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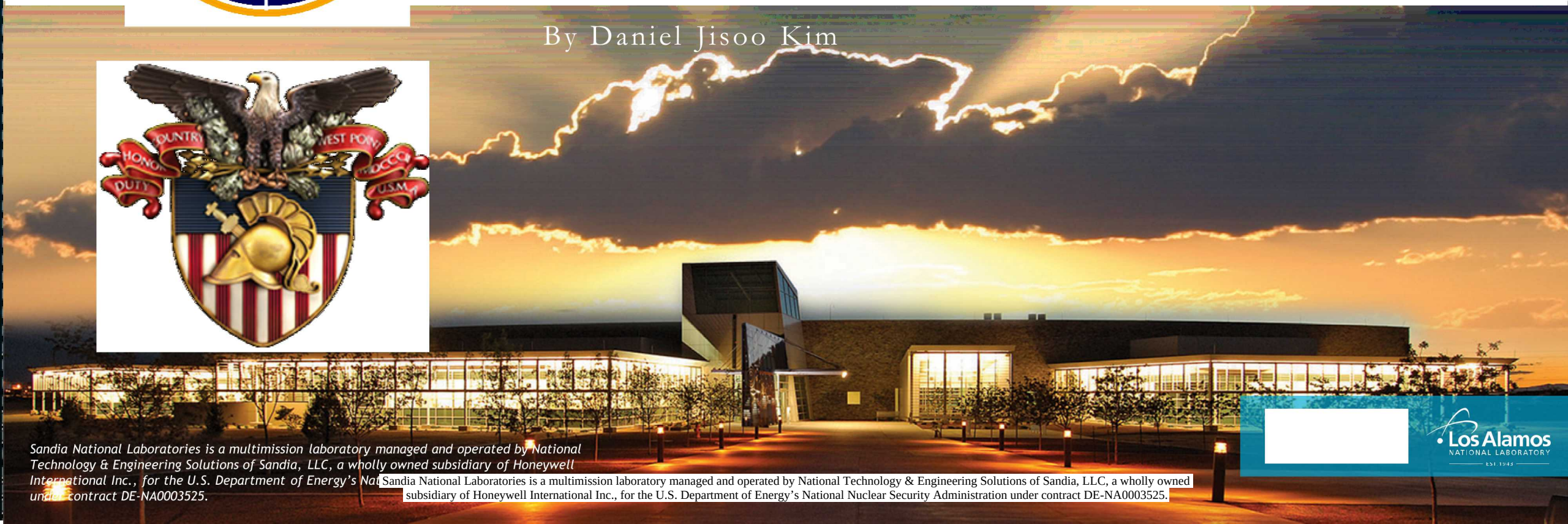
Vanadium Nanoparticles for Rejecting Solar Heat

By Daniel Jisoo Kim



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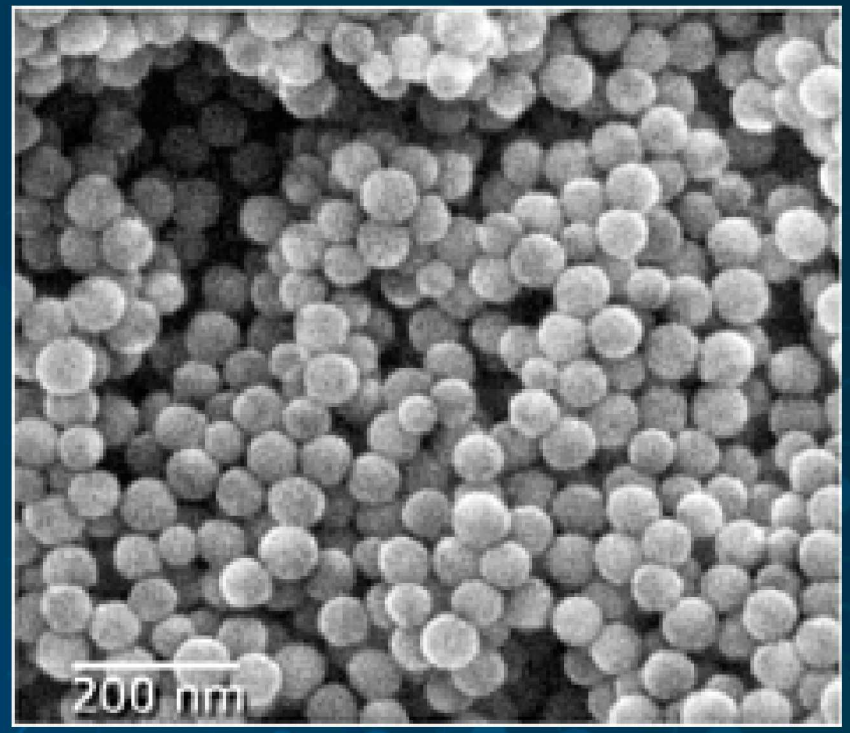
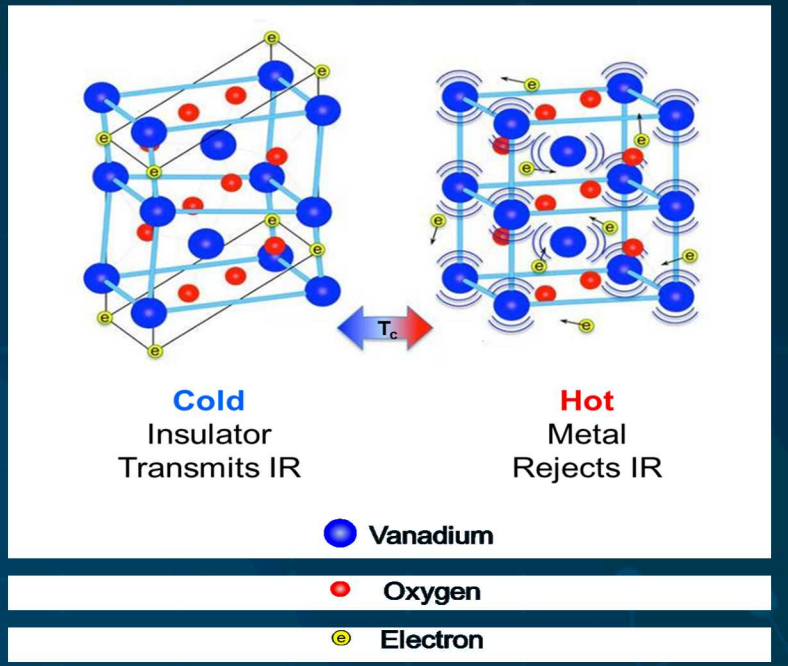
NANOPARTICLES

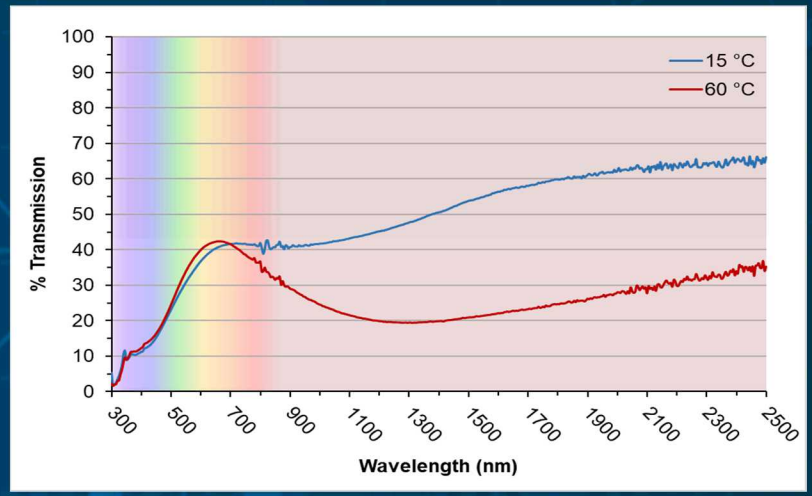
- Particles between 1 and 100 nanometers with a surrounding interfacial layer.
- Wide variety of potential applications in biomedical, optical, and electronic fields
- Depending on the size, nanoparticles exhibit different properties



VANADIUM NANOPARTICLES

- VO_2 experiences a solid state phase transition above a critical temperature (Tc)
- IR transmission through VO_2 is rejected above Tc
- Transmit warming IR radiation into interior spaces during winter daylight hours to reduce heating costs
- Reject IR during summer daylight hours to reduce cooling costs





VANADIUM NANOPARTICLES APPLICATION

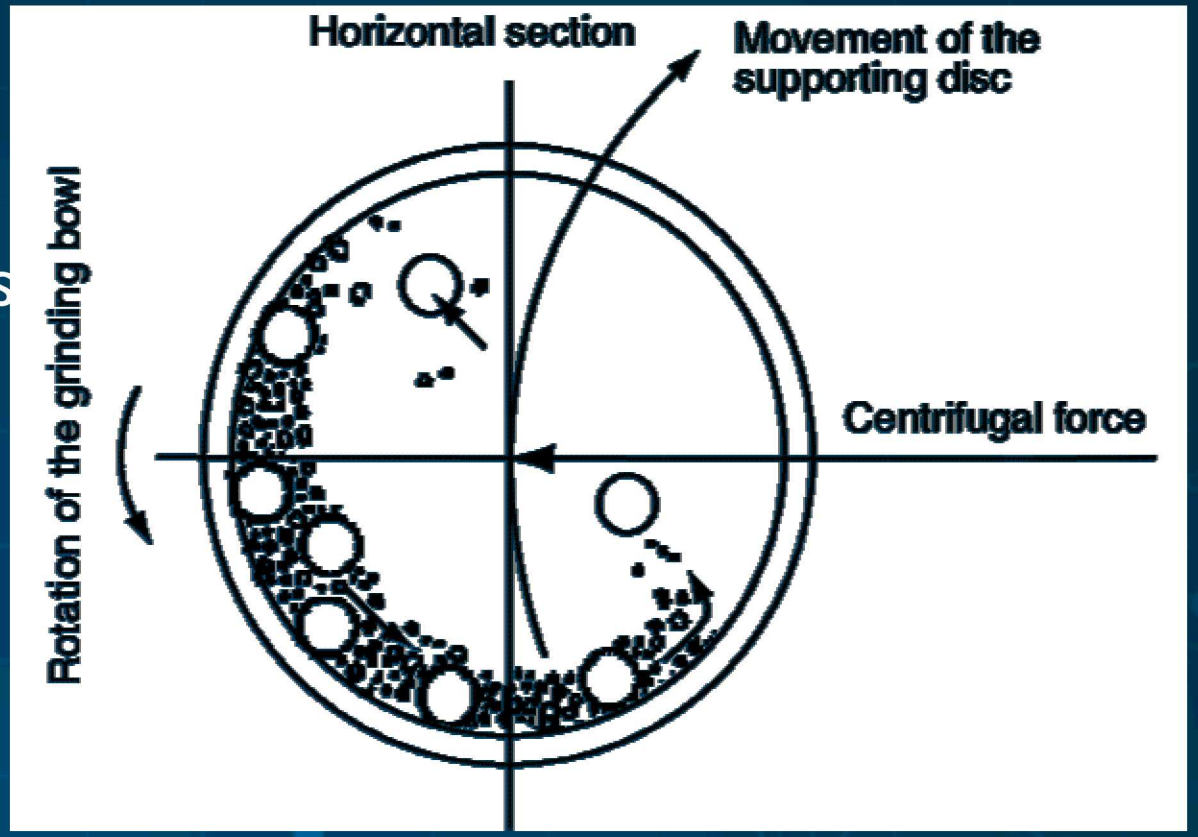
- Applied in thin layers onto windows
- Save you a lot of $$$
- Only need 5% of total volume to be made up of nanoparticles

METHODS

- Bottom-Up Synthesis
  - -Make nanoparticles atom by atom
- Top-Down Synthesis
  - -Break down bigger particles into smaller particles

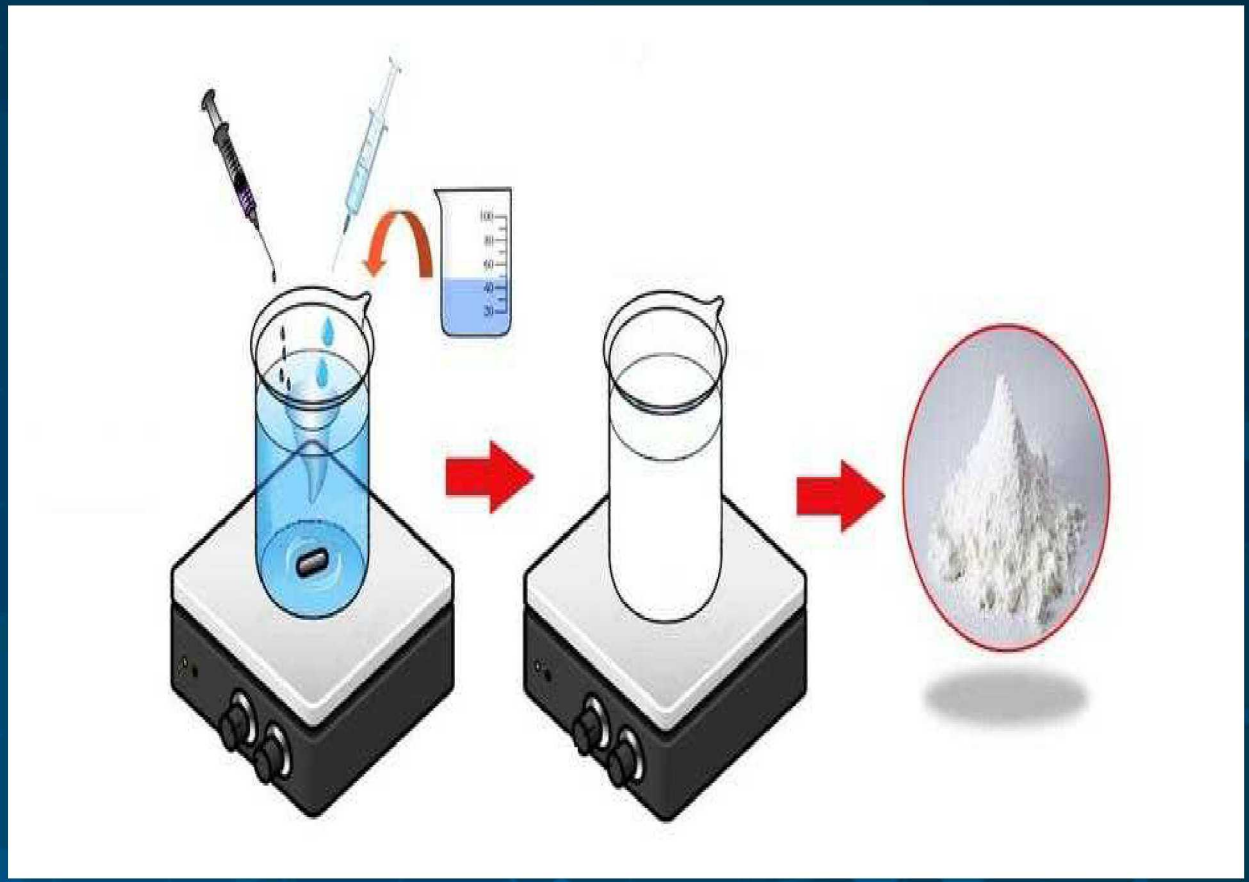
PHYSICAL TOP-DOWN METHOD

- Most crude method
- Utilizes ball mill to break down particles
- Low uniformity of shapes and sizes



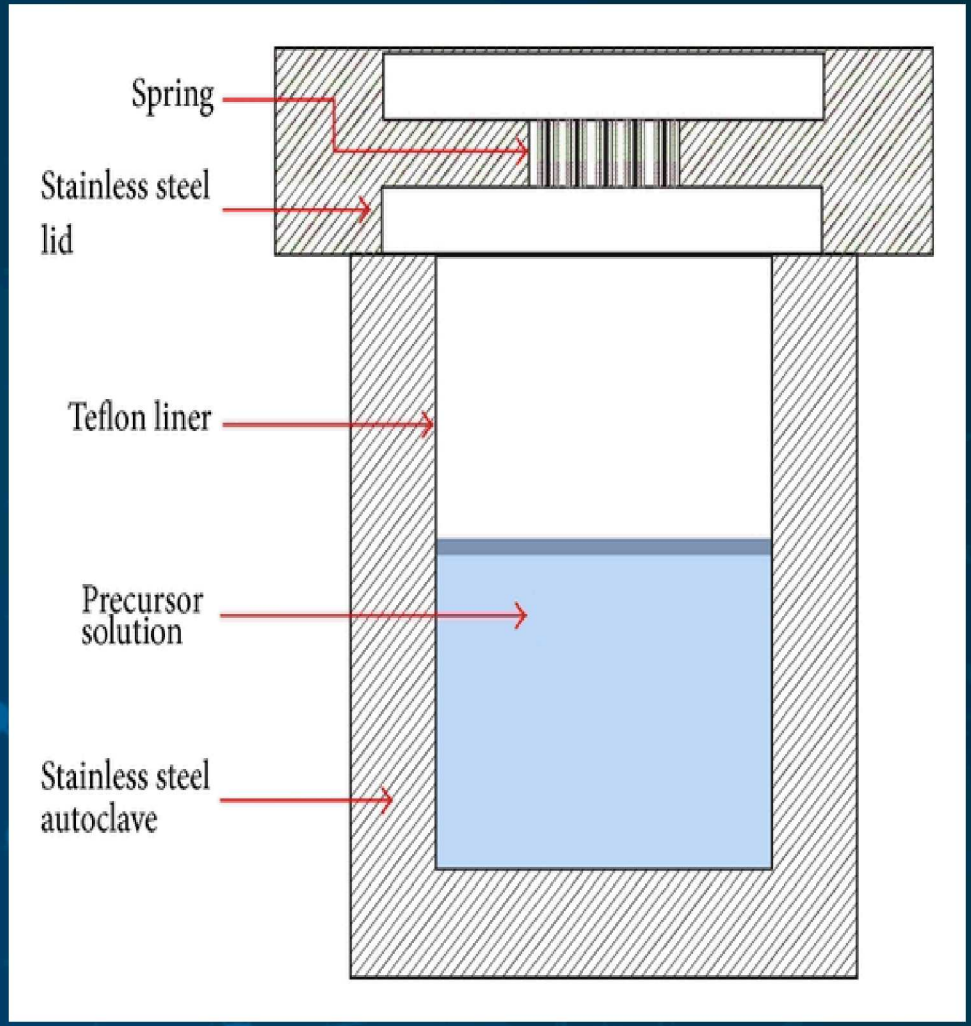
PRECIPITATION METHOD

- Allows for room temperature reaction & ambient pressure
- Rapid reaction
- Easy to do
- Poor size & shape control
- High level of non-uniformity



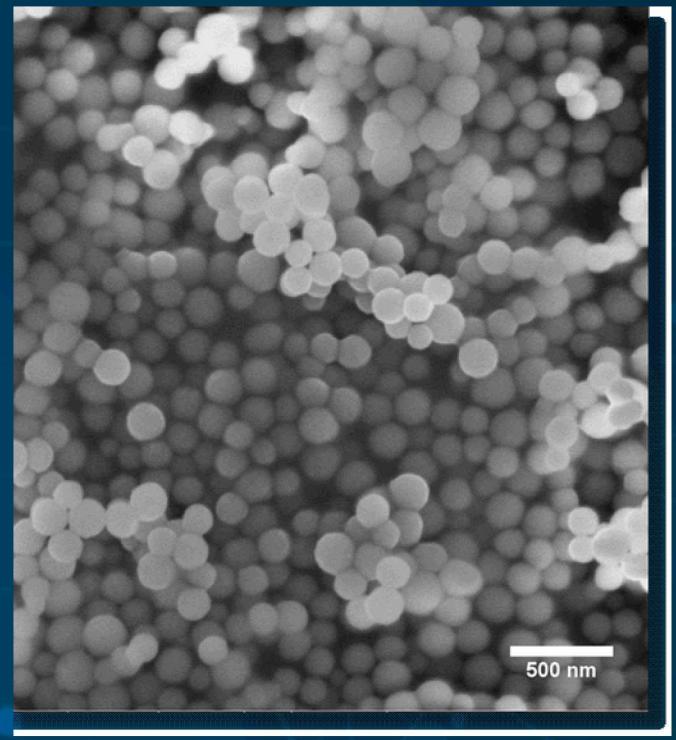
HYDROTHERMAL/SOLVOTHERMAL

- Adds high temperature & high pressure to the reaction
- Steel pressure cooker, called an autoclave
- Allows to work with solvents above their boiling points due to closed system
- Can’t see reaction
- Can’t sample during reaction
- Slow reaction rate
- “okay” size & shape control



OTHER WORKS WITH VANADIUM NANOPARTICLES

- Lots of papers on hydrothermal synthesis for VO_2
- No reproducibility in literature
- Not appealing shapes and sizes
- Too large, results in “hazy” window films
- No size control



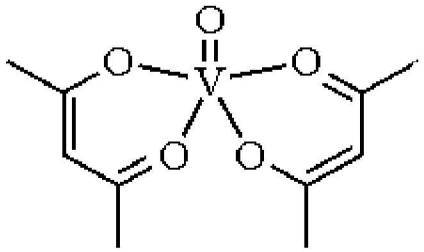
GOAL

- Develop a new synthesis method for VO_2 nanoparticles
- < 40 nm in diameter
- Uniform in size
- Reproducible
- Scalable

THERMOLYSIS (THERMAL DECOMPOSITION)

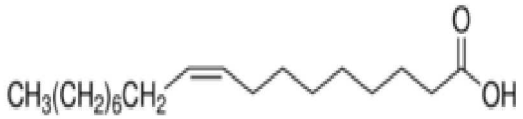
- High temperature & atmospheric pressure
- Utilizes high boiling solvents
- Open system
- Option to add more substance during reaction
- Size & shape control
- High Uniformity

THERMOLYSIS



Vanadyl Acetylacetonate

+



Oleic Acid

+ Δ =

Heat

Vanadyl Oleate

- Heat the reaction in the presence of high boiling point solvent
- The heat makes the precursor break apart and allow for the ligand to attach to the precursor
- Monomer is formed

THERMOLYSIS

Vanadyl Oleate

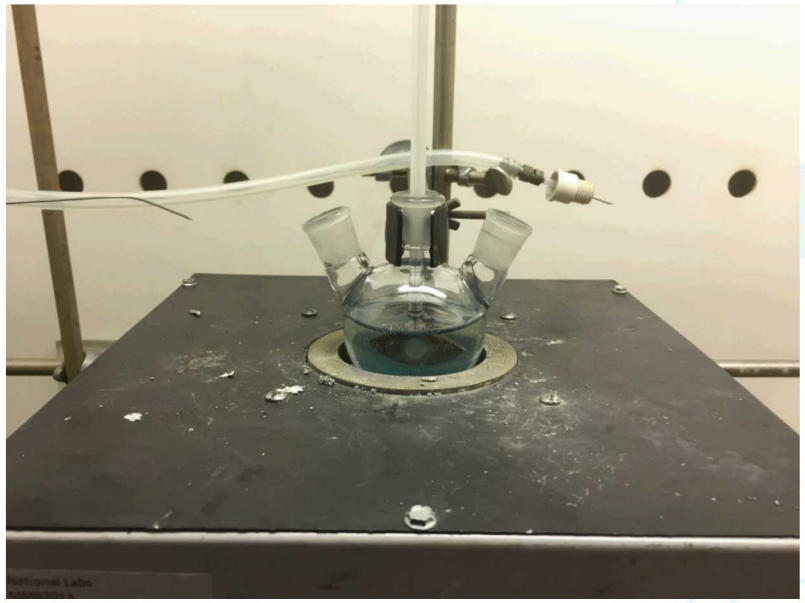
\+

Δ

Heat

=

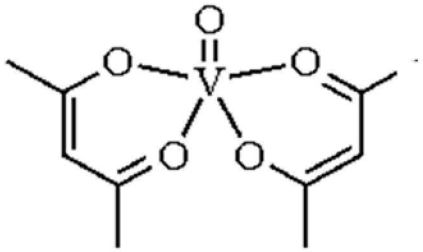
Vanadium Nanoparticles



- Once it becomes a saturated solution with enough energy, it forms particles

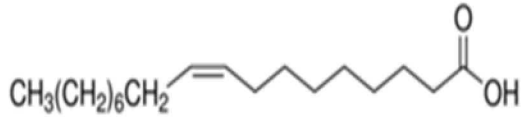
CHALLENGES

- Vanadium is oxyphilic
- It does not want to let go of its ligand
- Too much oleic acid dissolves the vanadium



Vanadyl Acetylacetonate

+



Oleic Acid

WHY DO WE NEED OLEIC ACID?

- Need oleic acid to act as the ligand because it allows for good quality nanoparticles
- Allows for spherical shape
- Sticks around and binds on the surface of the nanoparticles
- Nanomaterials have really high surface energy
- If the particles get a chance to bump into each other, they will stick
- Prevents nanoparticles from bumping into each other and getting stuck

MOLAR RATIOS

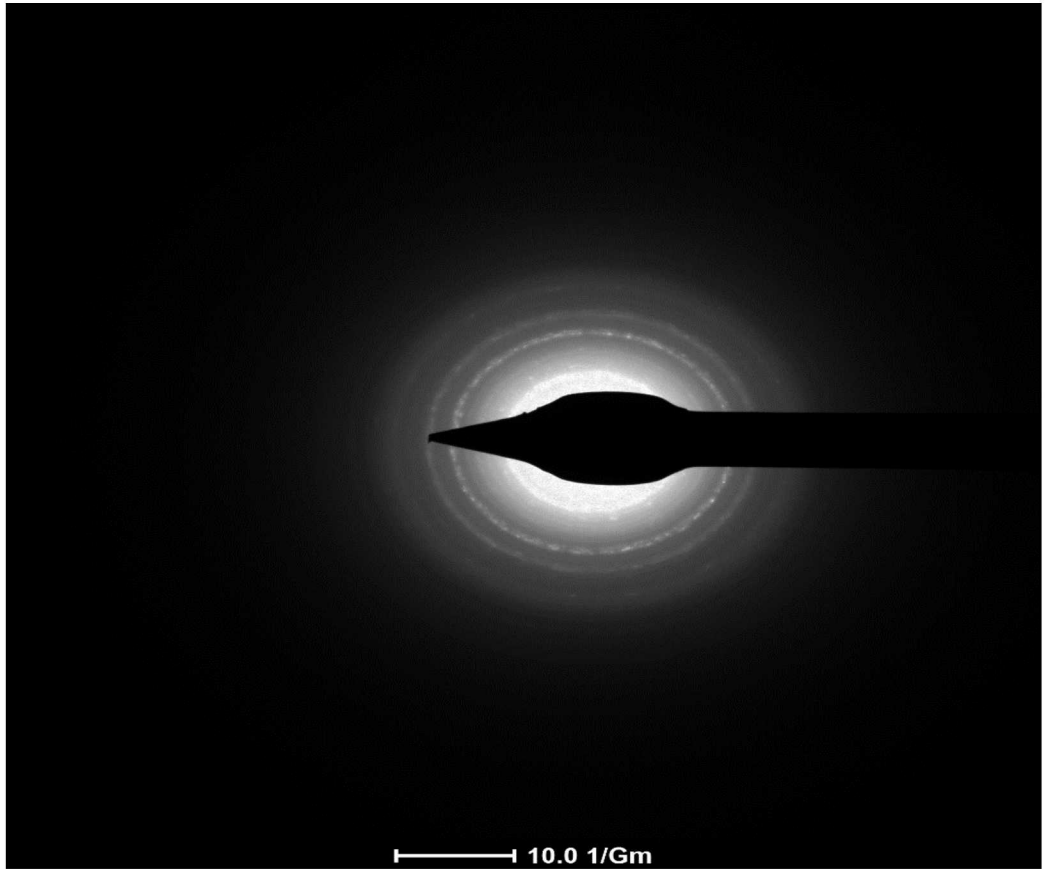
- Goal: find the right molar vanadium to oleic acid ratio
- Too much, the particles will dissolve
- Too little, no particle formation

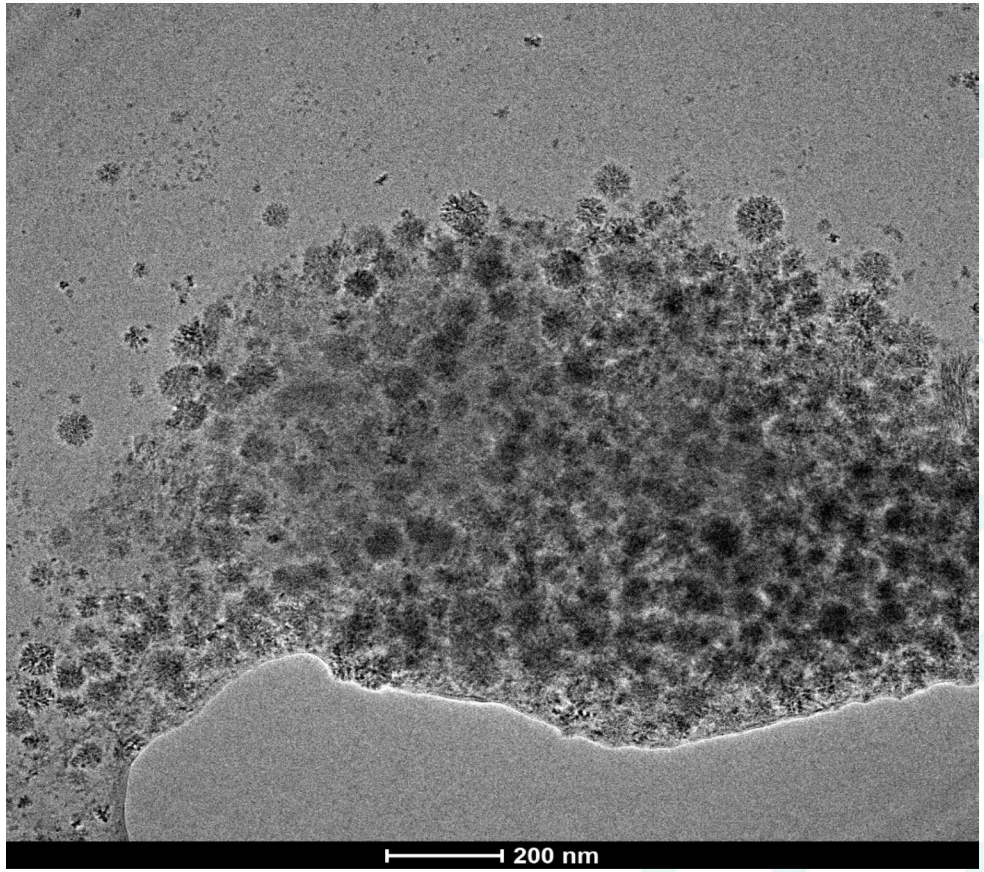
VANADIUM:OLEIC ACID RATIOS @ 320°C

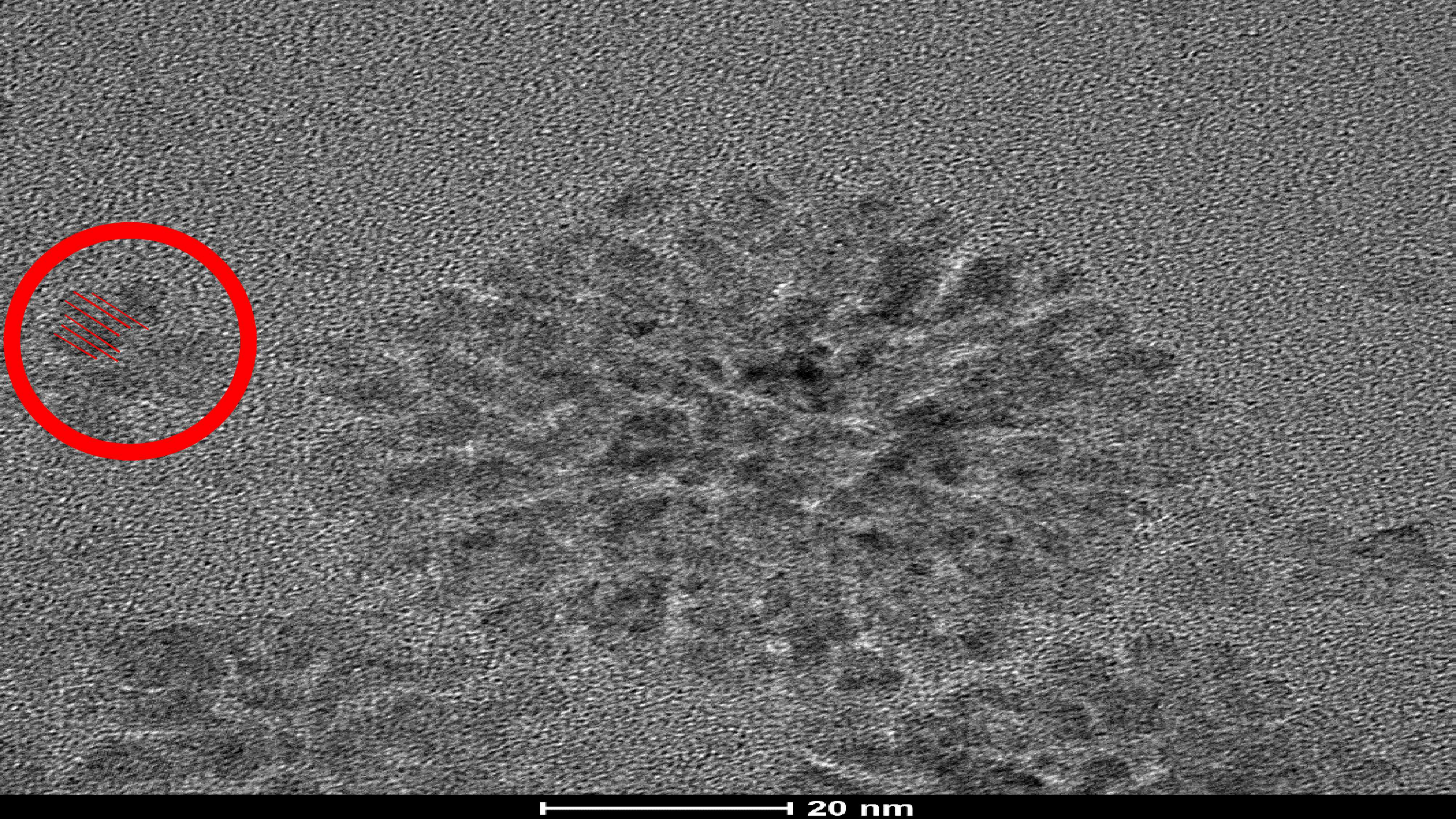
- 2:1 ratio: yielded nanoparticles
- 3:1 ratio: no nanoparticles
- 4:1 ratio: no nanoparticles
- 5:1 ratio: no nanoparticles

2:1 RATIO RESULTS

NANOPARTICLES UNDER TRANSMISSION ELECTRON MICROSCOPY






20 nm

FUTURE WORK

- Clusters indicate that there's not enough surfactant on the surface
- The bare surfaces are finding each other
- If we're not able to completely coat the surface without dissolving the particles in oleic acid, another coating agent must be added
- Esterification with esters as surfactants to break up clumps

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