

# Three-Dimensional Structure Investigation and Analysis of A Barrier Anticorrosive Marine Coating by Ptychographic X-ray Tomography

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Cambridge, SEP., 2014

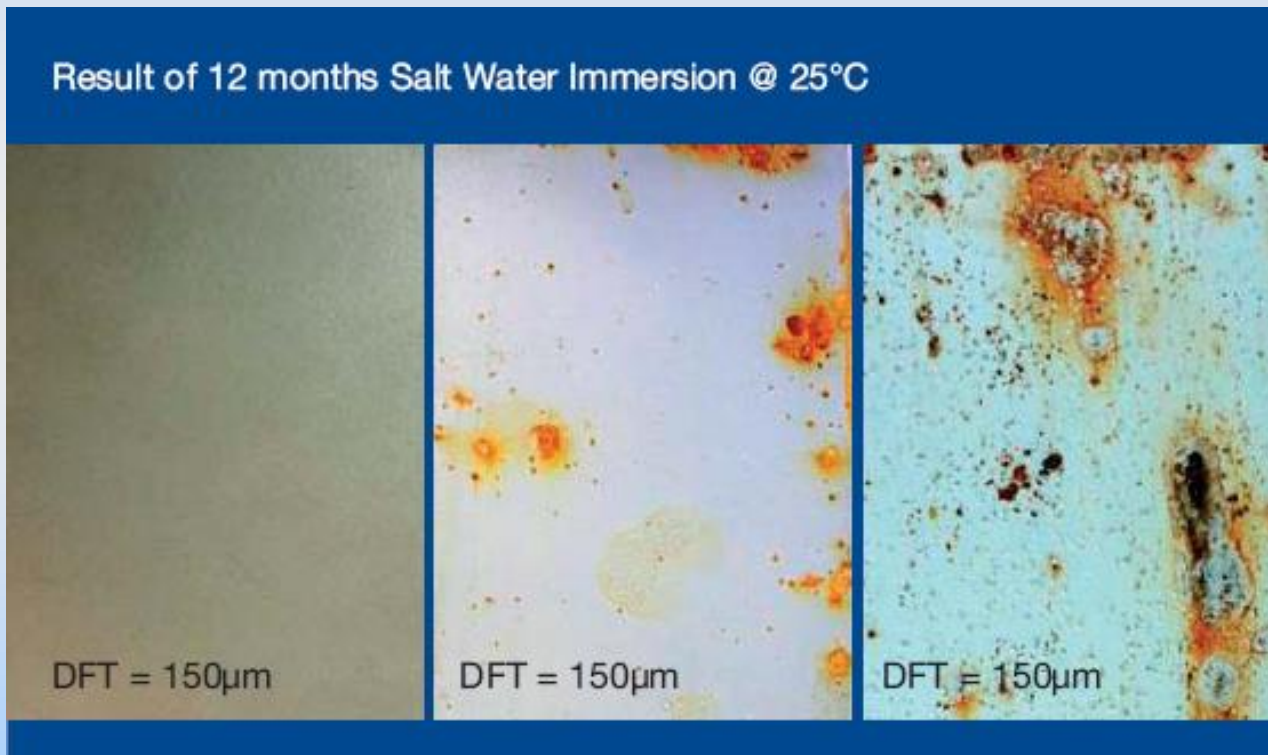
A DHPA (Dorothy Hodgkin Postgraduate Awards) PhD project supported by the EPSRC and AkzoNobel Group

# CONTENTS

- 1. Introduction of the coating sample;**
- 2. Introduction of 3D Ptychographic X-ray Tomography and results obtained;**
- 3. Quantitative analysis of 3D structure images and percolation property simulation based on the obtained real 3D structure.**

# 1. Barrier Anticorrosive Marine Coating

Our target sample is aluminium epoxy paint which is a kind of barrier anticorrosive marine coating for vessels.



**Al. Epoxy**

**Pure Epoxy A**

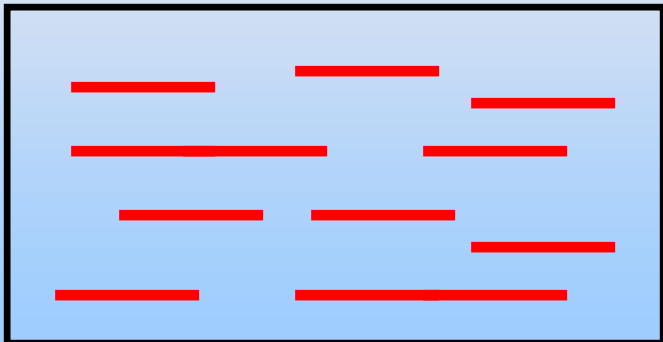
**Pure Epoxy B**

# 1. Barrier Anticorrosive Marine Coating

The target aluminium epoxy coating is mainly composed by aluminium flakes, iron oxide particles and epoxy resin.

It provides outstanding long term anticorrosive property. The flake-shape aluminium pigments and their alignment parallel to the surface improve the coating barrier properties by decreasing the transporting rate of corrosive substances like ion, water (vapour) and oxygen through coating films.

**Ideal structure expected to be revealed:**



— Aluminium Flake

# 1. Barrier Anticorrosive Marine Coating

Annual direct cost caused by corrosion is over 3% of GDP for industrial countries. Major part of this due to painting.

From Whitepaper of the World Corrosion Organization (2009)



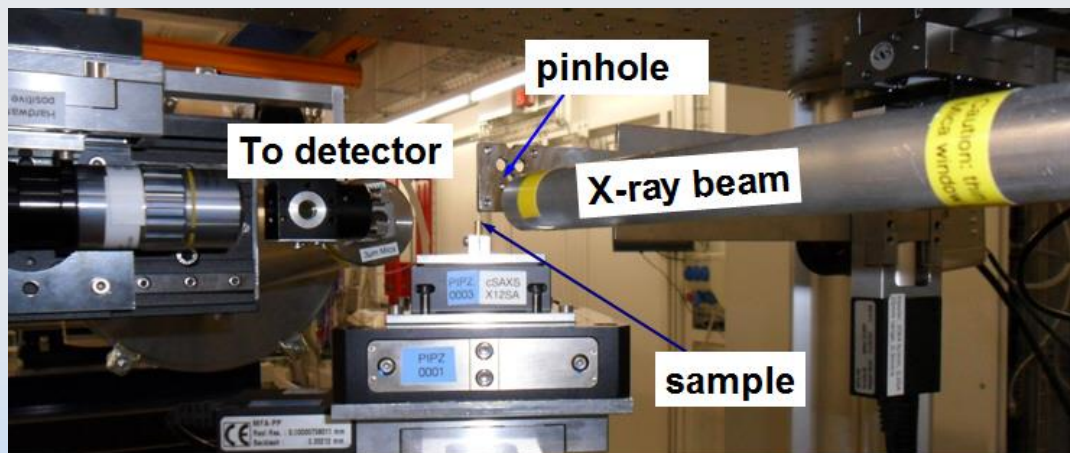
*Erika*, broke up in 1999 off the coast of Brittany, leaked 20,000 tonnes of oil into the sea. This was a “direct consequence of the serious rust corrosion”.

--(Judge Joseph Valantin)

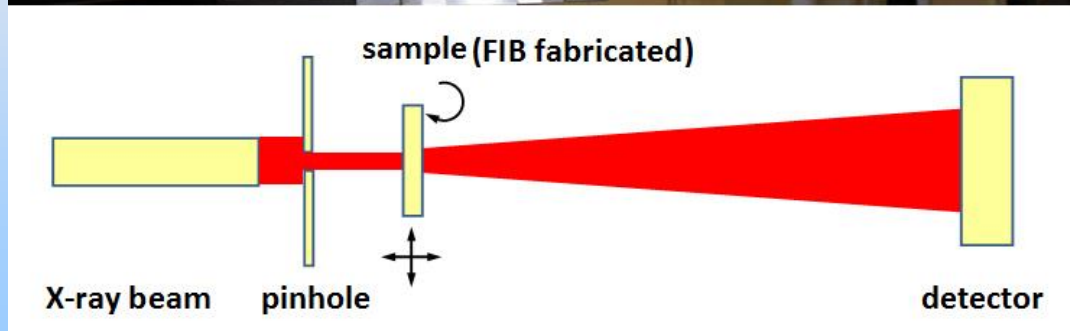


## 2. 3D Ptychographic Tomography

**3D Ptychographic X-Ray Tomography** is a scanning coherent X-ray diffractive imaging method which combines X-ray ptychography imaging together with 3D X-ray tomography technique. The following figure displays the experimental set-up of the method.

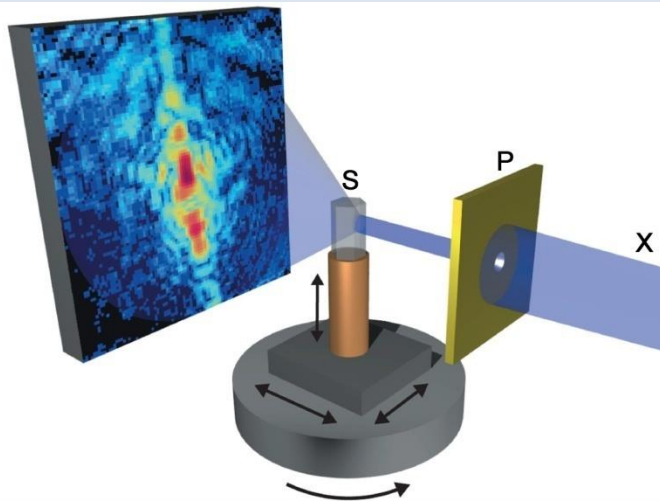


Set-up of the 3D ptychographic X-ray tomography. Upper photo is the on-site experimental set-up; lower diagram is a schematic expression.



## 2. 3D Ptychographic Tomography

OR



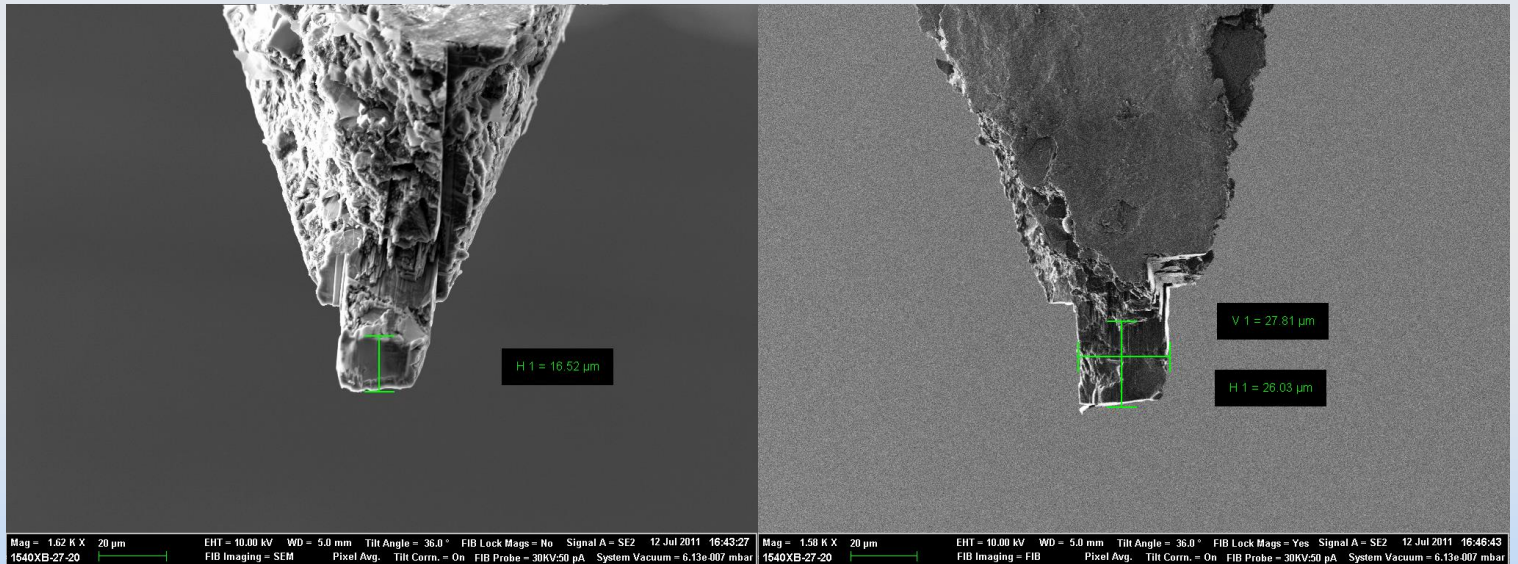
Tomographic projection at each rotation angle is reconstructed from multiple X-ray diffraction patterns by ptychography using a difference-map phase-retrieval algorithm. Generated Phase contrast projections are then reconstructed into 3D images by a revised filtered back-projection algorithm.

M. Dierolf et al., "Ptychographic X-ray computed tomography at the nanoscale," [Nature. 467, 436-439 \(2010\).](#)

## 2. 3D Ptychographic Tomography

### FIB fabricated samples for the 3D Ptychographic X-Ray Tomography

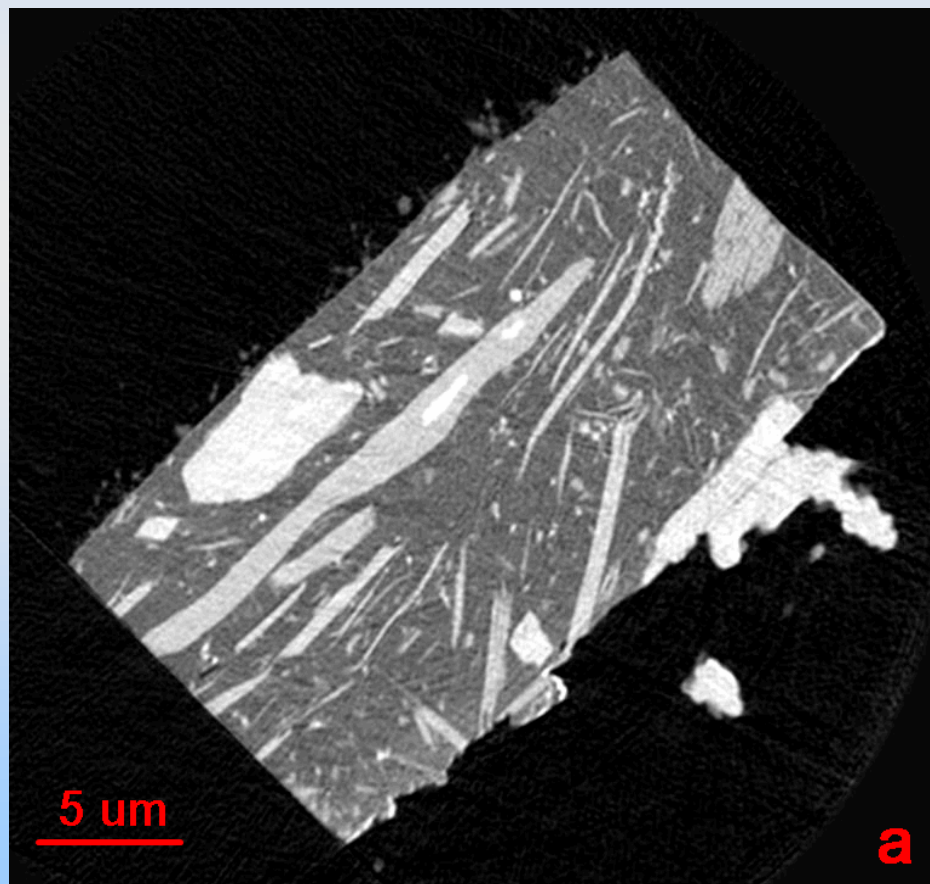
Al. epoxy  
marine  
coating



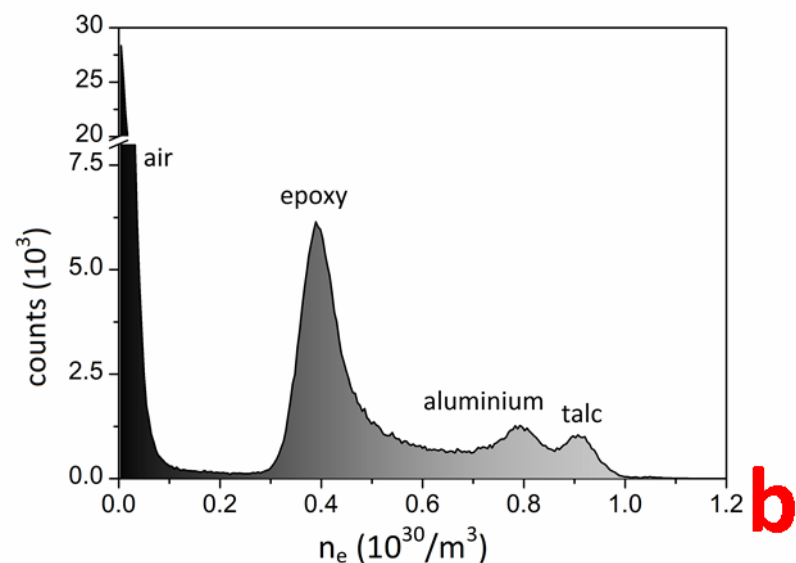


## 2. 3D Ptychographic Tomography

Results of the Al. epoxy marine coating obtained from 3D Ptychographic Tomography

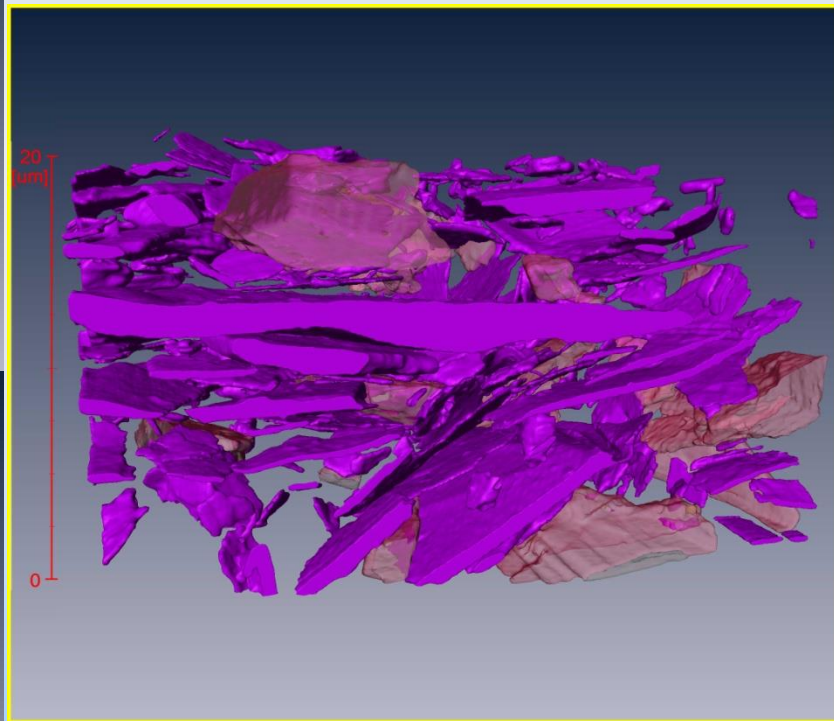
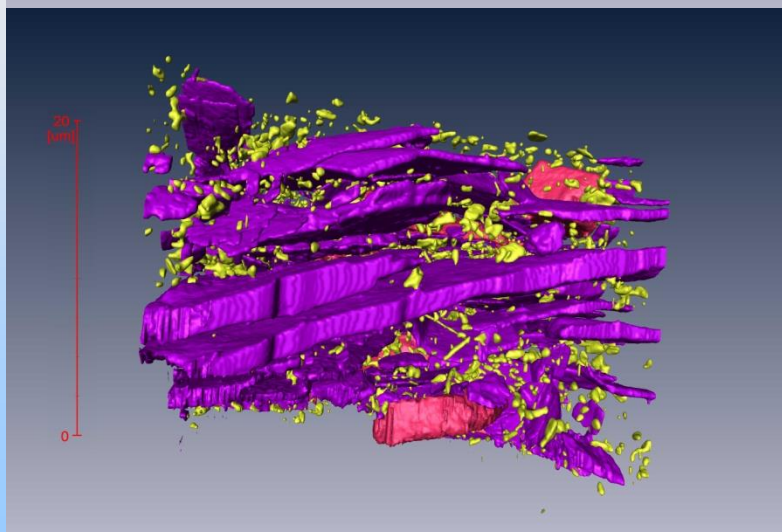
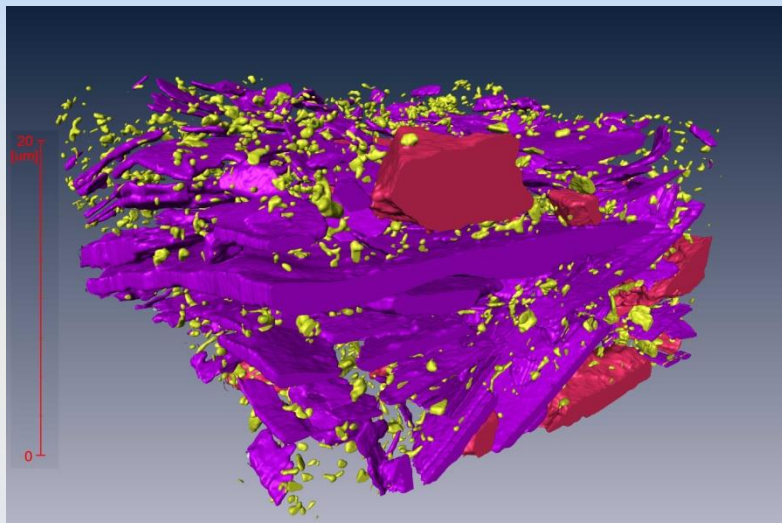


Degassed Al.  
epoxy marine  
coating



## 2. 3D Ptychographic Tomography

### 3D rendering of the degassed Al. epoxy marine coating

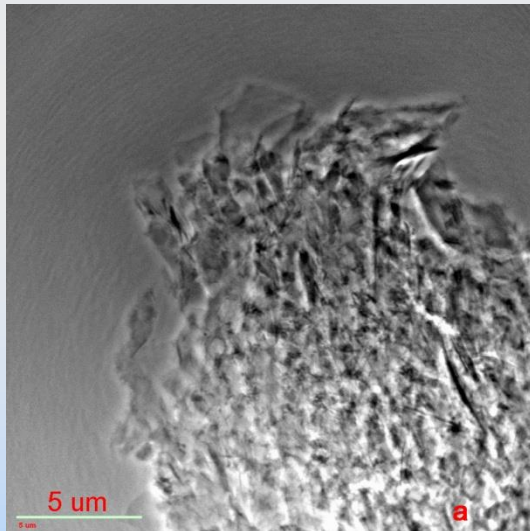


## 2. 3D Ptychographic Tomography

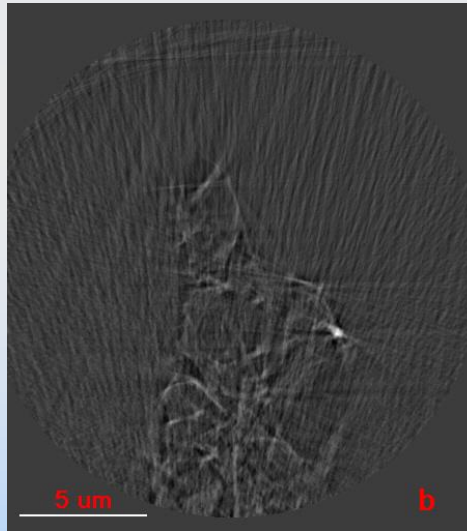
Compare with results from TXM:

**Sample:** Degassed Al. epoxy marine coating

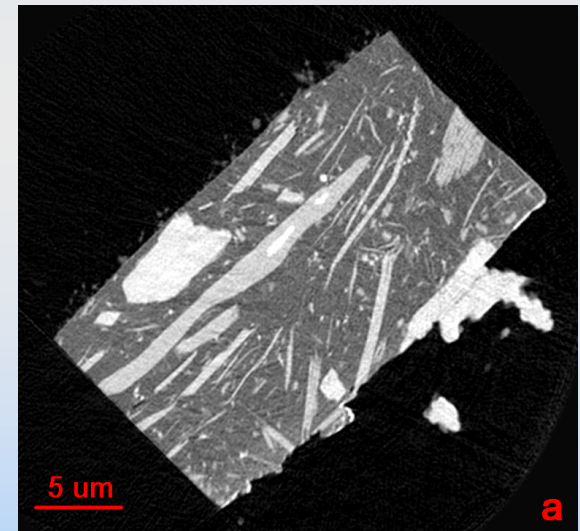
**TXM Projection**



**Reconstructed Slice**



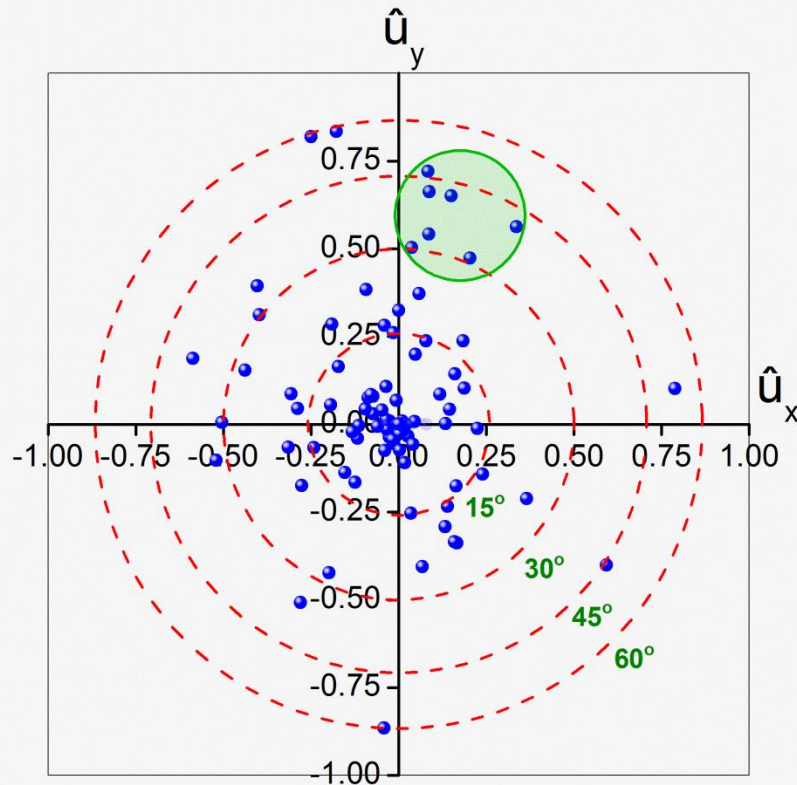
**Ptycho-tomo slice**



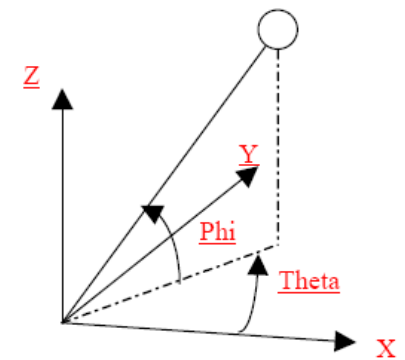
**BIG DIFFERENCE**

# 3. Data Analysis and Simulation

Orientation analysis of the Al. flakes in the marine coating sample based on results obtained from 3D ptychographic tomography:



Coordinate description for 3D images :





### 3. Data Analysis and Simulation

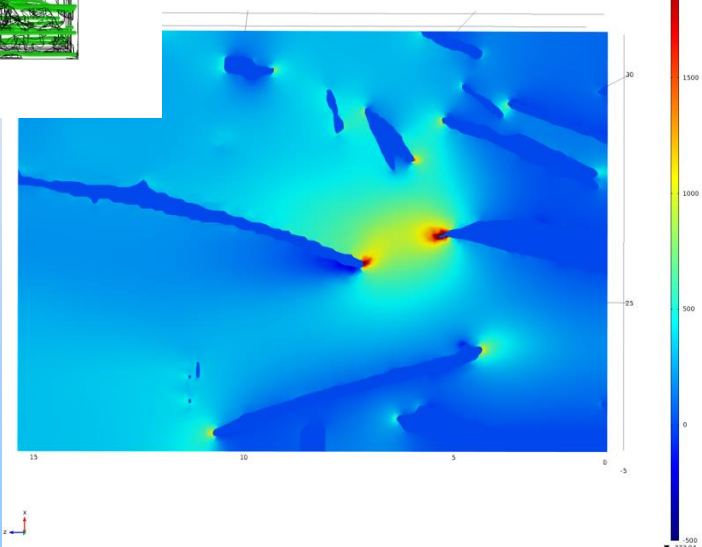
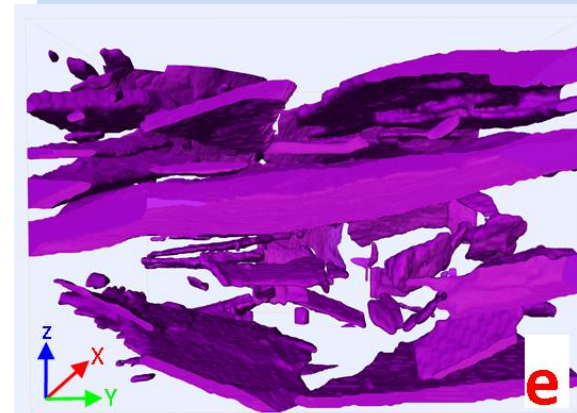
**Orientation analysis of the Al. flakes in the marine coating sample:**

**Most big Al. flakes in the materials are intend to be PARALLEL to each other and to the surface;**

**The deviations from the surface orientation of the majority of Al. flakes are 2-15 degree .**

# 3. Data Analysis and Simulation

Results of percolation coefficient simulation on X-ray results:



B. Chen, *et al*, *Sci. Rep.* 3 (2013) 1177

$$E = \sigma_z / \sigma_y$$

Relative Errors

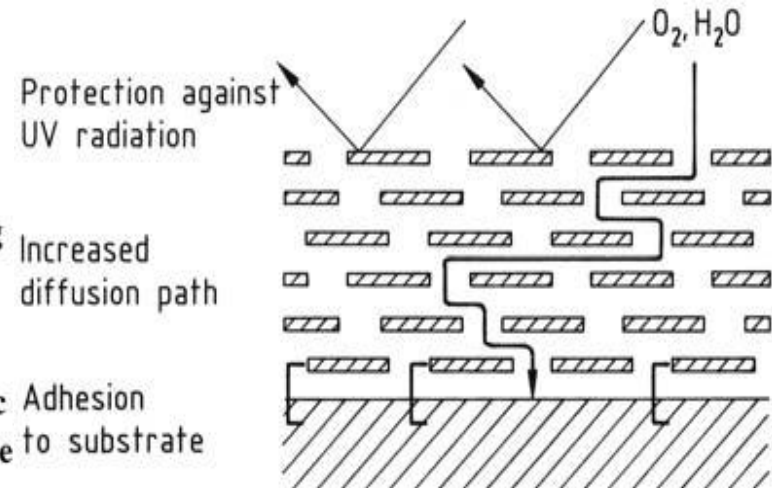
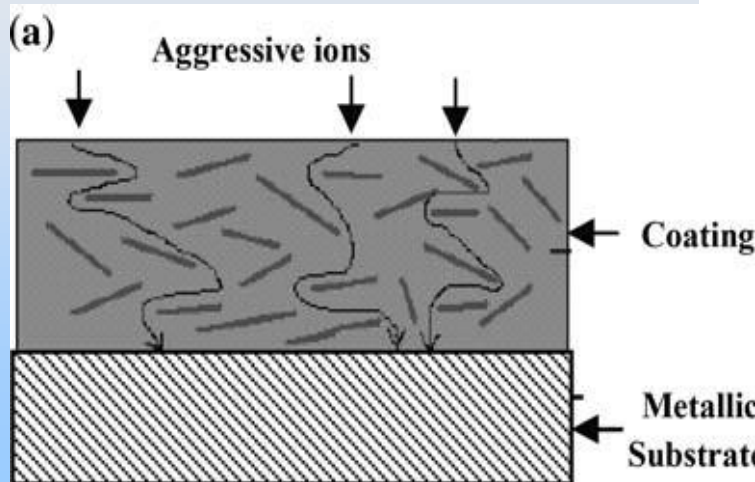
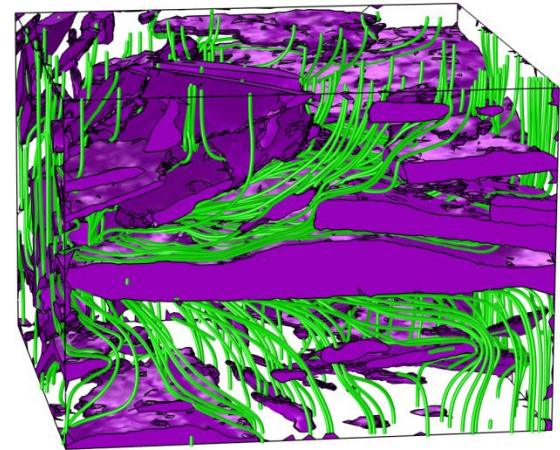
0.358

0.0084

# 3. Data Analysis and Simulation

B. Chen, *et al*, Sci. Rep. 3 (2013) 1177

**Simulated behaviour of ions through marine coatings VS Schematic diagrams established**

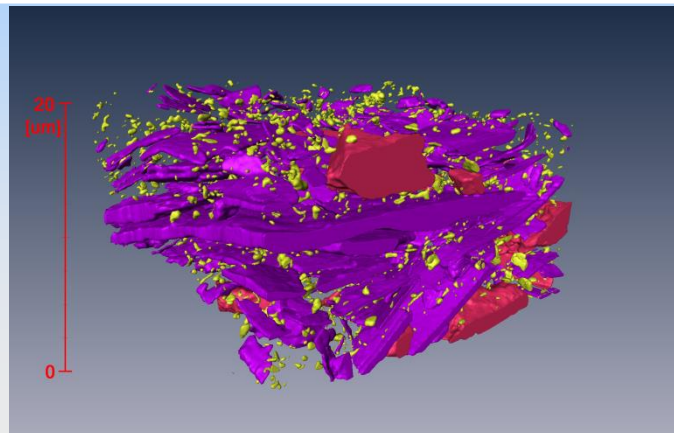
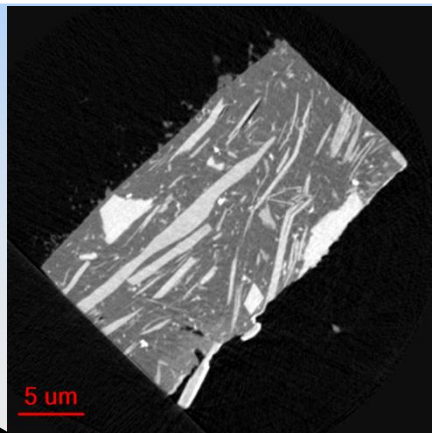


J. Coat. Technol. Res., 5 (2) 241–249, 2008

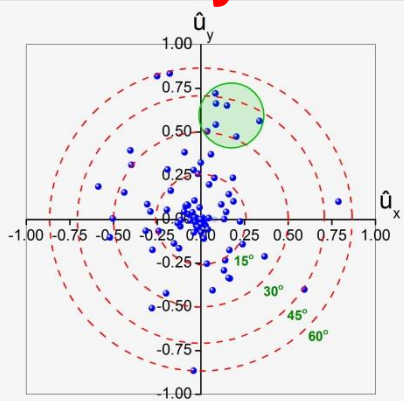


# 3. Data Analysis and Simulation

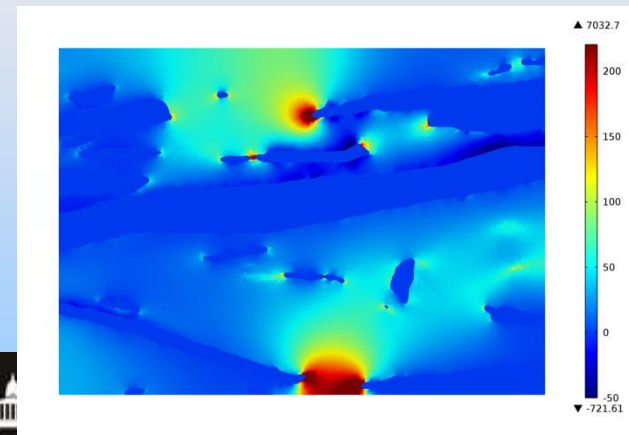
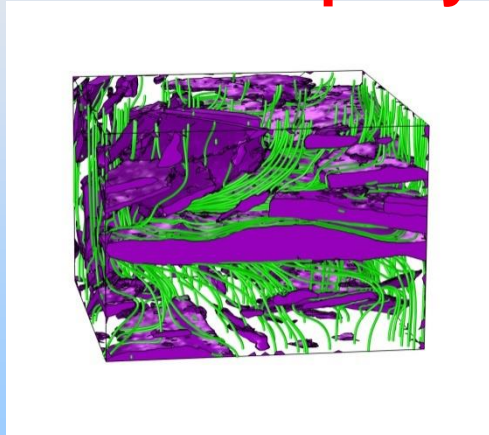
## Structure Characterization



## Analysis



## Property Simulation





**Thanks for  
Your Attention!**