

# Investigating the potential use of inorganic nanoparticles as antifungal agents for pre-treating timbers on HMS Victory

Dr Victor Jefferys

NHSF and Icon Heritage Science ECR and student seminar

09/06/2022

[victor.jefferys@nmrn.org.uk](mailto:victor.jefferys@nmrn.org.uk)

---

# What are nanoparticles?

- Any particle no more than 100 nm in diameter
  - For comparison:
    - Atom/small molecule – 0.1 nm
    - Nanoparticle – 1-100 nm
    - Dust – 2500-10,000 nm
    - Thickness of (standard printer) paper – 100,000 nm
  - Don't behave like their macroscopic counterparts
-

# Why are they useful?

- Small size
    - High surface area
    - Increased antimicrobial activity
    - Thorough permeation into wood
-

# Why are they useful?

- Small size
  - Highly tuneable
    - Dimensions
    - Properties
-

# Why are they useful?



- Small size
  - Highly tuneable
  - Low toxicity/environmental impact
    - Applications in medicine, agriculture, water purification
-

# Why are they useful?

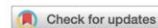
- Small size
- Highly tuneable
- Low toxicity/environmental impact

## Journal of Materials Chemistry B



PAPER

[View Article Online](#)  
[View Journal](#) | [View Issue](#)



Cite this: *J. Mater. Chem. B*, 2019,  
7, 6412

### Preventing fungal growth on heritage paper with antifungal and cellulase inhibiting magnesium oxide nanoparticles†

Isabel Franco Castillo,<sup>ab</sup> Esther García Guillén,<sup>c</sup> Jesús M. de la Fuente,<sup>ab</sup> Filomena Silva<sup>\*de</sup> and Scott G. Mitchell<sup>†\*de</sup>

*Langmuir* 2005, 21, 10743–10748

### Nanoparticles of Calcium Hydroxide for Wood Conservation. The Deacidification of the Vasa Warship

Rodorigo Giorgi, David Chelazzi, and Piero Baglioni\*

*Department of Chemistry and CSGI, University of Florence, via della Lastruccia 3-Sesto Fiorentino, 50019 Florence, Italy*



materials



Review

### Nanomaterials Used in Conservation and Restoration of Cultural Heritage: An Up-to-Date Overview

Madalina Elena David<sup>1,2</sup>, Rodica-Mariana Ion<sup>1,2,\*</sup>, Ramona Marina Grigorescu<sup>1</sup>, Lorena Iancu<sup>1,2</sup> and Elena Ramona Andrei<sup>1</sup>

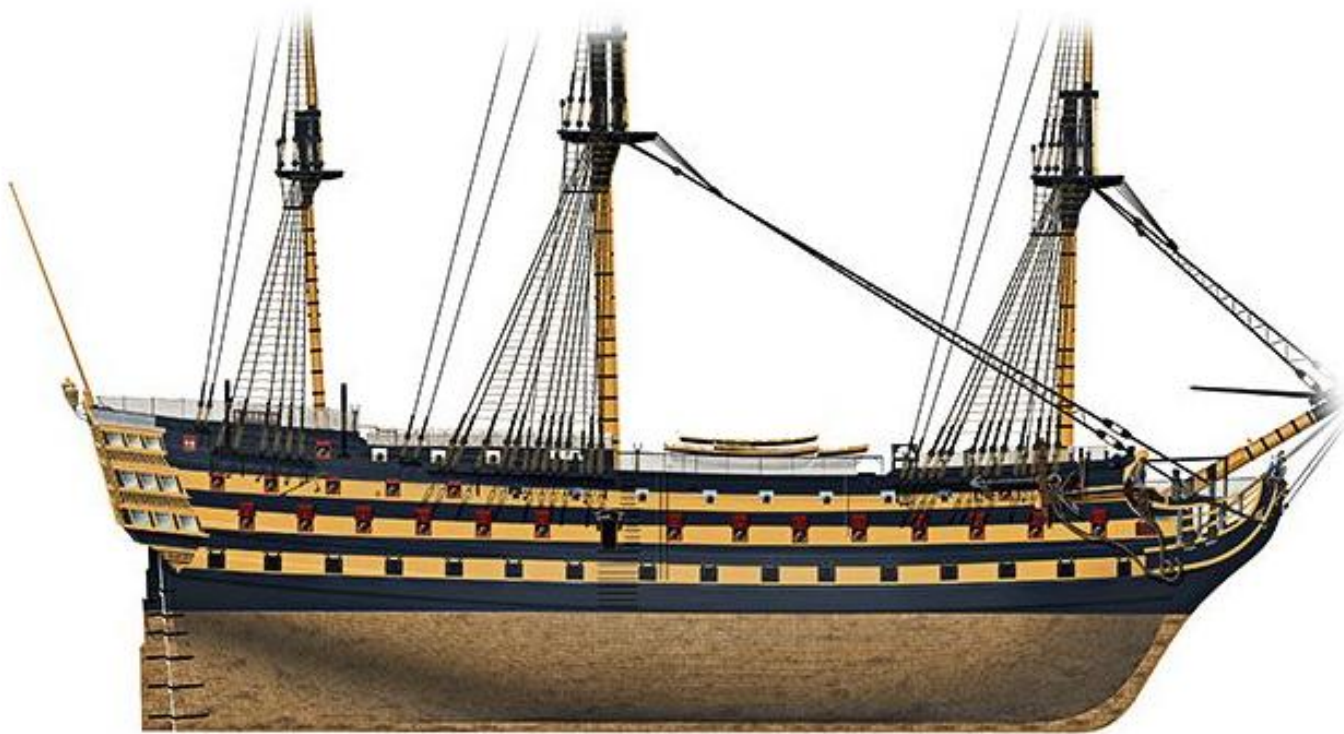
# HMS Victory

- Launched May 1765
- In dry dock since 1922
- Mostly wood
  - age and species vary
- Undergoing 10-year conservation project
  - Remove rotted outer planks and replace with modern oak
  - Can planks be pre-treated to prolong timber lifetime?



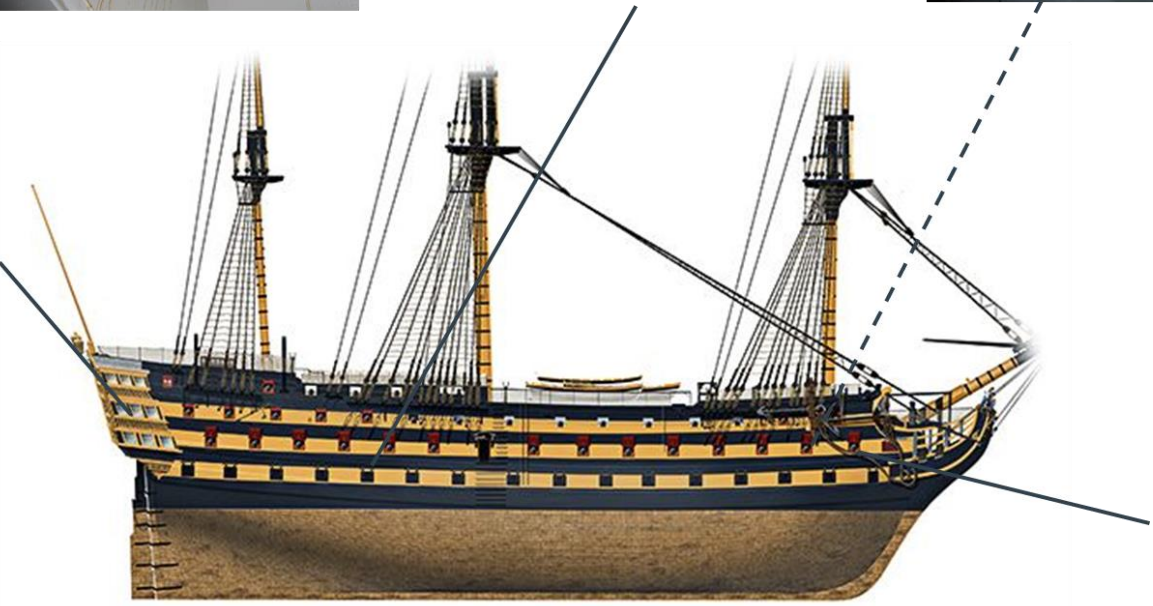
# Fungi on Victory

- Water ingress at many sites
- Painted timbers trap water
- Ideal conditions for fungi
- Fungi facilitate deathwatch beetle





# Fungi on Victory



# Project overview

- Are nanoparticles effective antifungal agents for oak?
    - *In vitro* antifungal activity
    - Permeation into modern oak
  - Are nanoparticles compatible with e.g. paint, mastics?
    - Any treatment must fit into workflow for replanking
-

# Project overview

- Are nanoparticles effective antifungal agents for oak?
    - *In vitro* antifungal activity
    - Permeation into modern oak
  - Are nanoparticles compatible with e.g. paint, mastics?
    - Any treatment must fit into workflow for replanking
-

# Nanoparticles tested

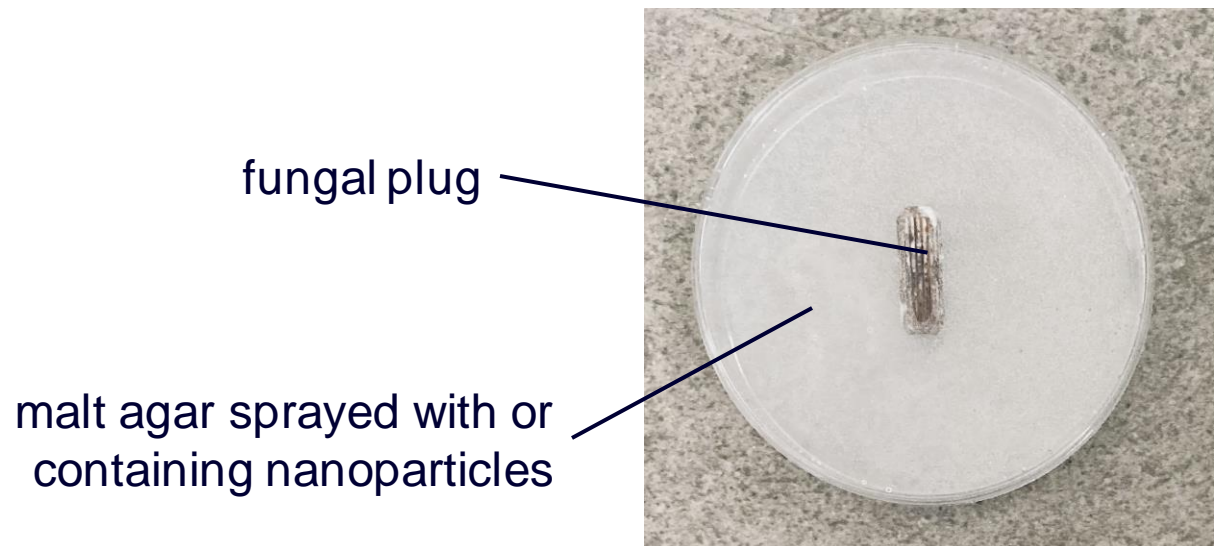
Properties*	ZnO	MgO	TiO <sub>2</sub>	SiO <sub>2</sub>
Antifungal	X	X	X	
Antibacterial	X	X	X	
Anti-insect	X	X		
UV protection	X	X	X	
Deacidification		X		
Hydrophobicity	X	X	X	X
Self-cleaning			X	X
Scratch resistance	X			X

\*as reported in literature

---

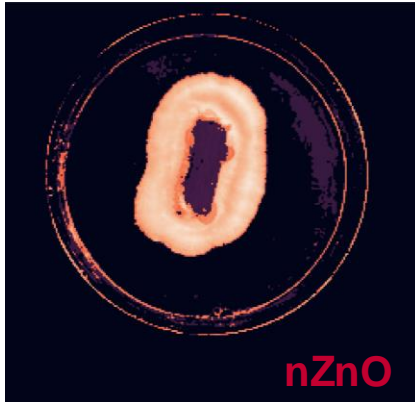
# *In vitro* antifungal tests

- Do nanoparticles stop fungal growth in the lab?
  - Method based on testing antibiotic efficacy
  - Nanoparticles on or in malt extract agar
  - Add fungi and observe how well they grow

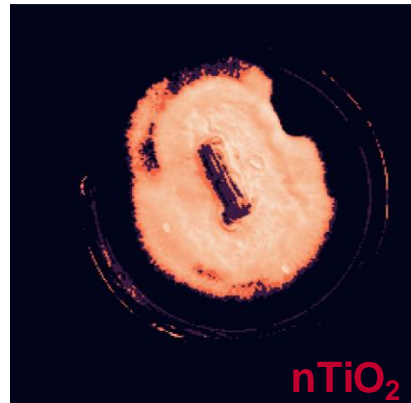
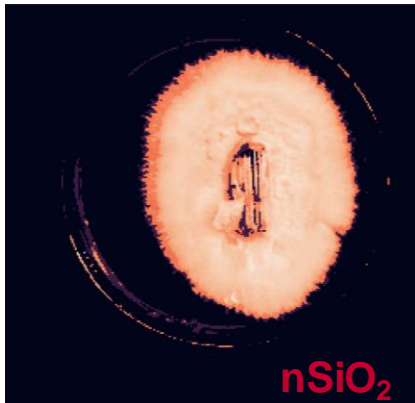
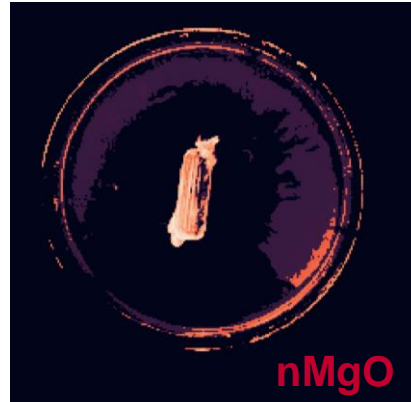


# 'Spiked' agar

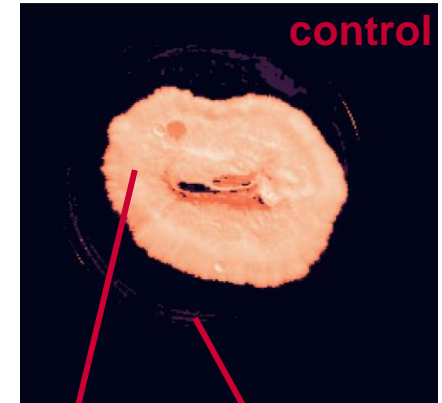
Some antifungal activity



Strong antifungal activity

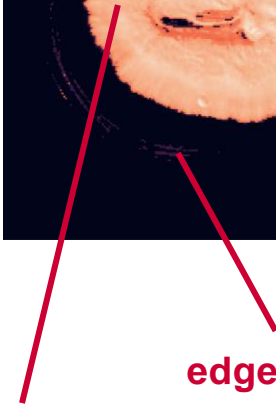


So apparent antifungal activity



fungal growth

edge of petri dish



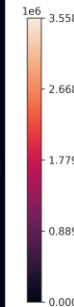
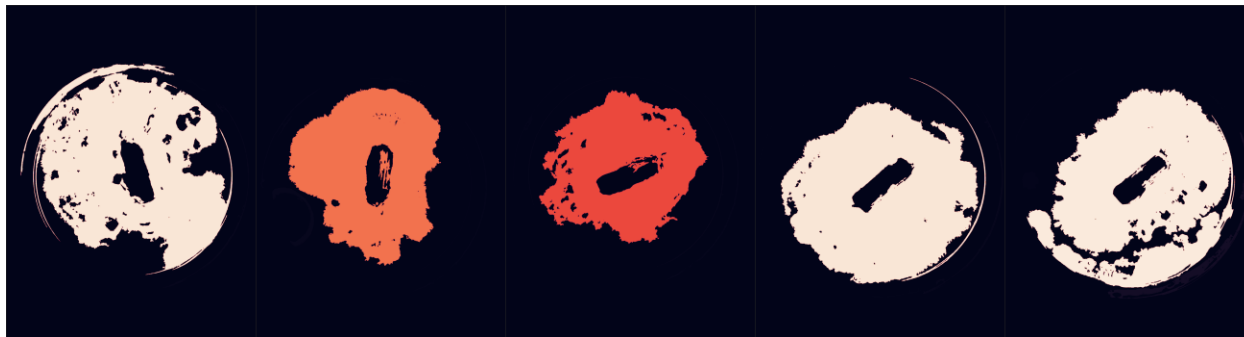
# Sprayed agar

THE  
NATIONAL  
MUSEUM

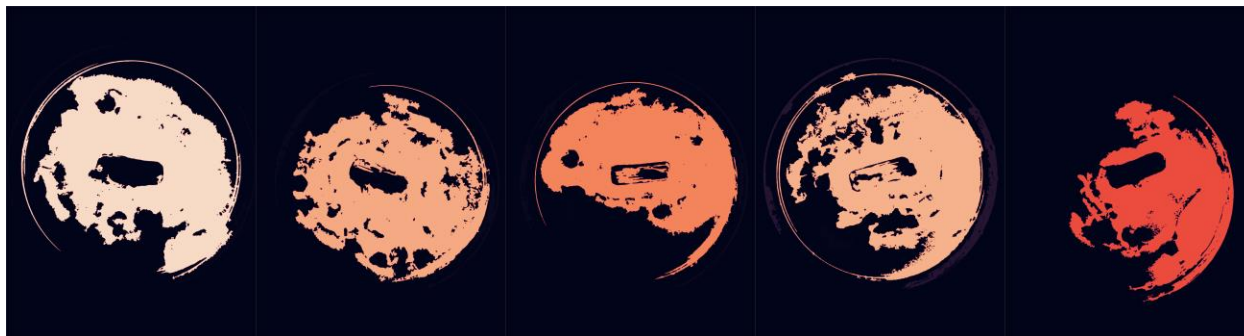


**control**  
water only

Colour reflects number of  
white pixels



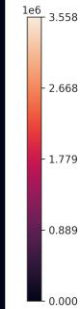
**nTiO<sub>2</sub>**  
no concentration-  
dependent inhibition



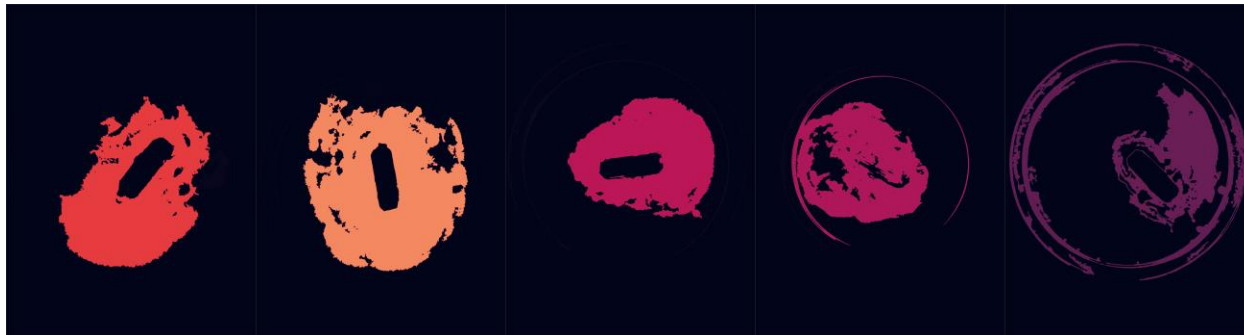
**nZnO**  
no concentration-  
dependent inhibition

# Sprayed agar

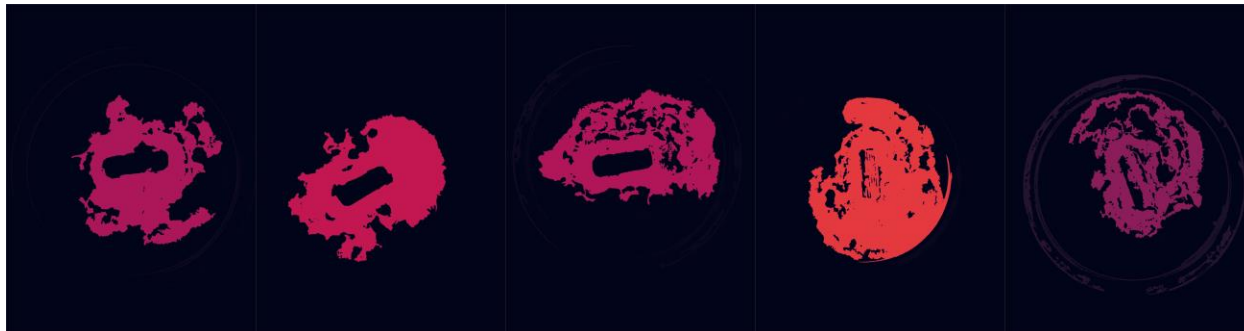
THE  
NATIONAL  
MUSEUM



**control**  
water only



**nMgO**  
concentration-  
dependent inhibition



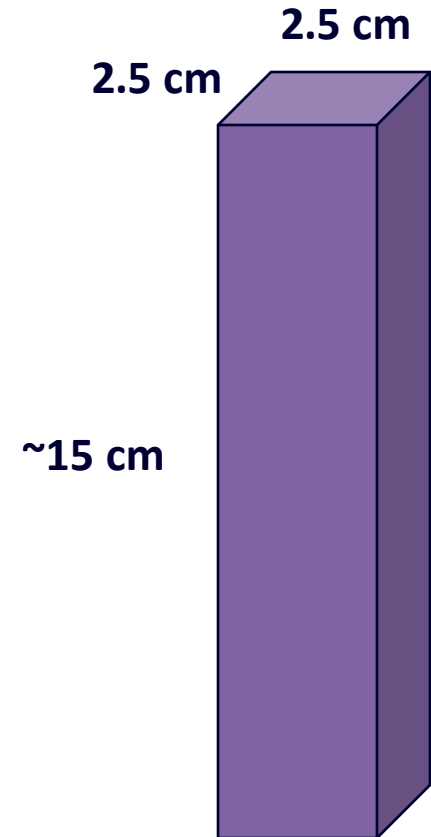
**nSiO<sub>2</sub>**  
some inhibition  
→ suspect indirect



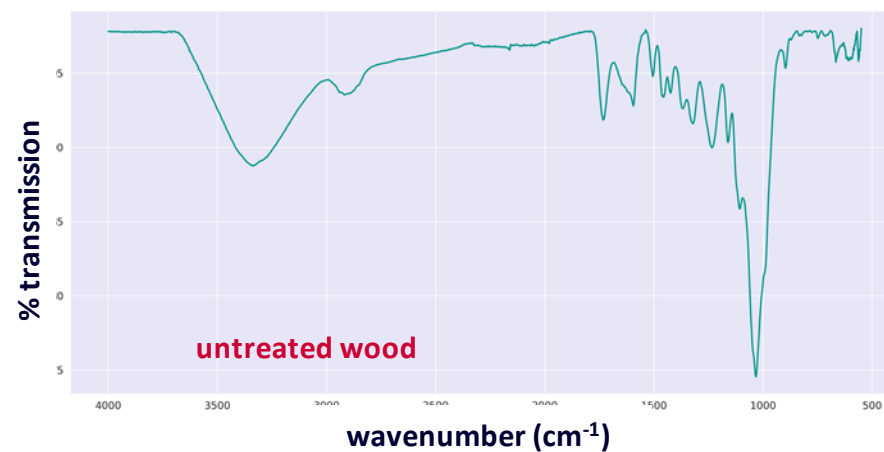
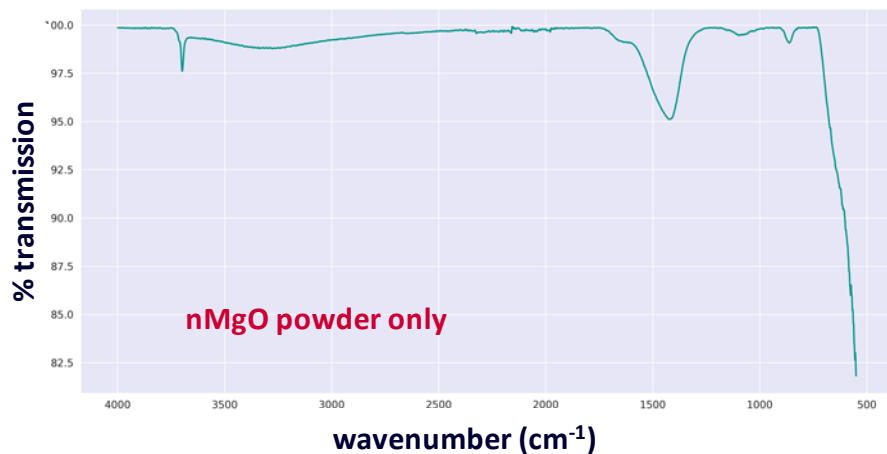
# Application to wood

## Pressure spray application

- 1) Spray with water to dampen wood
- 2) Mix 12.5 mg/mL nMgO dispersion in water
- 3) Shake vigorously
- 4) Spray wood surface until pooling
- 5) Remove excess
- 6) Leave overnight
- 7) Repeat



# FTIR\*



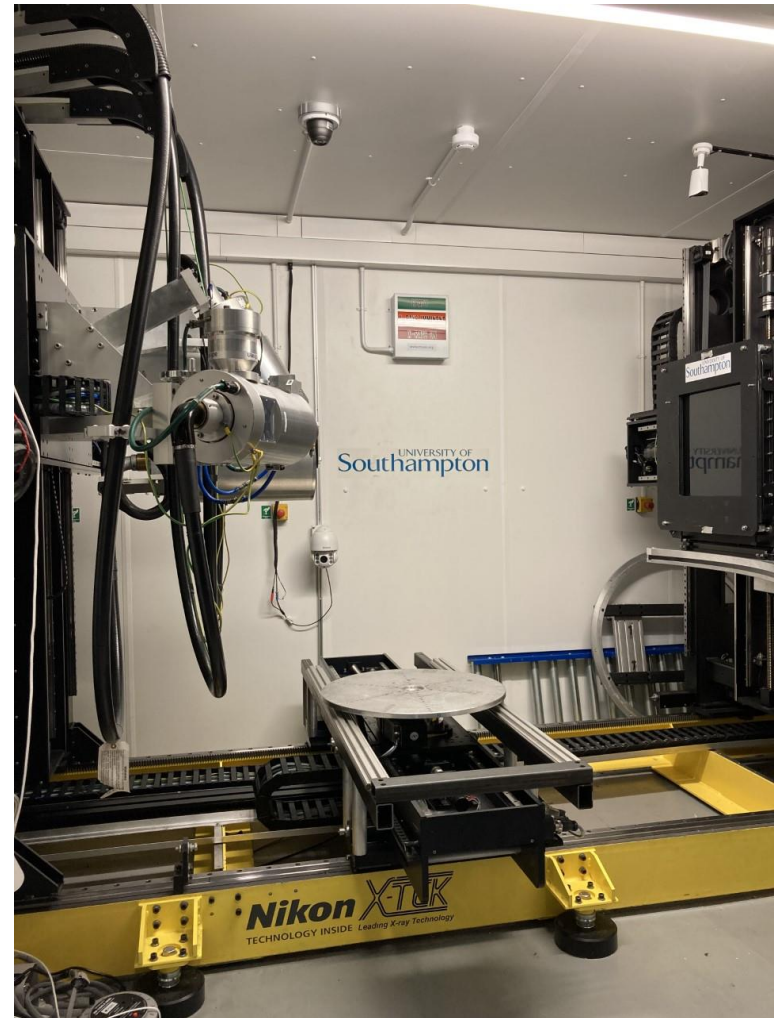
## \*Fourier Transform Infrared Spectrometry

→ detects specific chemical bonds

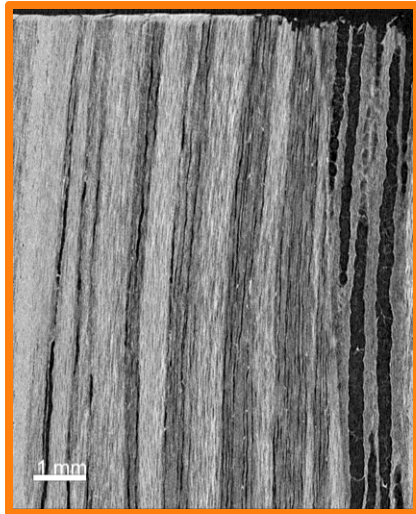
→ did not work for the other nanoparticles or boracol

- Observe internal structure
- Contrast based on different interaction with X-rays
  - Metal oxide nanoparticles show up as bright spots
- Low resolution but can scan whole sample without destroying the sample

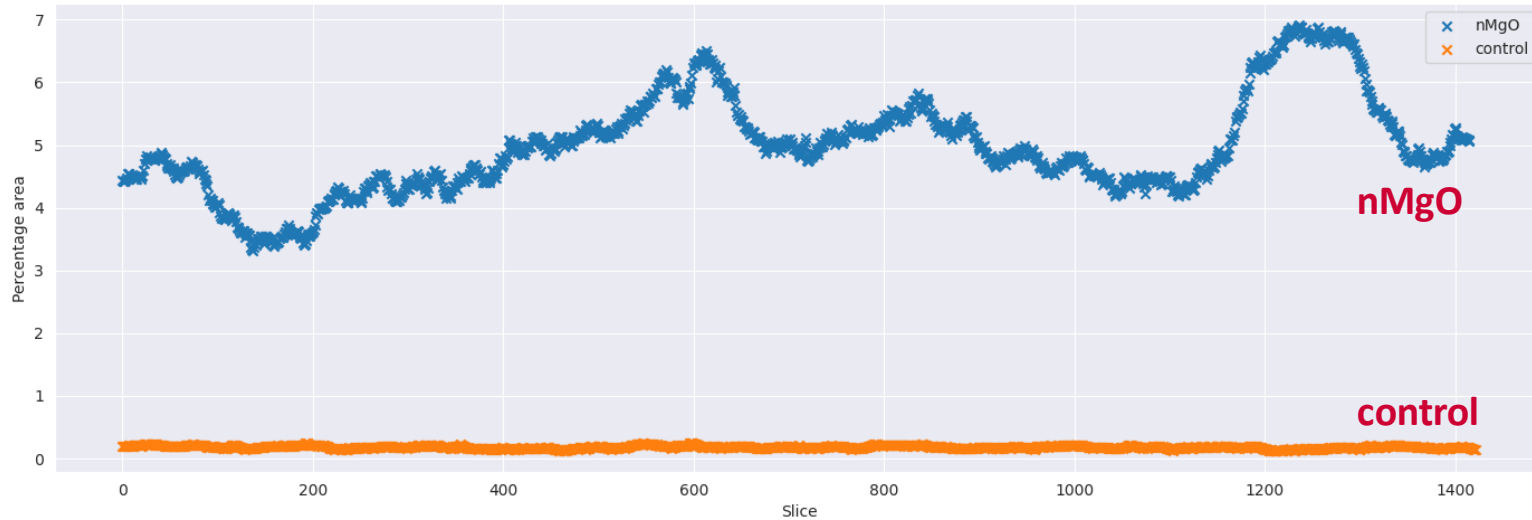
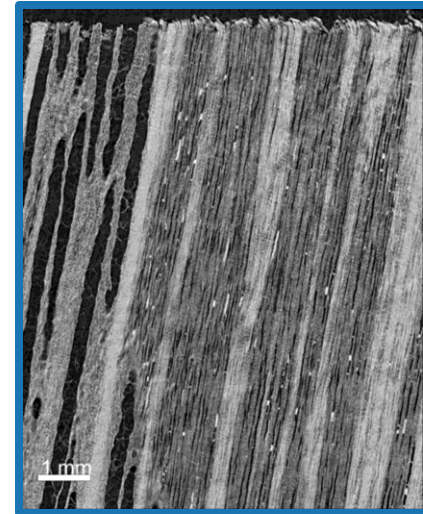
Micro computed tomography suite at  $\mu$ -Vis,  
Southampton University;  
used as part of NXCT scheme



# CT – control vs nMgO



Count  
number of  
bright spots  
per slice



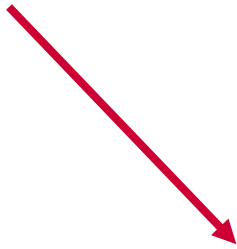
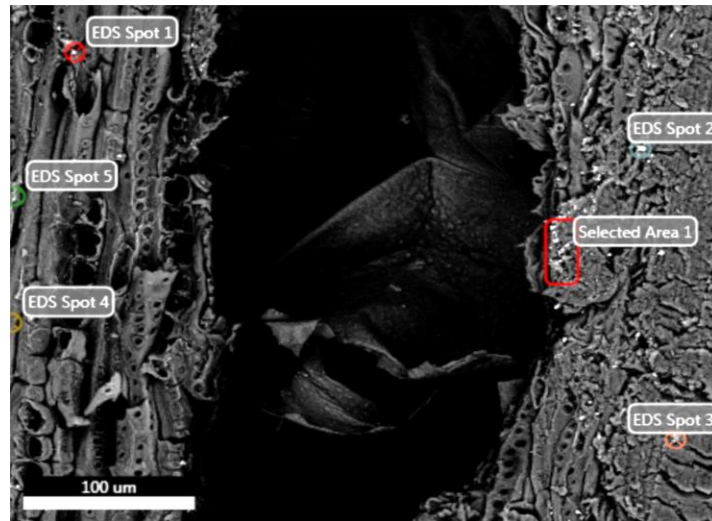
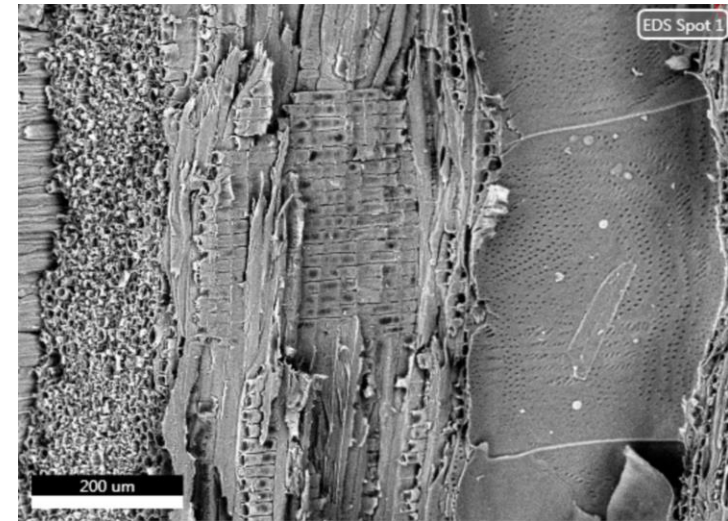
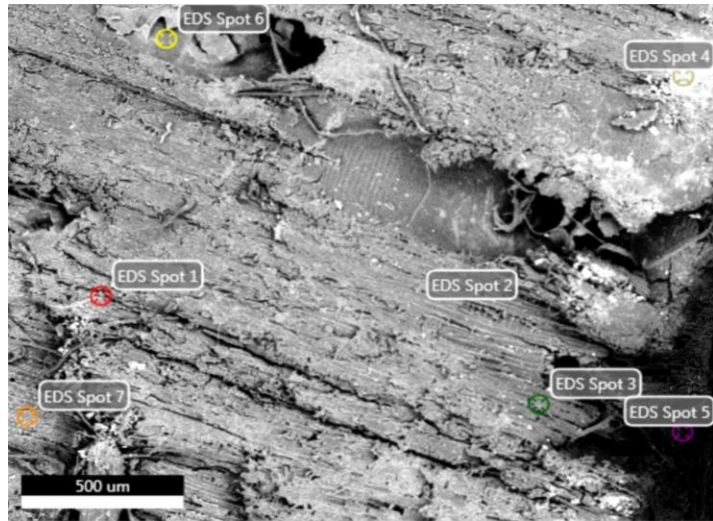
# SEM

- Scanning electron microscopy
- Visualise small structures
  - Nanoparticles still too small
  - Can only see clusters
  - Can detect elements

SEM facilities from Cranfield Defence Institute at  
Shrivenham

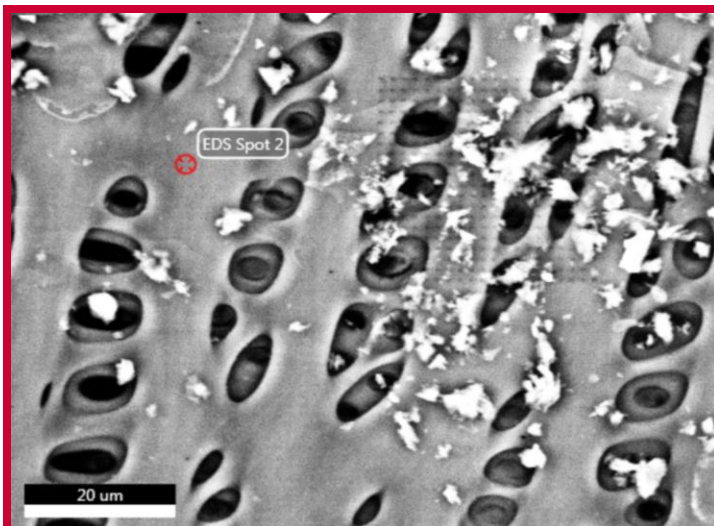


# SEM



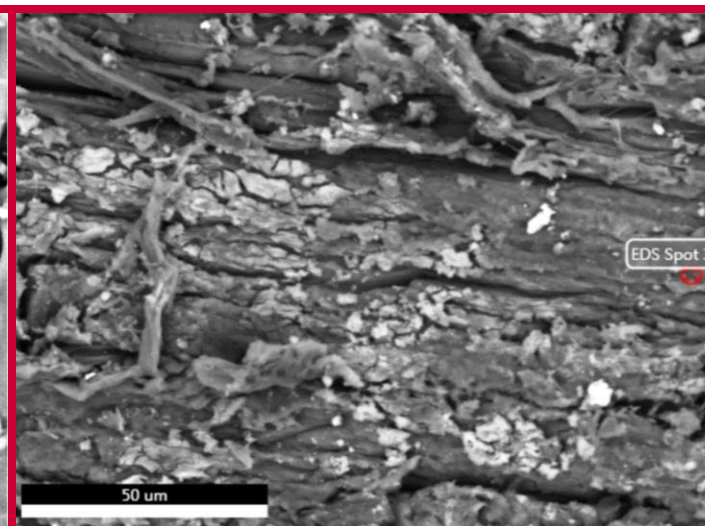
# SEM

nMgO

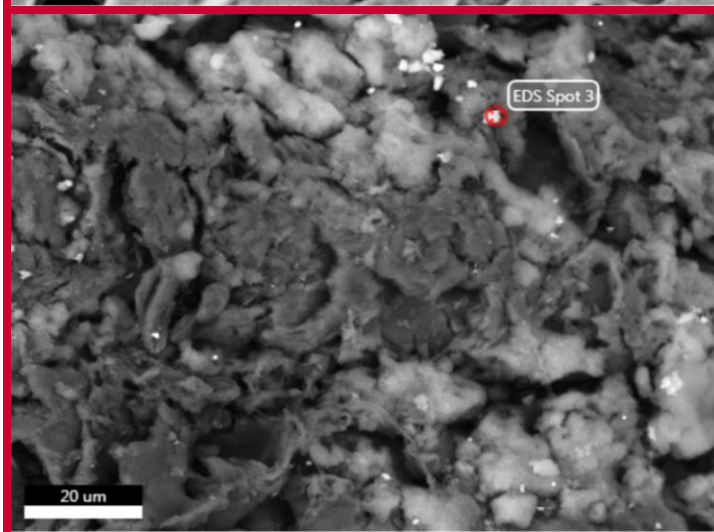


50 um

nZnO

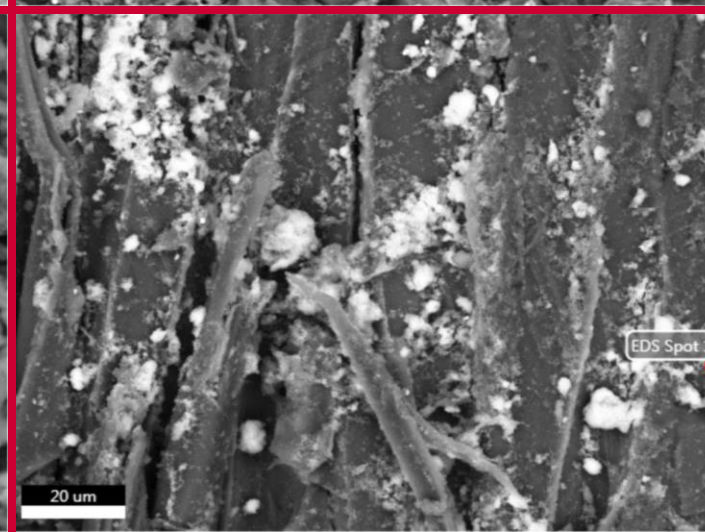


nSiO<sub>2</sub>



20 um

nTiO<sub>2</sub>



# Project overview

- Are nanoparticles effective antifungal agents for oak?
    - *In vitro* antifungal activity
    - Permeation into modern oak
  - Are nanoparticles compatible with e.g. paint, mastics?
    - Any treatment must fit into workflow for replanking
-



# Is it viable in practice?

- Spray application
  - Quick
  - Scalable
  - Relatively cheap (no expensive kit required)
- Test applicability with\*:
  - Paint
  - Caulking
  - Adhesives

\*Testing done by NC2 at Southampton University

---

# Further work

- Scaled up test
    - On plank closer to the size used on Victory
    - Does it still work?
    - How long to dry? etc.
  - SEM after UV exposure or soaking of painted samples
  - nMgO on fungal fruiting bodies
  - High resolution CT scans
  - CT and SEM of boracol-treated samples
-

# Acknowledgements



## **National Museum of the Royal Navy**

Diana Davis  
Sadie Wilson  
Rachel Trembath  
Morgan Creed  
Jenna Taylor  
Jimmy Green

## **Mary Rose (FTIR use)**

Dr Eleanor Schofield

## **nC<sup>2</sup> (material testing)**

Dr Spencer Court  
Dr Nicola Symonds  
Rachel Triggs

## **μ-Vis (CT scans)**

Dr Kathryn Rankin  
Dr Fernando Alvarez-Borges

## **Cranfield University (SEM use)**

Dr Fiona Brock  
Dr Jonathon Painter

---