Novel Nano-Sized, Chitosan-Coated, Meta-Vivianite and its Solubility in an Electrolyte Solution and a Soil Saturated Paste Extract

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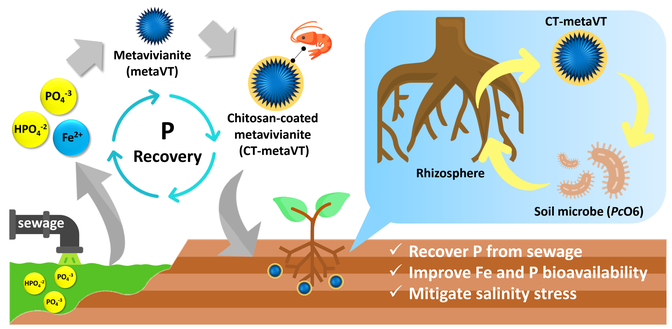
Graphical Abstract



Objectives

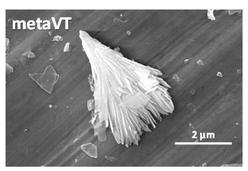
- Synthesize nano-sized chitosan-coated metavivianite (CT-metaVT).
- Characterize the metavivianite (metaVT) and CT-metaVT.
- Evaluate the kinetics of Fe and P release from metaVT and CT-metaVT in known solutions (0.01 M KCl and a calcareous soil saturated paste extract (SPE)).

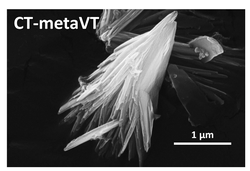
Material & Methods

I. Synthesis of metaVT & CT-metaVT

- Ammonium phosphate + ferrous sulfate, at 4 °C under Ar atmosphere

II. Characterization of metaVT & CT-metaVT





2-D surface morphology (SEM)

- Zeta potential analysis for surface charge
- N, C, H, O content (Elemental Analyzer, EA)
- Surface composition (X-Ray Photoelectron Spectroscopy, XPS)

III. Solubility experiments

Continuous experiment kept shaking in the dark → Sampling times: 0, 24, 48, 72, 96, 120, 144, 168 h → Samples are centrifuged and filtered to remove NPs → Total Fe & P in solution analyzed by ICP-MS

Results & Discussions

I. Thickness and surface charge

The thickness of the CT coating is ~ 14 nm. The surface charge of CT-metaVT becomes positive due to the CT coating.

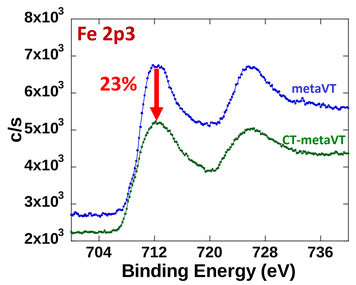
	Morphology	Thickness (nm)	Zeta Potential (mV)
metaVT	Feather-like	24.9	-14.6 ± 5.6
CT-metaVT	Feather-like	38.9	22.0 ± 2.8
CT	-	-	10.8 ± 2.1

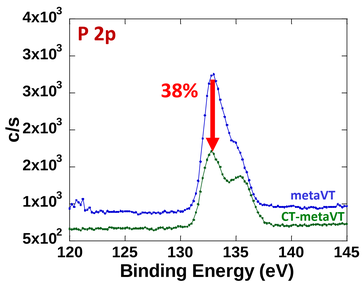
II. N, C, H, O content

The N and C contents of CT-metaVT increase relative to metaVT due to the presence of the CT coating.

	N %	C %	H %	O %
metaVT	0.14	0.06	2.26	22.90
CT-metaVT	0.32	1.31	2.59	24.61

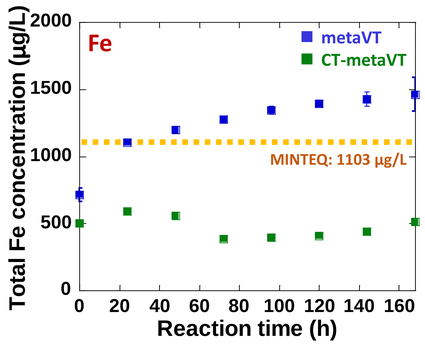
III. X-ray photoelectron spectra (XPS)

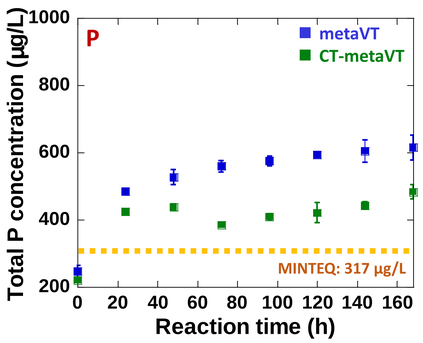




XPS only detects elements on the surface of material 7-10 nm deep. The results show a decrease in the Fe & P signals of CT-metaVT due to the CT coating.

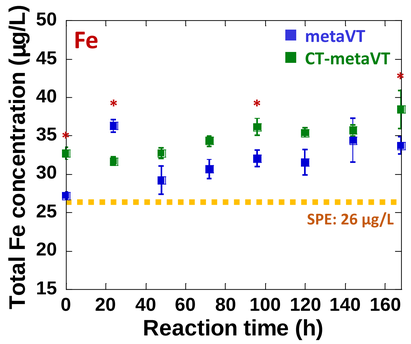
IV. Total Fe and P concentration in electrolyte solution (0.01 M KCl, pH 5.6)

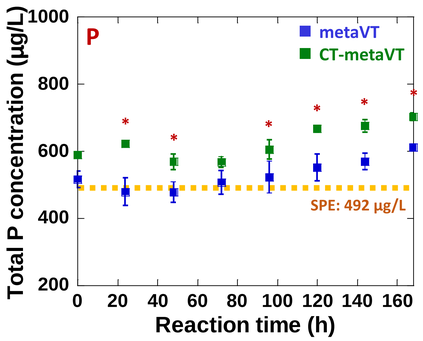




Total dissolved Fe and P in the CT-metaVT - KCl suspensions are significantly lower than in the metaVT – KCl suspensions ($p < 0.05$), suggesting that the CT coating is controlling dissolution of the metaVT.

V. Total Fe and P concentration in soil saturated paste extract (SPE, pH 8.4)





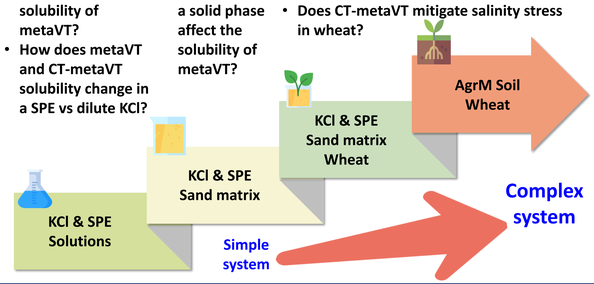
Total dissolved Fe and P in the CT-metaVT- and metaVT- SPE suspensions drop due to precipitation in the high pH, complex solution. The dotted yellow line indicates the background Fe and P concentrations of the SPE. Fe or P concentrations marked by a red asterisk are significantly different ($p < 0.05$).

Conclusions

- Nano-sized metaVT can be synthesized.
- Characterization results demonstrated that metaVT was successfully coated with chitosan, as demonstrated by the increased thickness, N & C contents, surface charge, and the decreased Fe & P signals from the material surface.
- The chitosan coating controlled the release of Fe and P from meta-VT in 0.01 M KCl.
- The total dissolved Fe and P in the metaVT- and CT-metaVT- SPE suspensions were low due to complexation and precipitation in the complex, pH 8.4 SPE solutions.

Future Work

- Does the CT coating affect the solubility of metaVT?
- How does metaVT and CT-metaVT solubility change in a SPE vs dilute KCl?
- Does the presence of a solid phase affect the solubility of metaVT?
- Does CT-metaVT improve the uptake of Fe and P by wheat?
- Does CT-metaVT mitigate salinity stress in wheat?



Acknowledgments

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