# Physical Characterization of Silica Nanoparticles in Extreme Environments

## Consolidation Materials

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# Conservation Science

Physical characterization to assess artwork

**Development of conservation treatments**





*Liam James Doyle/NPR*

# Experimental Treatments: Consolidation

Consolidation: reinforcement of deteriorating materials

Nanomaterials approach

**Silica ($SiO_2$)**
- Fire resistance
- Hydrophobicity
- Scratch resistance

David, M. E.; Ion, R.-M.; Grigorescu, R. M.; Iancu, L.; Andrei, E. R. Nanomaterials Used in Conservation and Restoration of Cultural Heritage: An Up-to-Date Overview. *Materials (Basel)* **2020**, *13* (9), 2064.
*Monument Conservation Collaborative | Consolidation*. Monument Conservation Collaborative.

# Current Research on Silica-based Consolidation

**Treatment type**          Impregnation

**Decrease swelling**        Impregnation with $SiO_2$ in wood

**Reinforcement**         Formation of calcium silicate hydrate (C-S-H)

**Knowledge gap**        Longevity in fluctuating environmental conditions

Borůvka, V.; Zeidler, A.; Doubek, S. Impact of Silicon-Based Chemicals on Selected Physical and Mechanical Properties of Wood. *WOOD RESEARCH* **2016**, *61*.
Zarzuela, R.; Luna, M.; Carrascosa, L. M.; Yeste, M. P.; Garcia-Lodeiro, I.; Blanco-Varela, M. T.; Cauqui, M. A.; Rodríguez-Izquierdo, J. M.; Mosquera, M. J. Producing C-S-H Gel by Reaction between Silica Oligomers and Portlandite: A Promising Approach to Repair Cementitious Materials. *Cement and Concrete Research* **2020**, *130*, 106008.

# Goal: Understand Behavior of $SiO_2$ Nanoparticles in Environmental Conditions

*Experimental Overview*

| **Sample Preparation** | **Impregnation Treatment** | **Hot Environment** | **Cold Environment** |
|---|---|---|---|

- $SiO_2$-$H_2O$ solution

Test materials
- Beech wood
- Portland cement

Determine ideal treatment length: 2 hours, 1 day, 2 days, 1 week
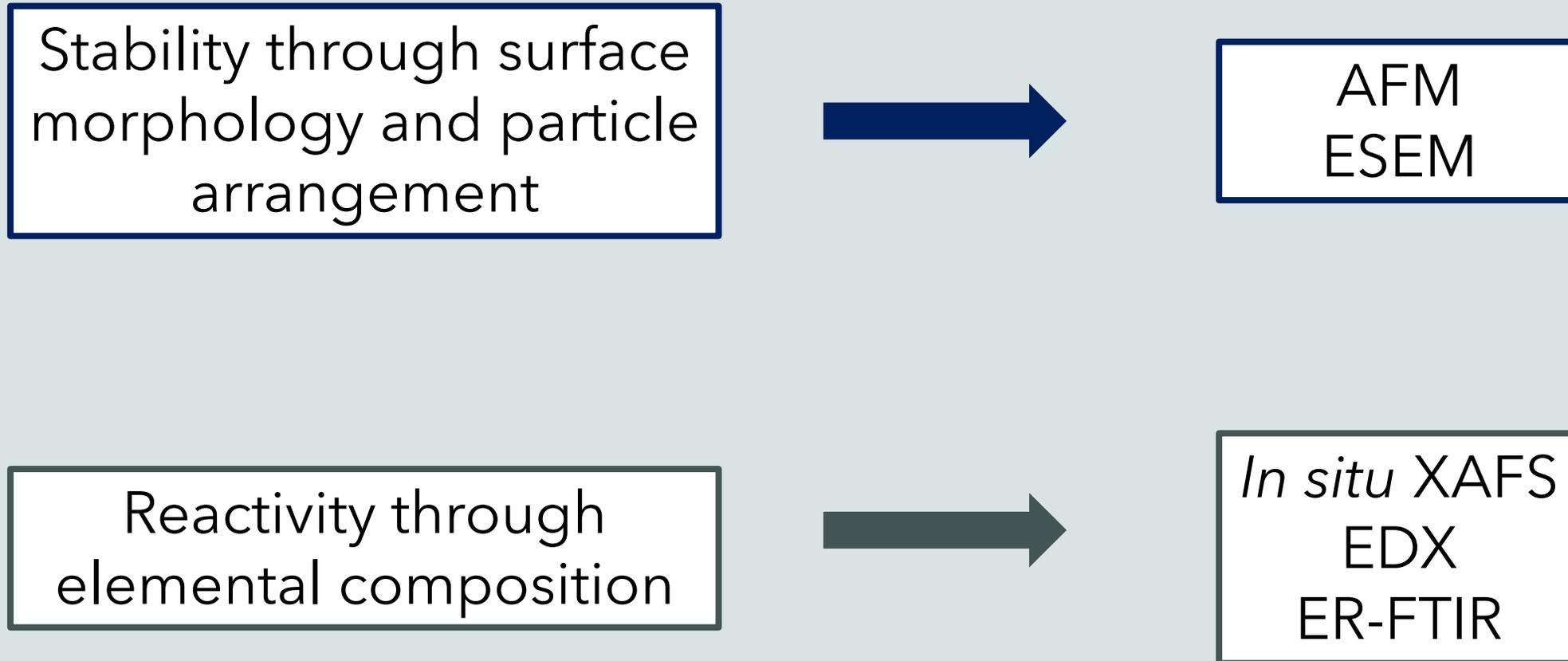
At ambient environment (22 °C, 65% RH)

38 °C
90% RH

- 0 °C
40% RH

# Specific Aims

Stability through surface morphology and particle arrangement $\rightarrow$ AFM ESEM

Reactivity through elemental composition $\rightarrow$ *In situ* XAFS EDX ER-FTIR
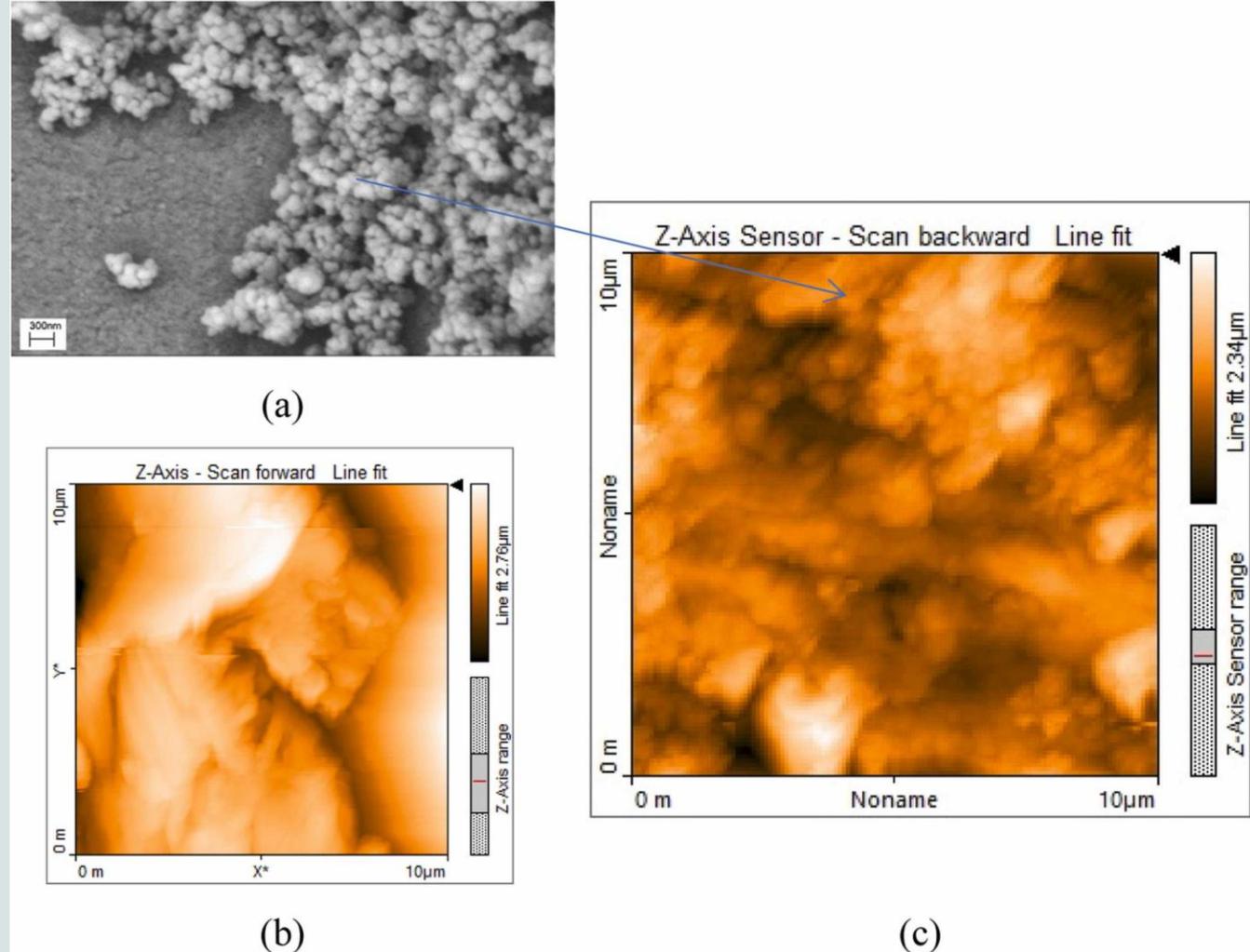
# Analysis of both surface and layers to monitor stability

AFM
ESEM

SEM image (a) of Ag-doped TiO$_2$ nanoparticles.
AFM images of (b) untreated wood and (c) coated wood.

Jafarpisheh, F.; Kolvir, H. R.; Ghorbanpour, M. Photocatalytic Self-Cleaning and Antibacterial Activity of Modified Wood by Ag Doped TiO2 Nanoparticles. *Next Materials* **2024**, *4*, 100207.

# Reactivity can be evaluated through oxidation state changes

**In situ XAFS**
EDX
ER-FTIR

XAFS spectra for (a) three sets of TiO$_x$ particles, before and after heat treatment (b-d).

Arif, A. F.; Balgis, R.; Ogi, T.; Iskandar, F.; Kinoshita, A.; Nakamura, K.; Okuyama, K. Highly Conductive Nano-Sized Magnéli Phases Titanium Oxide (TiOx). *Sci Rep* **2017**, *7* (1), 3646.
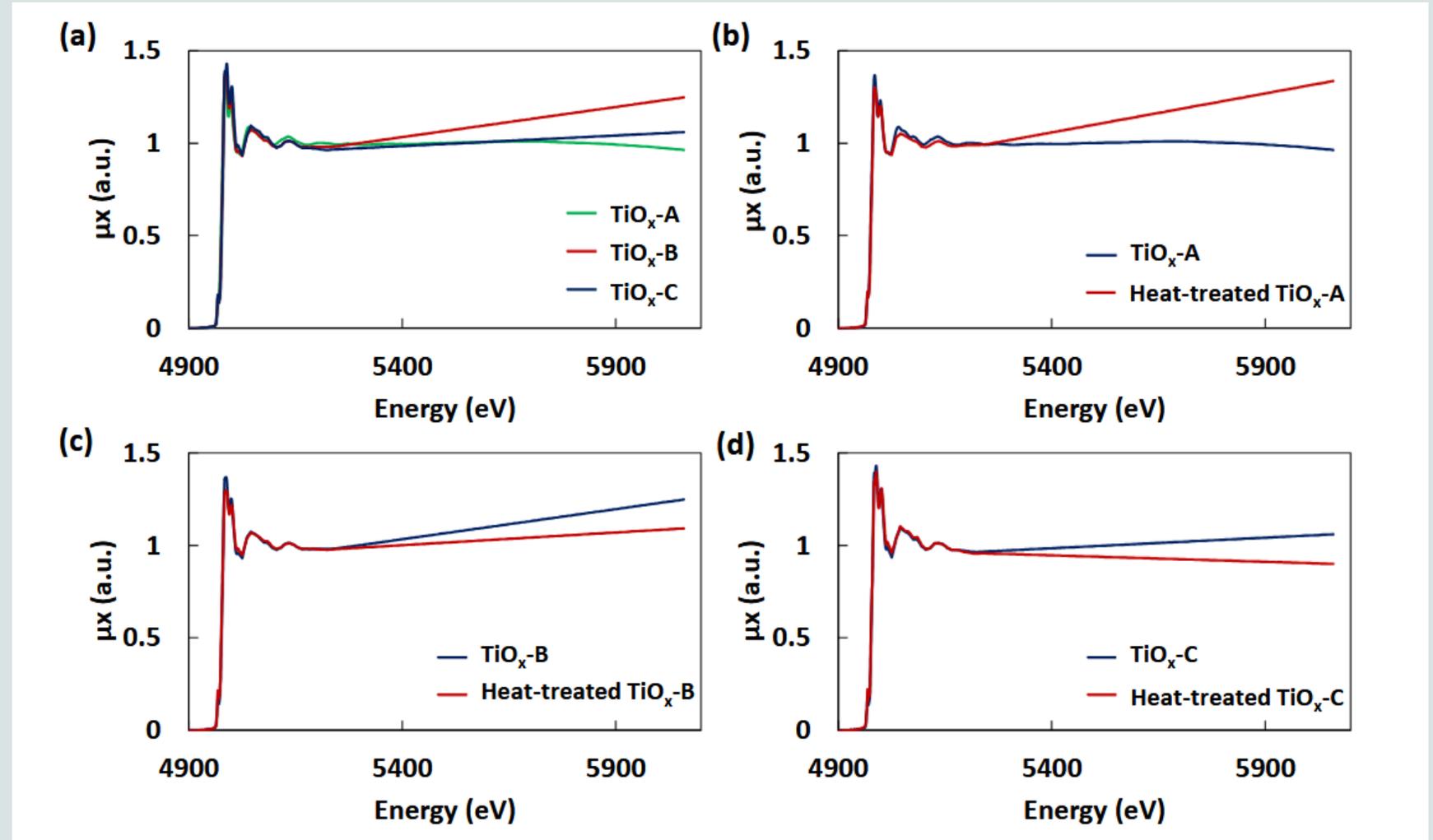
# Significance

**Museum sustainability**
Guide for green storage practices

**Predict behavior**
Works not housed in controlled environment

# Thank you!