SAND2014-18025PE

2014 UNM Research Experience for Teachers Program

Synthesis of Cobalt and Iron Oxide Nanoparticles & What's in our water and where did it come from?

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Supporting Program

Energizing Engineering Education (E3): An RET site at the University of New Mexico investigating energy research and engineering practice, The University of New Mexico, School of Engineering & College of Education.

Acknowledgements

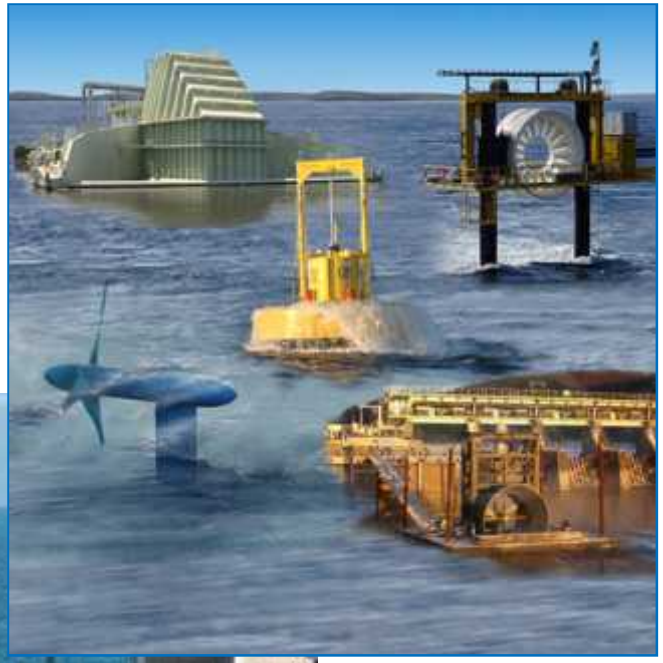
I'd like to thank Colin McGlinchey, Thao Nguyen, Marion Gerhart, and Isabella Stork for their assistance and support in the laboratory. This curriculum was developed under National Science Foundation RET grant # EEC1301373. However, these contents do not necessarily represent the policies of the National Science Foundation, and you should not assume endorsement by the federal government. Sandia National Laboratories is a multi-program laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

School of Engineering, University of New Mexico
Advanced Materials Laboratory, Sandia National Laboratories

Laboratory Research

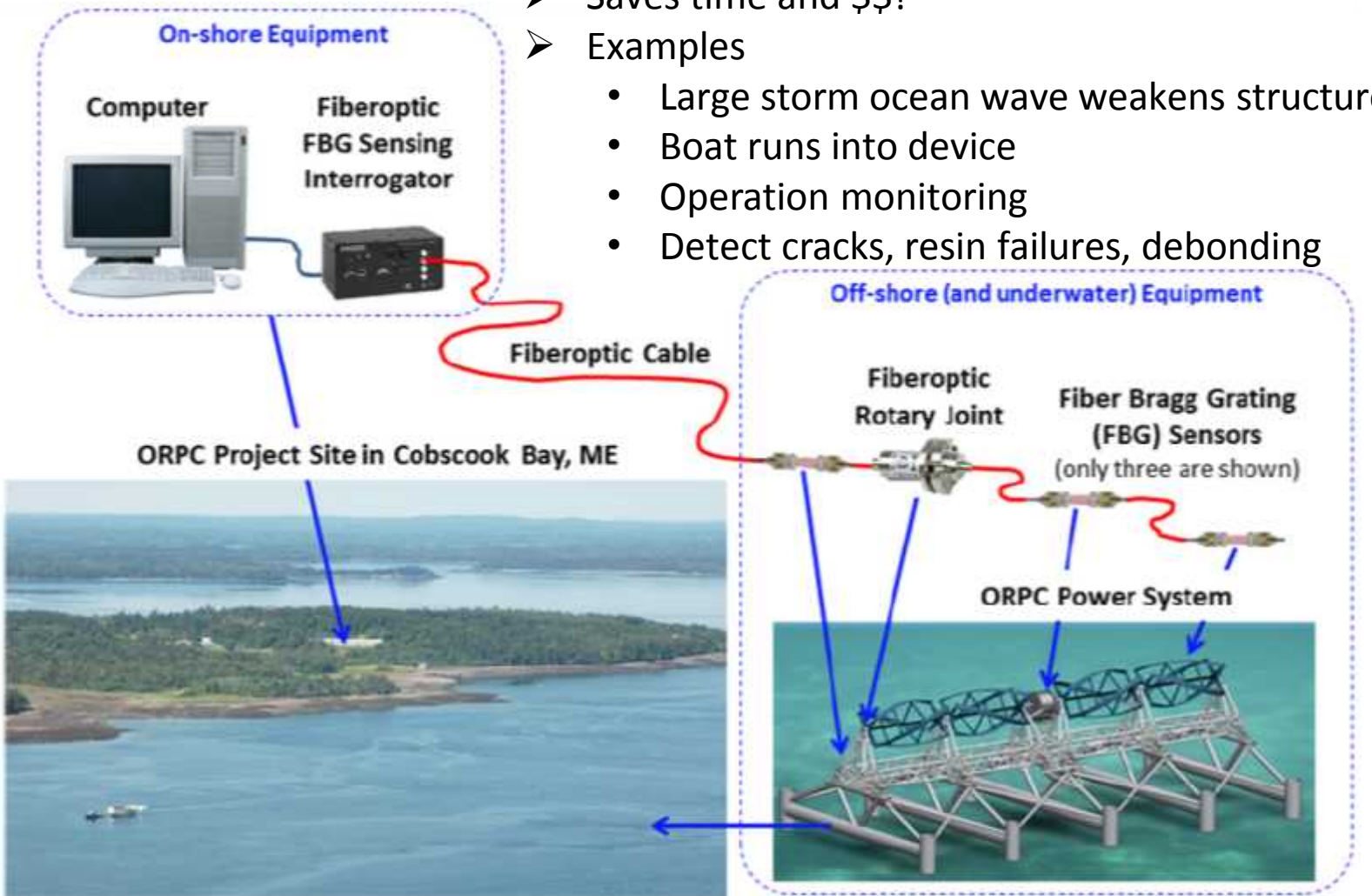
Marine Hydrokinetic Technology (MHK) Project

- Converts the energy of waves, tides, and river and ocean currents into electricity
- Some equipment also desalinates ocean water (Wave2O™ by Resolute Marine Energy, Inc.)



Structural Heath Monitoring of MHK Composite Materials

- Remote detection of flaws/damage done to underwater strctr
- Saves time and $$!
- Examples
  - Large storm ocean wave weakens structure
  - Boat runs into device
  - Operation monitoring
  - Detect cracks, resin failures, debonding



Developing Novel Fiber Composite Sensors for Structural Health Monitoring

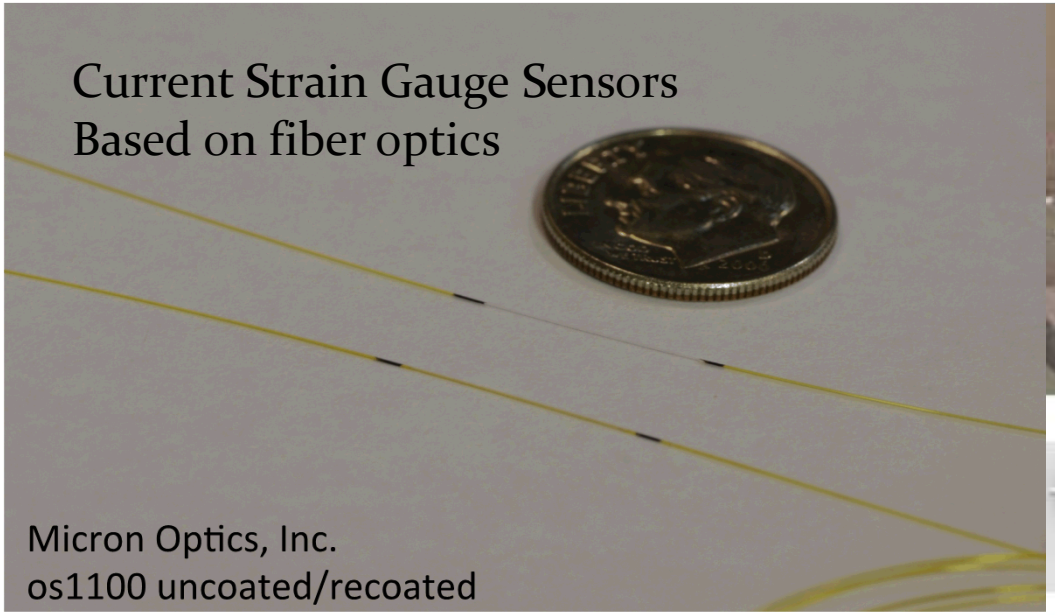


Figure 2 – Section of an ORPC-supplied foil,from which coupon substrates were cut.

Figure 3 – Cross-section of the ORPC-supplied foil showing the laminate layup.

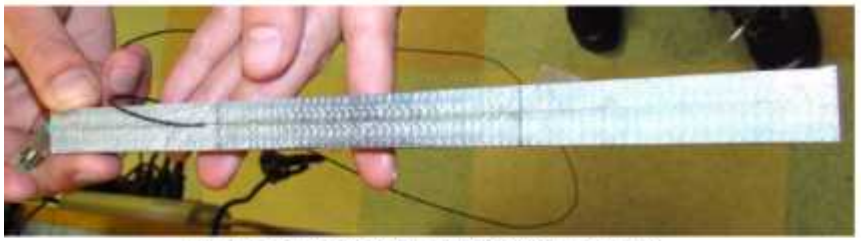


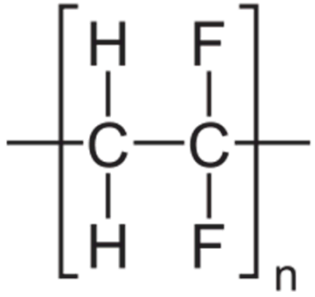
Figure 4 – Test specimen with a mounted MOI bare FBG sensor.

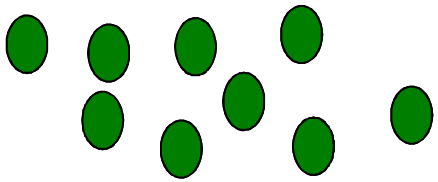
Problems with these sensors:

- Large fibers
- One time use
- Can act as a defect site

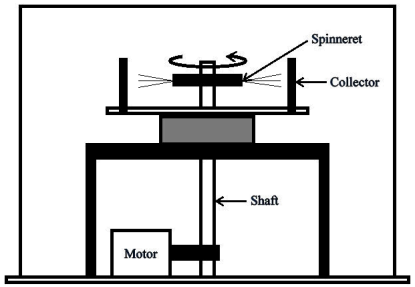
Project Goal:
To develop novel structural health sensors

PVDF= Polyvinylidene fluoride
Piezoelectric polymer
Produces charge with mechanical stress

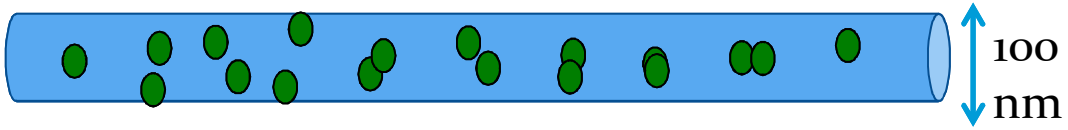




Magnetic Nanoparticles
Co_3O_4 or Fe_2O_3 (5-10 nm)



Force Spun Fiber Sensor



Combined polymer & Nanoparticles will be force spun into fibers that can be embedded into composite layup

My Research Goals:

To develop **cobalt oxide and iron oxide nanoparticles** to be used in non-destructive health monitoring of MHK technology

Periodic Table of the Elements

1 IA	2 IIA	3 IIIV	4 IVB	5 VB	6 VIB	7 VIIB	8	9 VII	10	11 IB	12 IIB	13 IIIA	14 IVA	15 VA	16 VIA	17 VIIA	18 VIIIA
1 H																	2 He
3 Li	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne
11 Na	12 Mg											13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
55 Cs	56 Ba	57-71	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn
87 Fr	88 Ra	89-103	104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110 Ds	111 Rg	112 Cn	113 Uut	114 Fl	115 Uup	116 Lv	117 Uus	118 Uuo
6		57 La	58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb	71 Lu	
7		89 Ac	90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No	103 Lr	

Alkali Metals | Alkali Earth Metals | Transition Metals | Other Metals | Metalloids

Other Non Metals | Halogens | Noble Gases | Lanthanides & Actinides

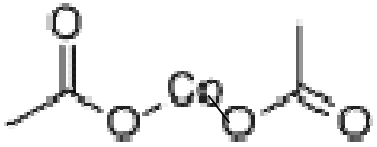
Precursors and Solvents

Precursors:

Reactions 1 & 2:

Cobalt acetate

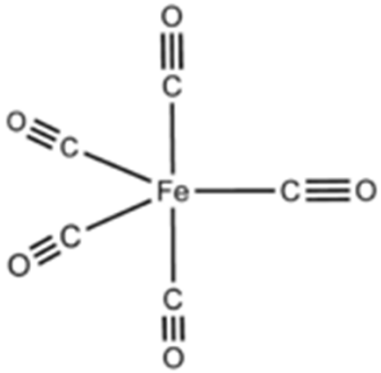
$Co(C_2H_3O_2)_2$



Reaction 3:

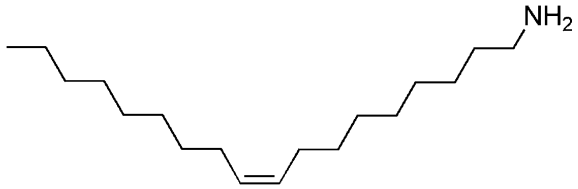
Iron pentacarbonyl

$Fe(CO)_5$

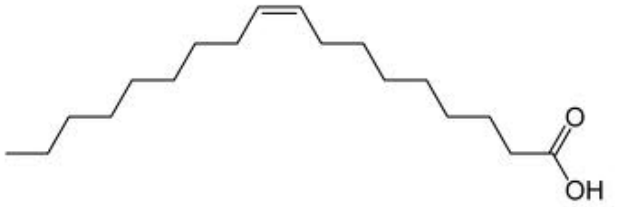


Solvents:

Oleylamine (Oly)



Oleic Acid (OA)



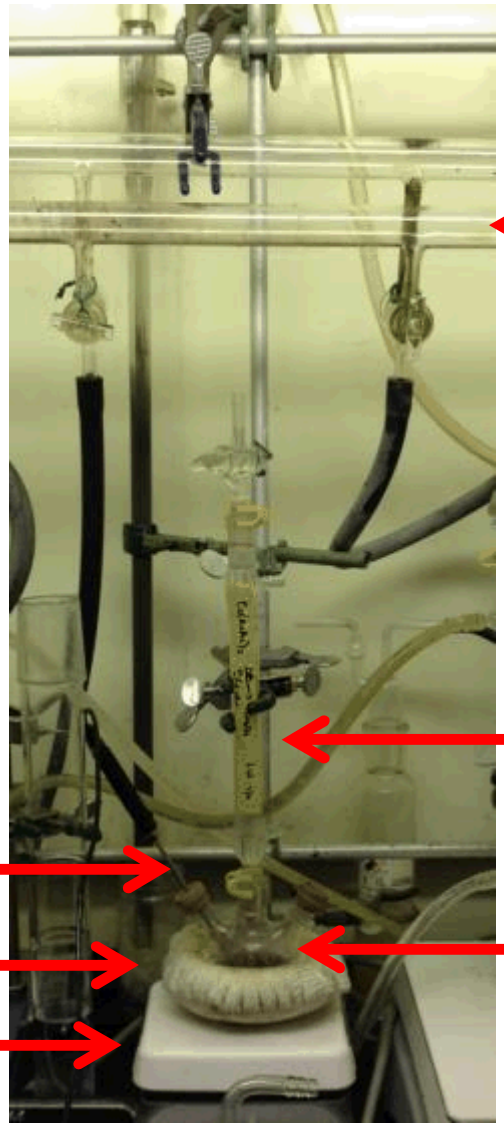
Dioctyl ether (DOE)

Image Sources: Encyclopedia of Reagents for Organic Synthesis, Royal Society of Chemistry, Department of Engineering, University of Utah, Chemical Book

Materials and Procedures Used

Solution Precipitation Reaction Experimental Setup

- Precursors and solvents heated, decomposition of precursor occurs
- Used to synthesize nanoparticles



X-Ray Diffraction (XRD)

- Used to characterize (identify) product

Crystal structure of desired product: Co_3O_4

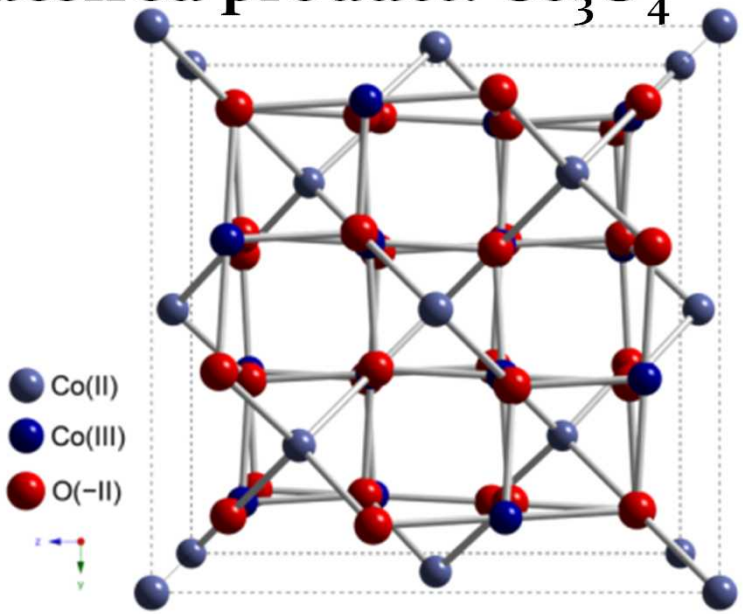


Image source: Wikipedia

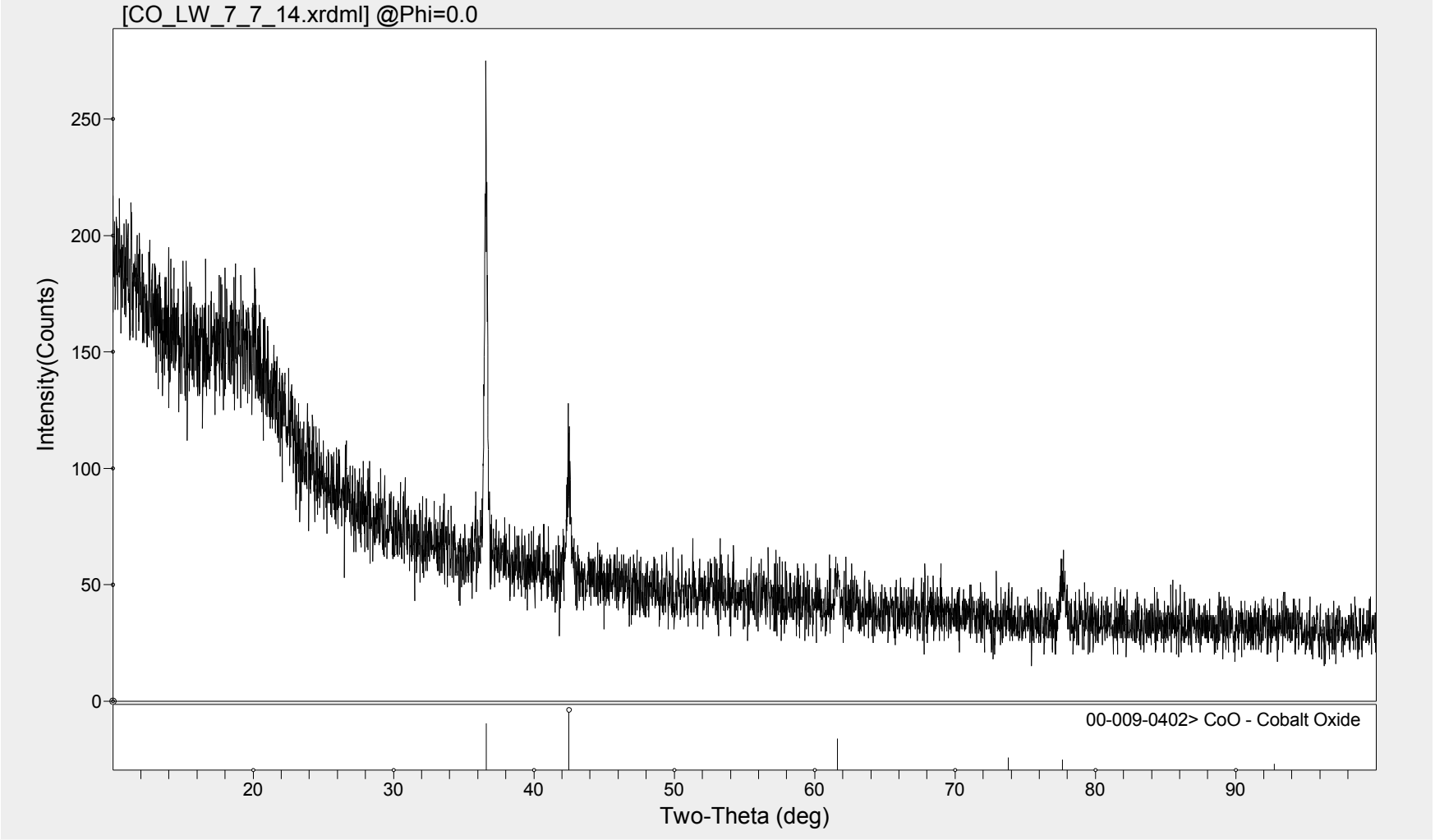
Summary: Cobalt and Iron Oxides Nanoparticle Synthesis

via Solution Precipitation Reaction

Reaction	Precursor	Solvents	Heat	Product
1	$Co(C_2H_3O_2)_2$	OA, Oly, DOE	210 min @ ~290°C	CoO
2	$Co(C_2H_3O_2)_2$	OA, Oly, DOE	210 min @ ~290°C, 60 min @ 100 °C 60 min @ ~282°C Calcinated	Co_3O_4
3	$Fe(CO)_5$	OA, Oly, DOE	120 min @ ~ 300°C	Fe_2O_3

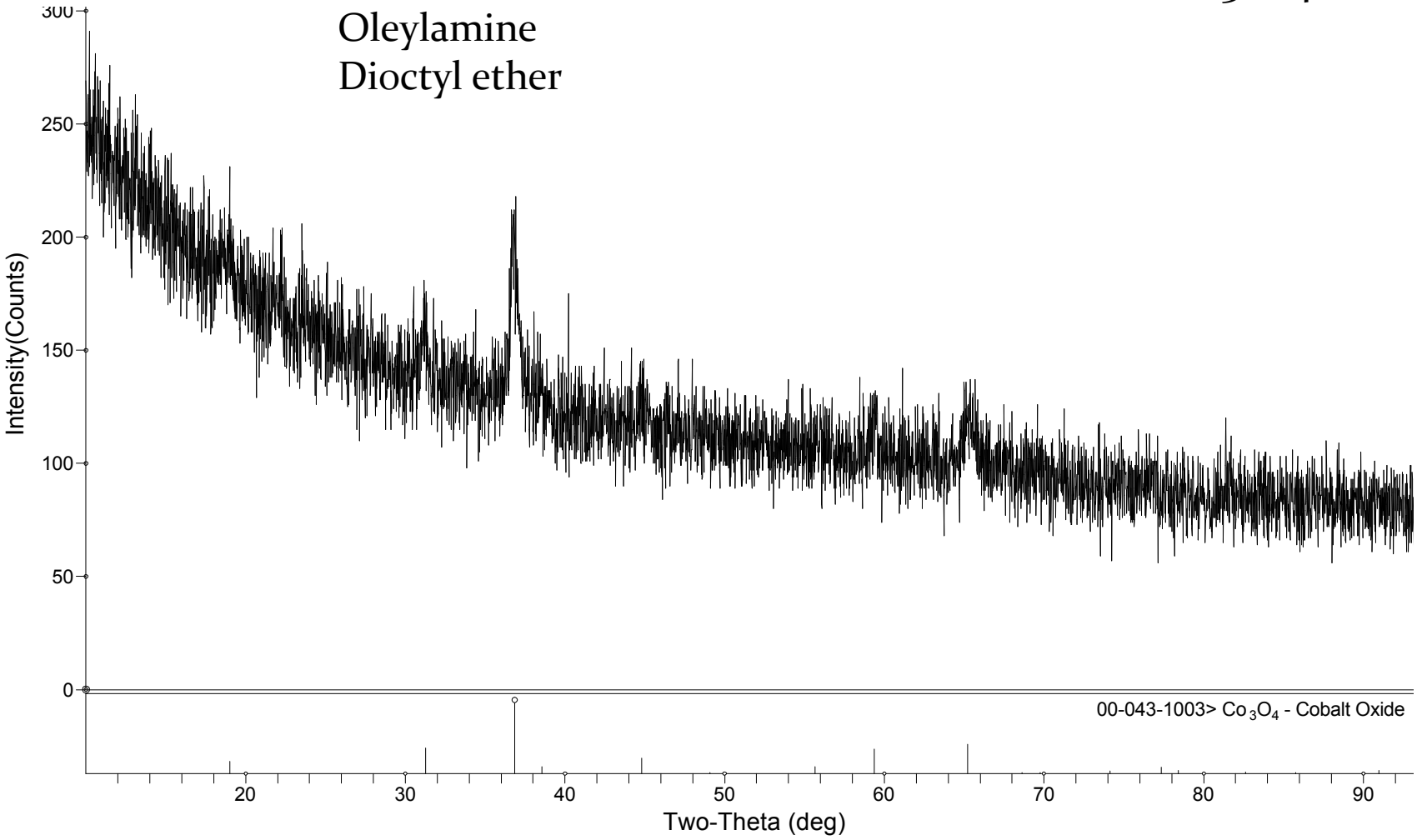
Reaction 1:
Cobalt (II) oxide nanoparticle synthesis

$$Co(OAc)_2 \xrightarrow[\text{Oleic Acid}\\ \text{Oleylamine}]{\Delta\ 210\ \text{min}} \cancel{Co_3O_4}\ \ CoO$$



Reaction 2:
Cobalt (II, III) oxide nanoparticle synthesis

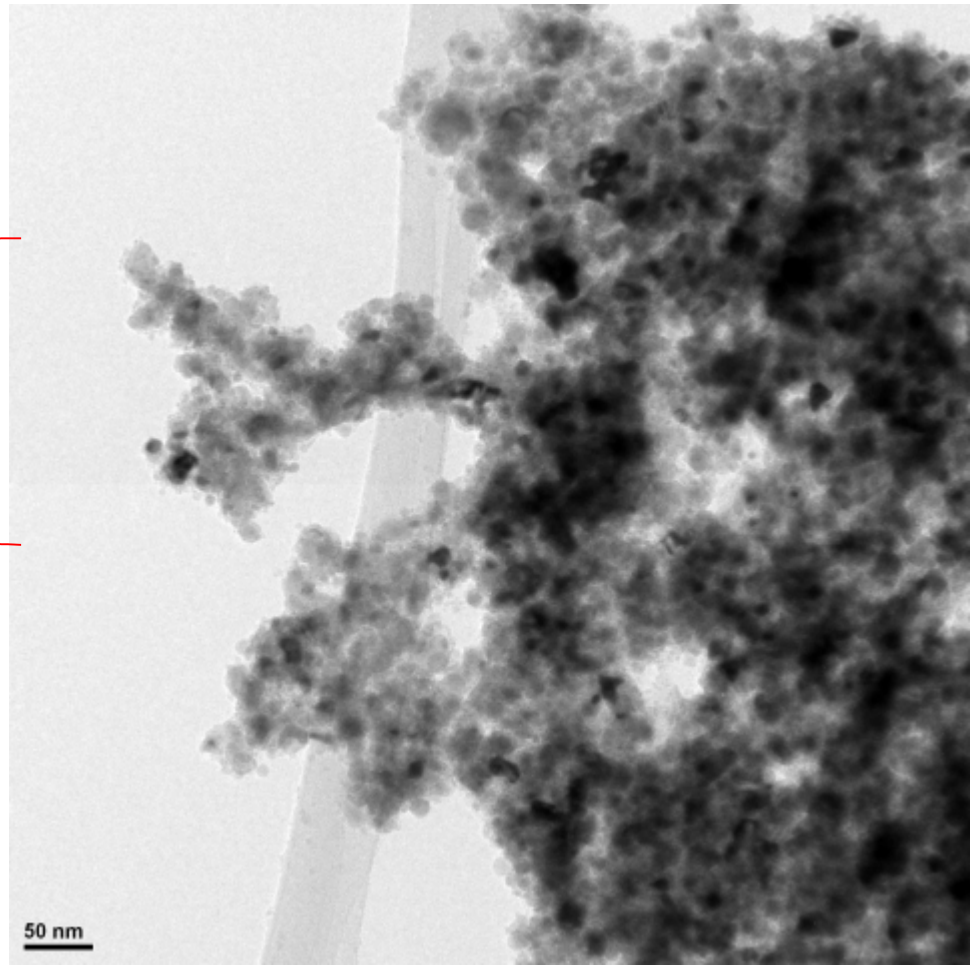
$$Co(OAc)_2 \xrightarrow[\text{Oleic Acid, Oleylamine, Dioctyl ether}]{\Delta\ 210\ \text{min}} CoO \xrightarrow{\text{calcination}} Co_3O_4$$



Reaction 3:
Iron (III) oxide nanoparticle synthesis

$$Fe(CO)_5 \xrightarrow[\text{Oleic Acid}\ \text{OA}\ \text{Oly}]{\Delta\ 240\ \text{min}} Fe_2O_3$$

TEM image:
Aggregated iron oxide nanoparticles (5-10 nm)



Taking it to nex+Gen Academy:

What's in our water, and where did it come from?

What's in our water?

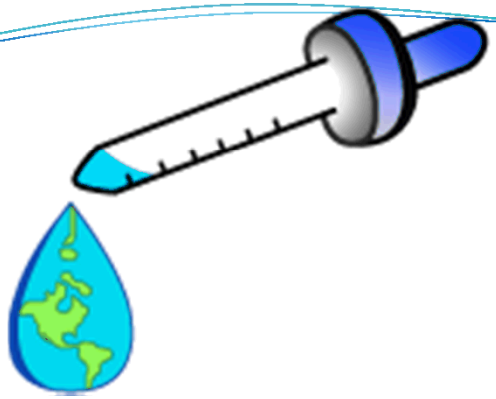
Bosque Ecosystem Monitoring Program

Students will sample and analyze water from our local river and irrigation ditches

Students will participate in the BEMP Stormwater Science program

- goal of this program is to help students understand that the health of the Rio Grande is directly tied to the health of the surrounding watershed and arroyos

Image sources: City Data, Bosque Ecosystem Monitoring Program



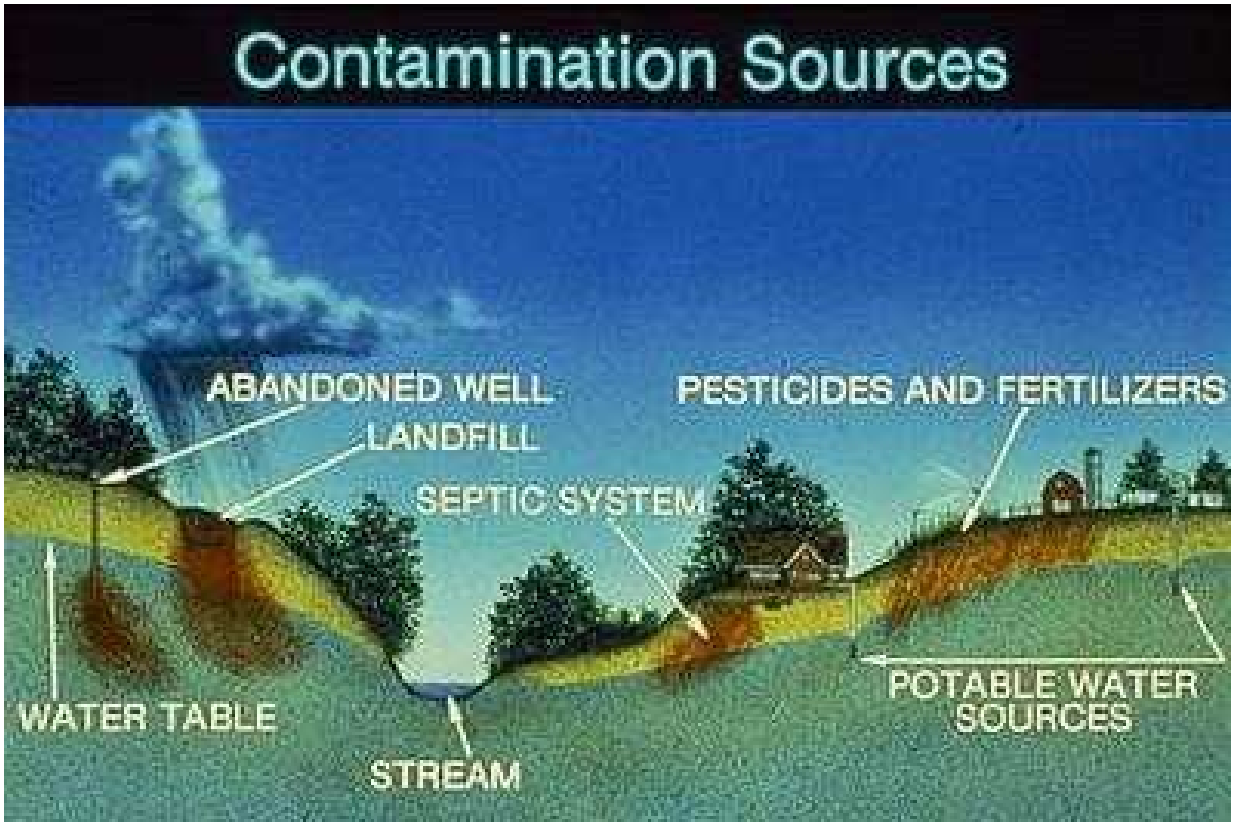
The Global Water Sampling Project

An Investigation of Water Quality

- Data will be collected, analyzed and shared with the **Global Water Sampling Project**
- International collaborative project sponsored by CIESE, The Center for Innovation in Engineering & Science Education at Stevens Institute of Technology.

…and where did it come from?

Then, students conduct research to find out the sources of and regulations on water contaminants.



- Deliverable: Lab Report

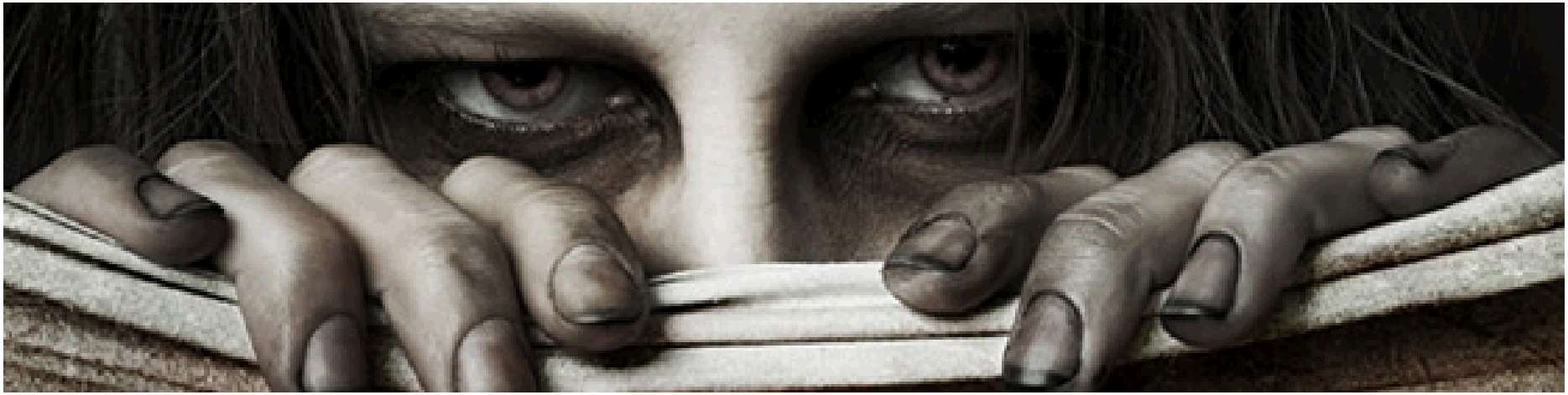
Image source: Environmental Protection Agency

Skills & Chemistry Concepts Students Will Learn

- Process Skills:
  - Conduct experiment
  - Analyze and interpret results
  - Convey results of investigations
- Concepts:
  - Physical and chemical properties of water
    - High melting & boiling points, high specific heat
    - Polarity, adhesion, cohesion
  - Hydrophilic / hydrophobic / superhydrophobic

PROJECT TWIST: Zombie apocalypse

Students develop a water purification system



- Water treatment plant is no longer functioning
- How can we produce clean water without the use of electricity?
- Deliverable: Lab report, presentation of prototype

Skills & Chemistry Concepts Students Will Learn

- Process skills:
  - Design and conduct experiment
  - Analyze and interpret results
  - Convey results of investigations
- Concepts:
  - Physical & chemical separation of mixtures
  - Types of chemical reactions

Questions?