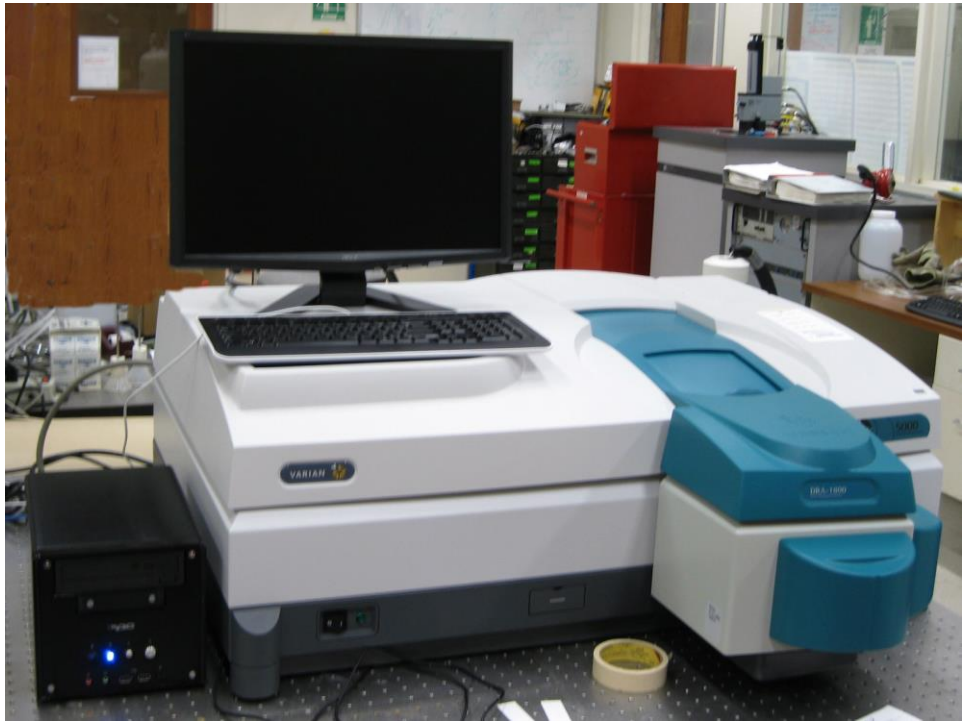
Bad news: corresponded to at most 70% of NO_x

Where does the nitrogen go?

http://knowyourmeme.com/photos/1231999-stock-photography

We looked at nitrate mixed with HCl with UV-Vis

- Before: we'd tried to just use a color reagent and could not find nitrate
- Now: we found some

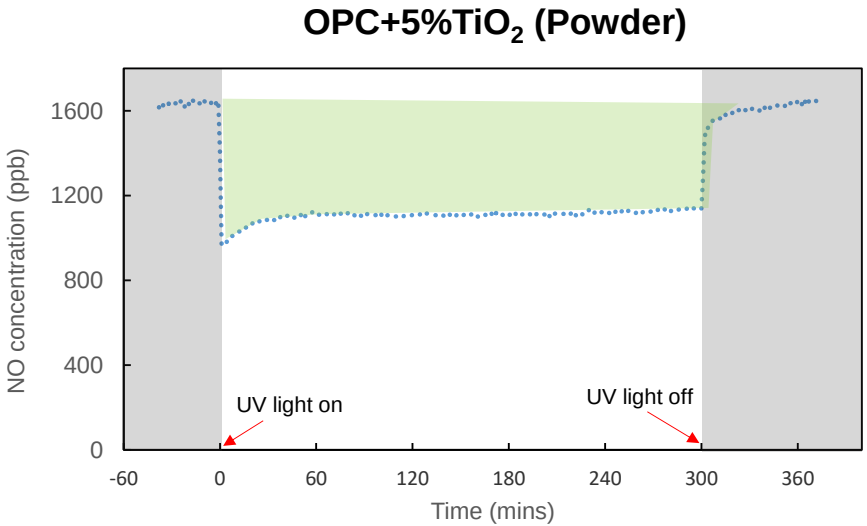


http://mmrc.caltech.edu/Cary%20UV-Vis%20Int.Sphere/Cary%20UV-vis.html

. . . We found too much nitrate

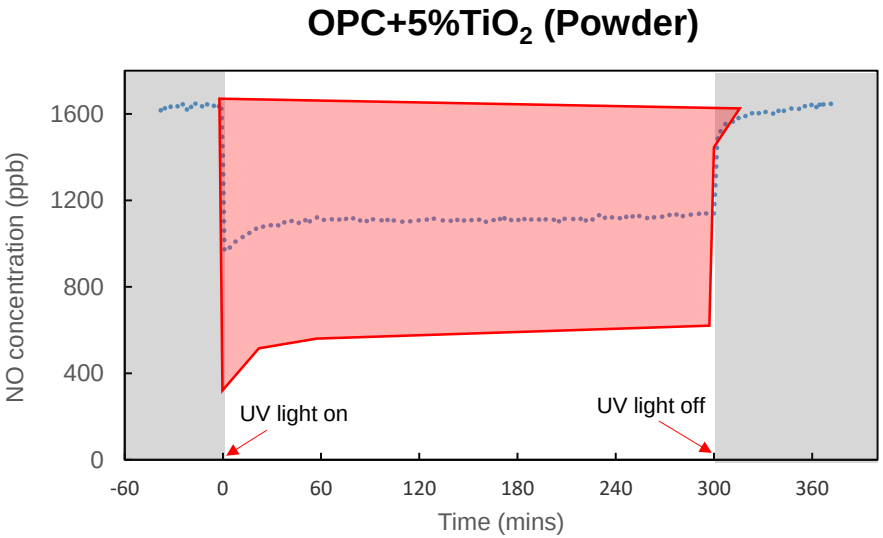
Known: 70% NO_2^-

Assume: 30% NO_3^-



Known: 70% NO_2^-

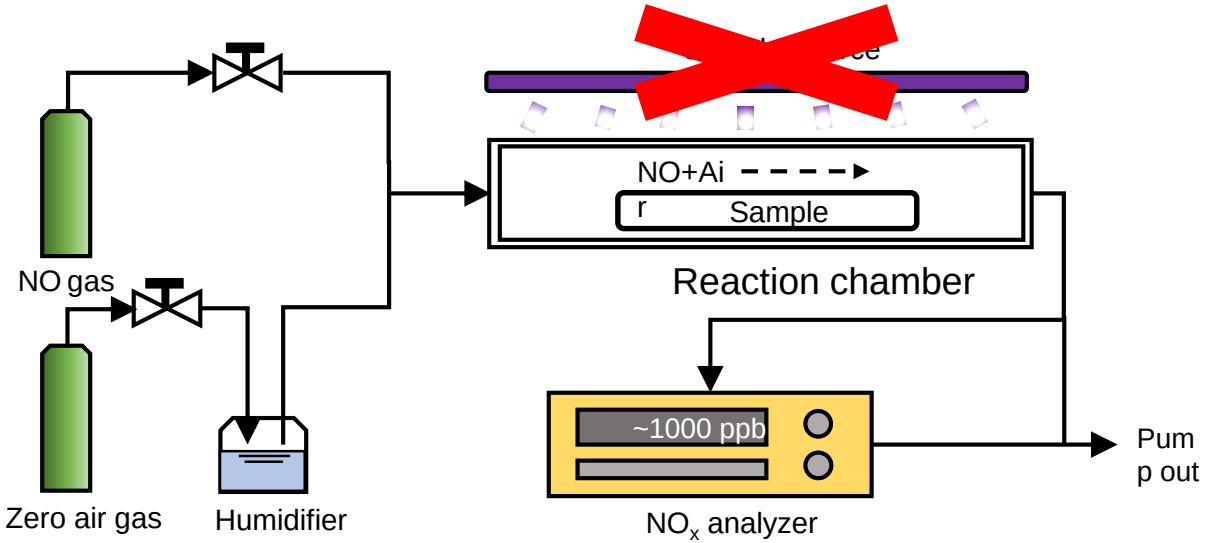
Known: 200% NO_3^-



Where did the nitrogen come from?

Theory: NO_x is being taken in even when not exposed to UV

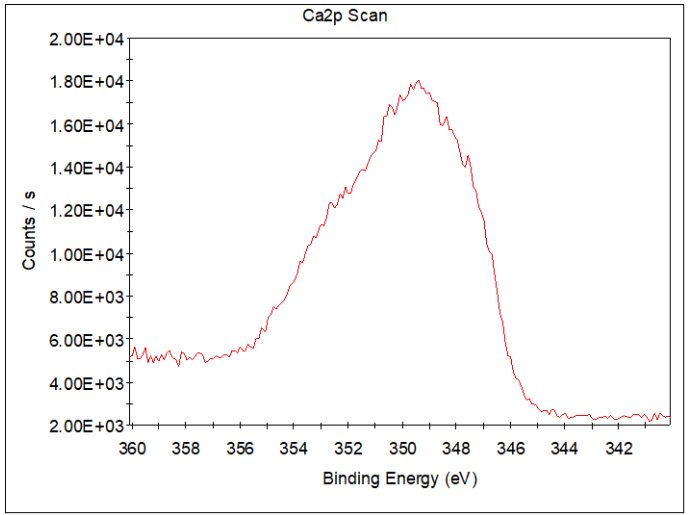
Now we decide to add a different exposure: NO gas only



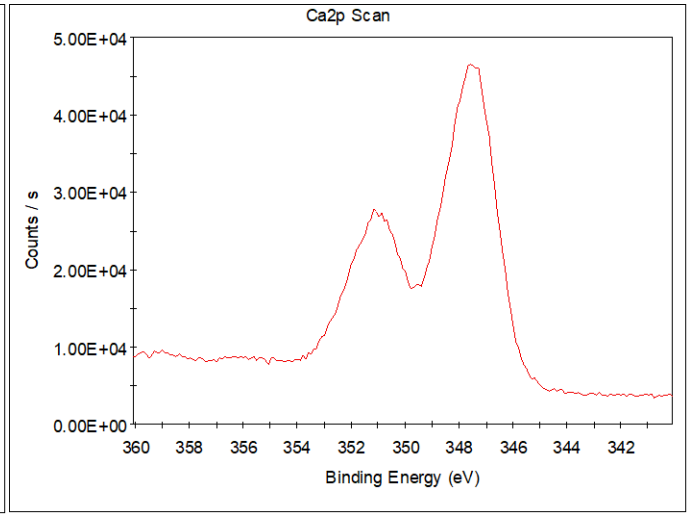
- Found both nitrites and nitrates

The non-NO_x information may lead us in a new direction

Before UV



After UV



- XPS shows a marked difference in calcium
- That along with XRD indicates calcium hdroxide

In Summary…

- Nitrites and nitrates were present in the exposed cement
- NOx abatement also occurs without UV light
- The nitrogen is either amorphous, or does not significantly shift the crystalline structure
- Calcium hydroxide might be the significant phase in the reaction

More tests are needed in the future

- More NO_x only runs
- Pure phase runs
- Corrosion tests

Right Image by Dr. David Scott

Special thanks to…

- Bill Jin
- Dr. Kimberly Kurtis
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- The Kurtis Lab

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References

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Any Questions?