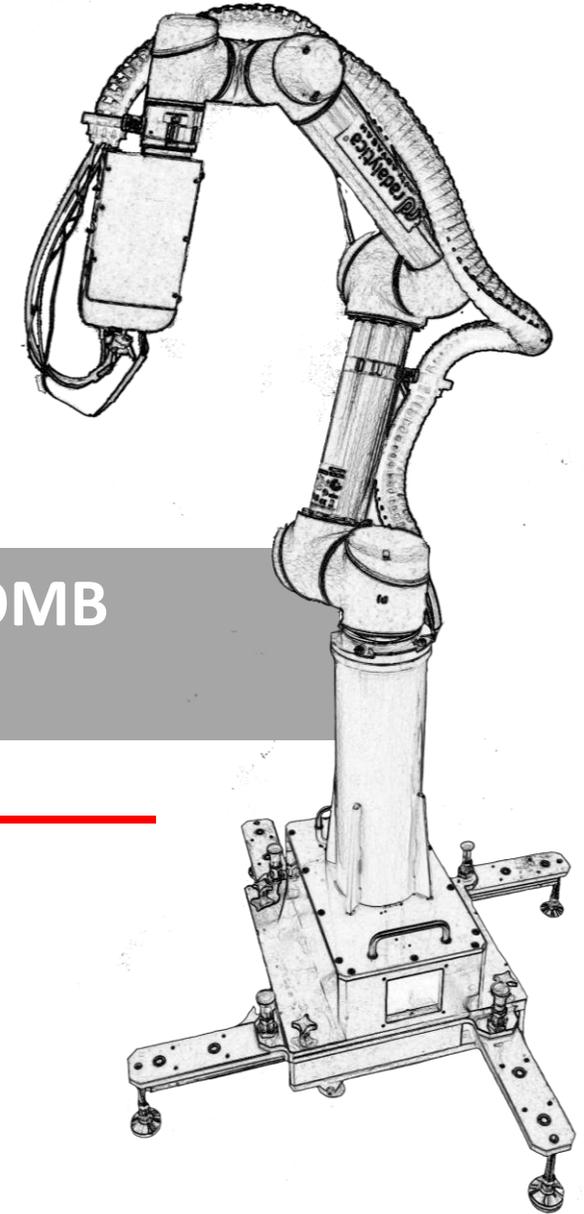


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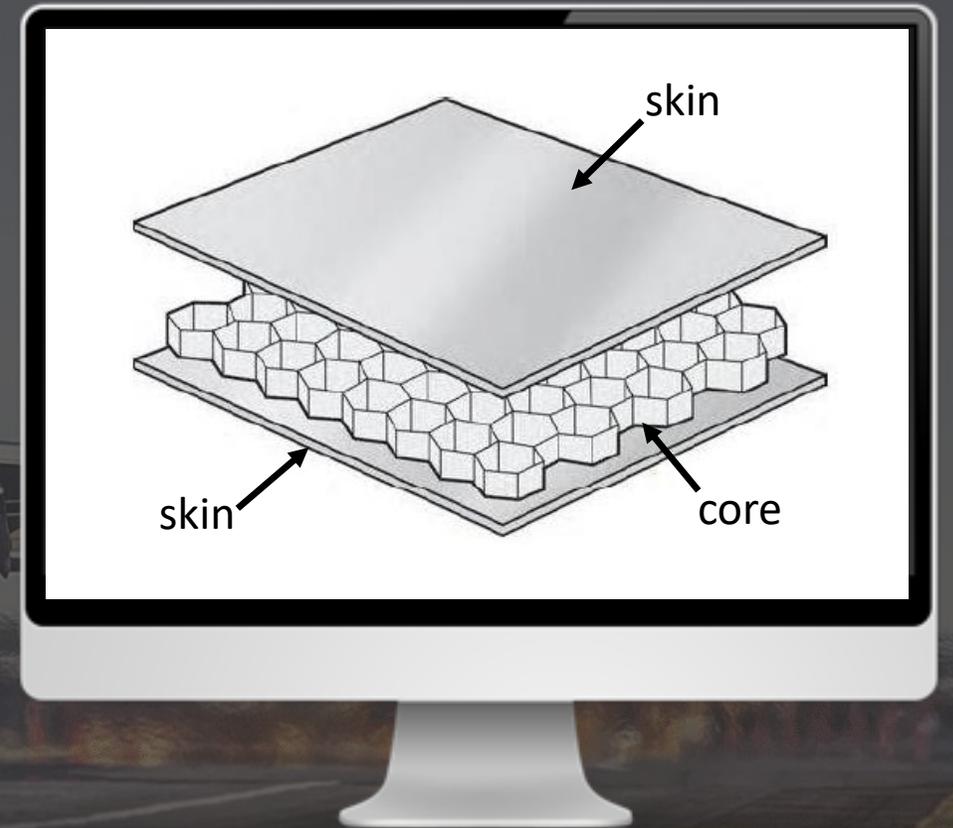
**DETECTION OF WATER IN HONEYCOMB
STRUCTURES**

HONEYCOMB SANDWICH STRUCTURES

Honeycomb structures

Honeycomb structures, inspired from bee honeycombs, are one of the most valued structural engineering innovations developed by the composites industry. Combination of two skins with a metallic, plastic or other honeycomb core increases stiffness of the structure up to 40x.

**Water in
honeycomb cells may lead to
sandwich destruction
in flight!**



WHY TO DO WATER INGRESS CHECK ON HC PANELS ?

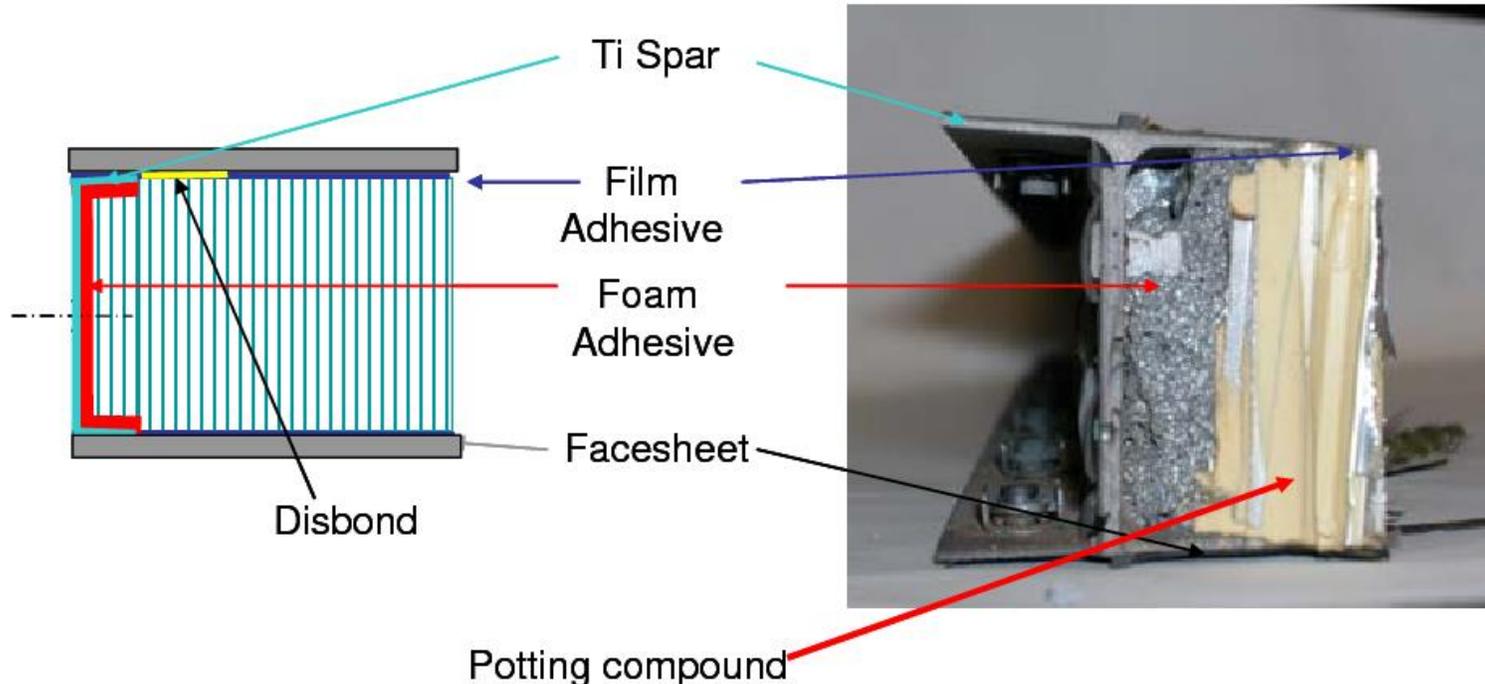


In-flight disintegration of a rudder on a CF-18 Hornet in 1999 and other similar occurrences in the F-18 fleets of other countries led to extensive investigations of in-service degradation of these sandwich structures. The flight control surfaces of F/A-18 aircraft are composed of carbon/epoxy skin and aluminum honeycomb core composite material that has a known susceptibility to water ingress. The rudder has failed in flight due to moisture induced bond degradation between skin and core.

WHY TO DO WATER INGRESS CHECK ON HC PANELS ?

Moisture ingress in aircraft honeycomb sandwich structures is an ongoing issue that has attracted significant attention from aircraft operators, maintenance depots and the research community. Moisture ingress can lead to skin-to-core bonding degradation, affecting structural integrity.

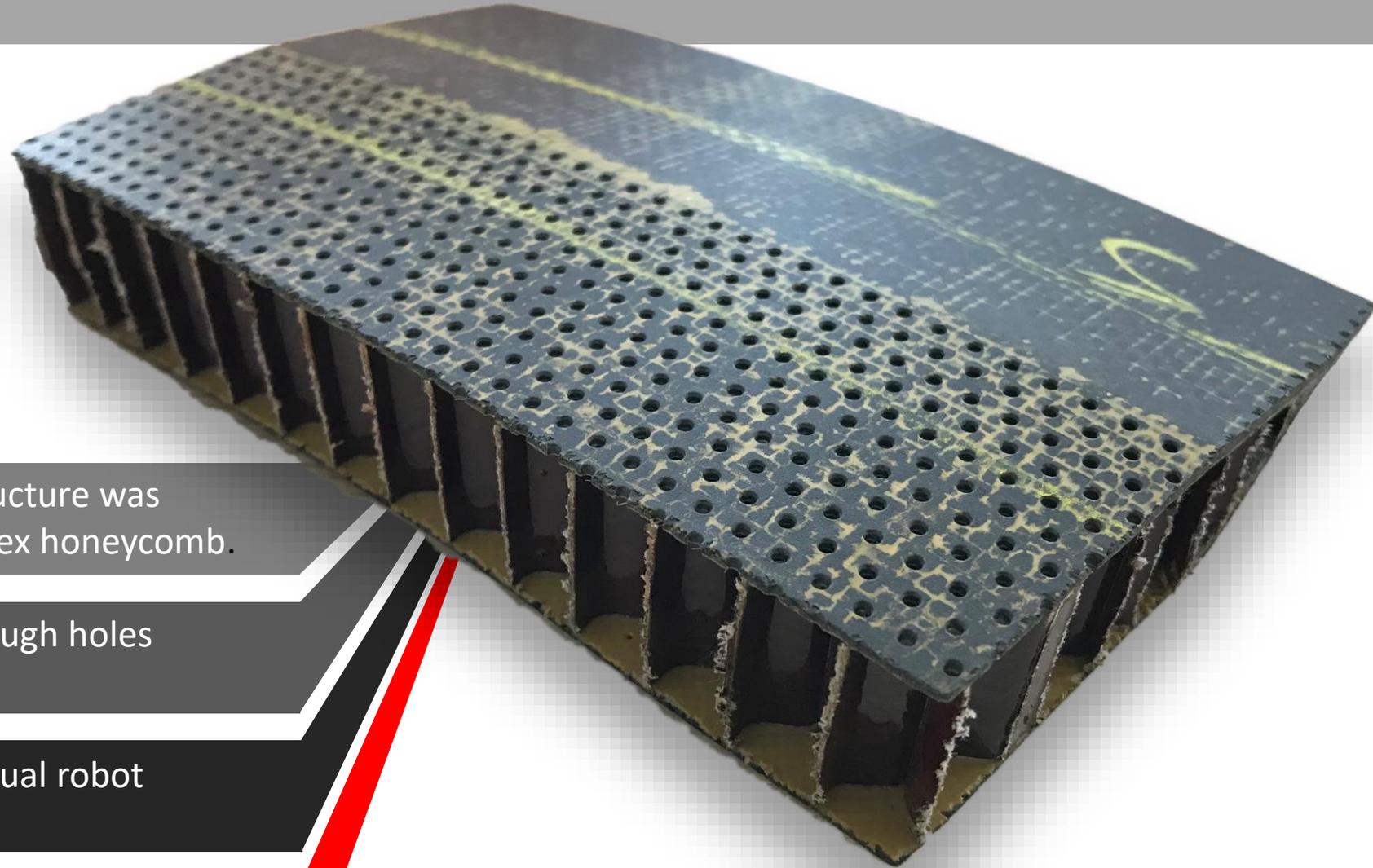
It is a big maintenance burden and excessive aircraft downtime. Moisture removal approaches used for similar structures are usually complex and invasive.



Typical affected areas:

- Rotor blades
- Nose landing gear doors
- Elevator/ Rudder

TEST SAMPLE – HONEYCOMB SANDWICH WITH WATER



Detection of water in honeycomb structure was tested on a CFRP sandwich with Nomex honeycomb.

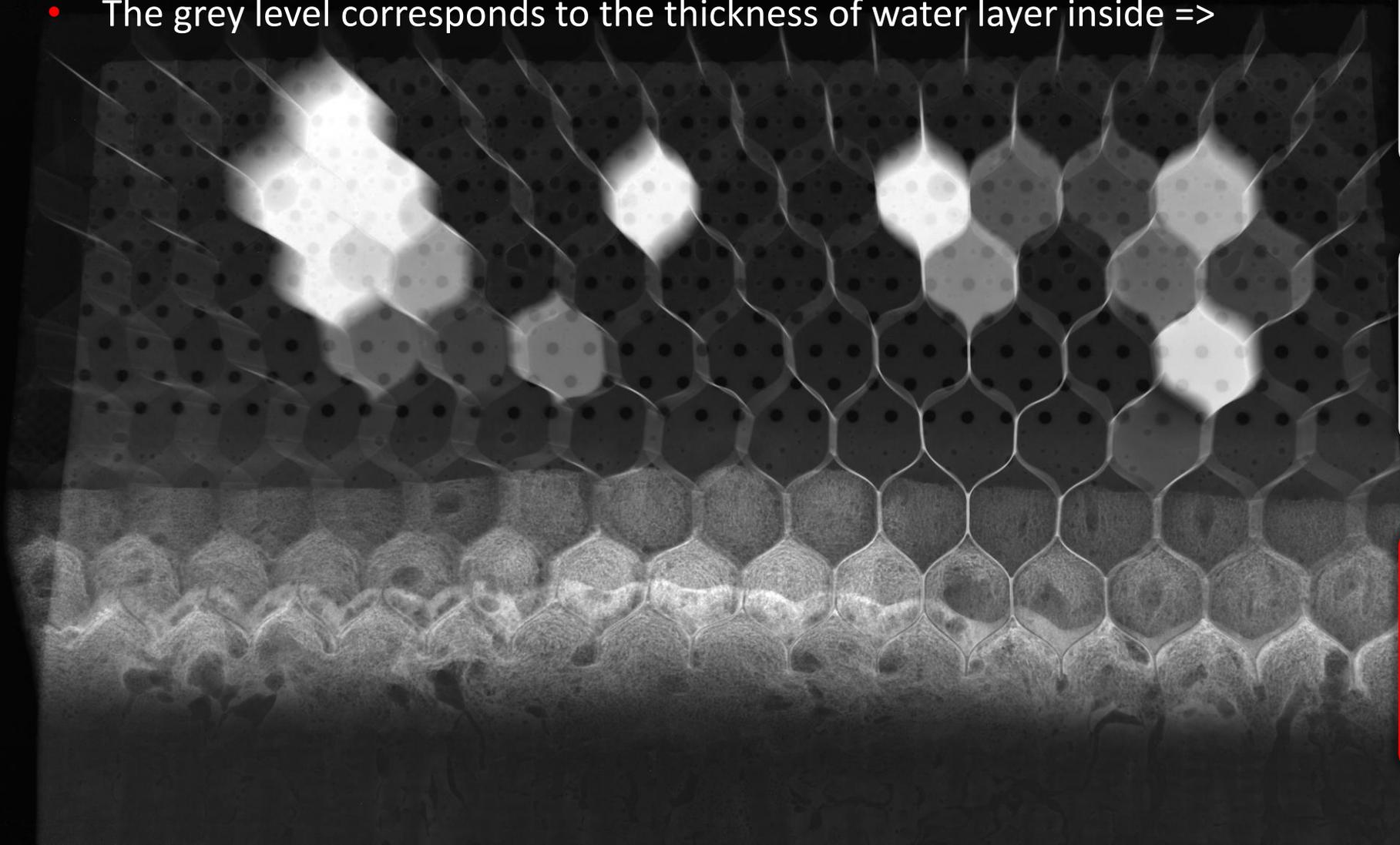
The water was injected into cells through holes in one of skins.

The sample was measured with the dual robot RadalyX scanner.

Different amounts of water were used to simulate changing filling of cells with water.

2D X-RAY SCAN

- 2D x-ray image easily **reveals cells with water**.
- The grey level corresponds to the thickness of water layer inside =>



X-ray imaging can be used to **detect amount of water**.



Potting and core fillers are well detectable too.



This common X-ray image **does not** provide depth perception.

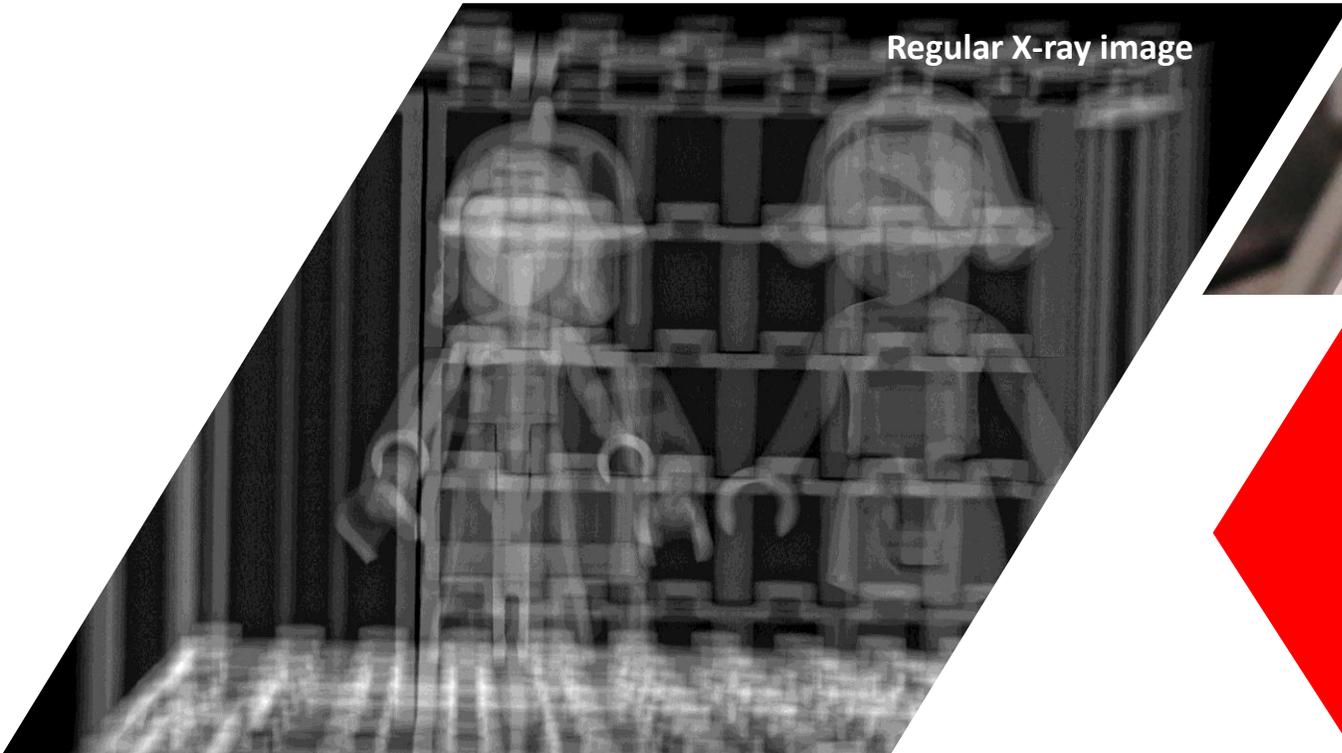
TOMOSYNTHESIS = FOCUS TO SELECTED DEPTH

Recognize the difference.

The flexibility of robot allows also focusing X-ray images to different depth. It is demonstrated on this lego sample where one figure is in front and two behind the wall.



Regular X-ray image



Standard X-ray image is hard to understand. All structures are mixed, figures have different sizes.

TOMOSYNTHESIS = FOCUS TO SELECTED DEPTH

Recognize the difference.

rd radalytica®



Front figure

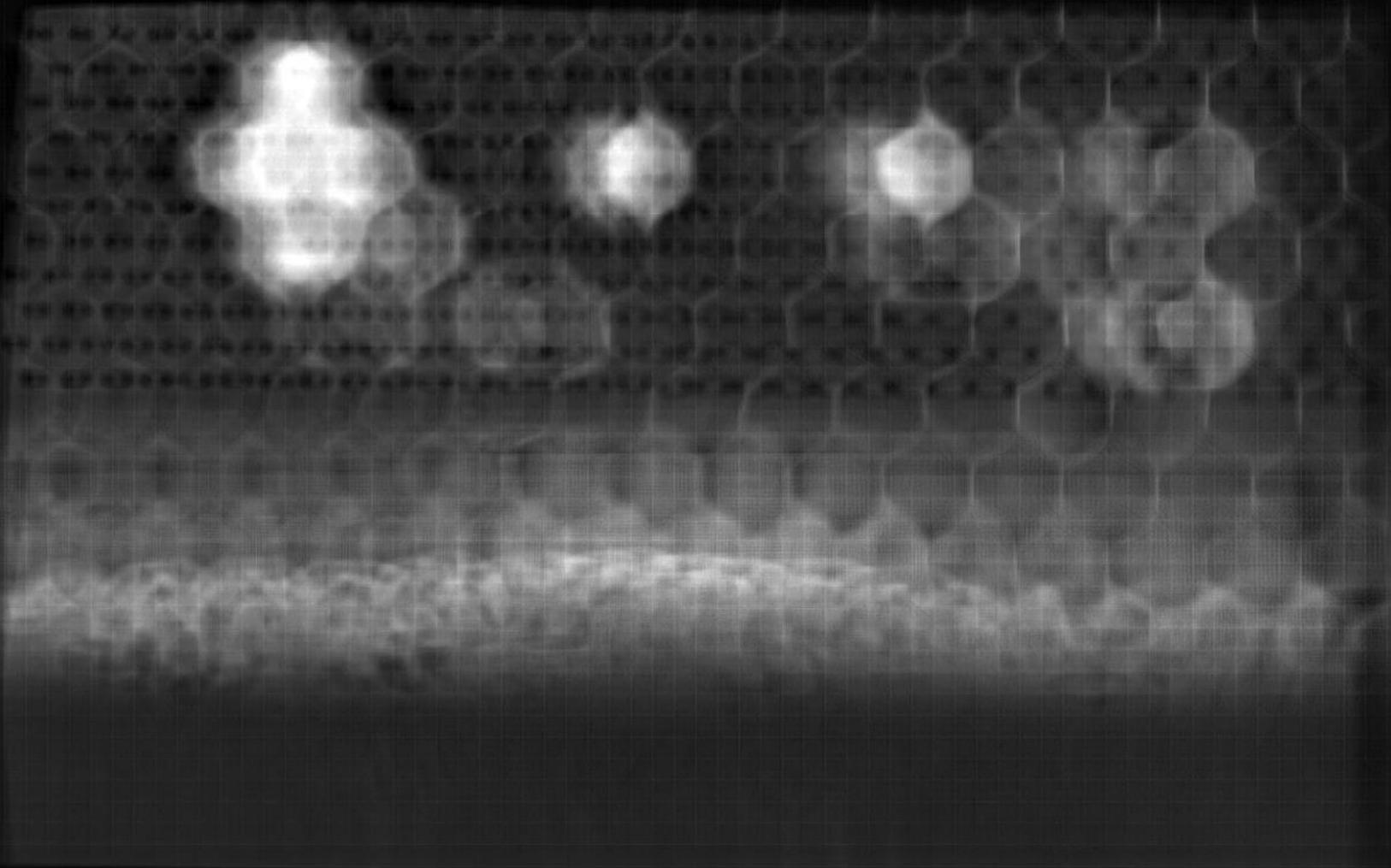
Wall

Back figures

Our X-ray imaging system can focus to a selected depth and show different layers of the sample. Moreover dimensions are correct thus metrology is possible.

3D X-RAY SCAN: TOMOSYNTHESIS

- Tomosynthesis “**focuses**” the X-ray image into selected depth of sample.

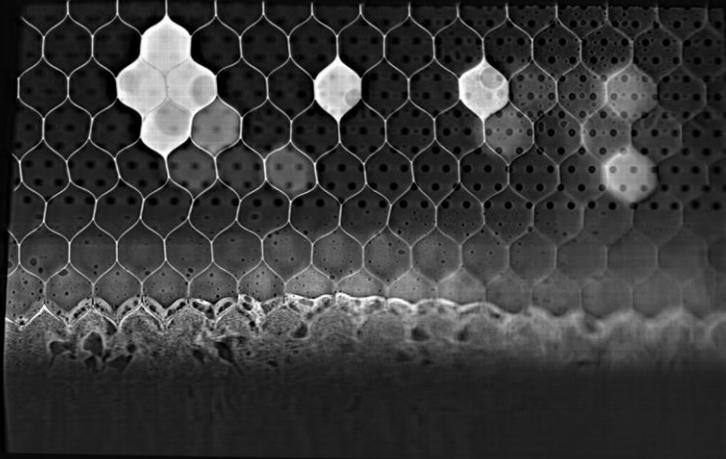
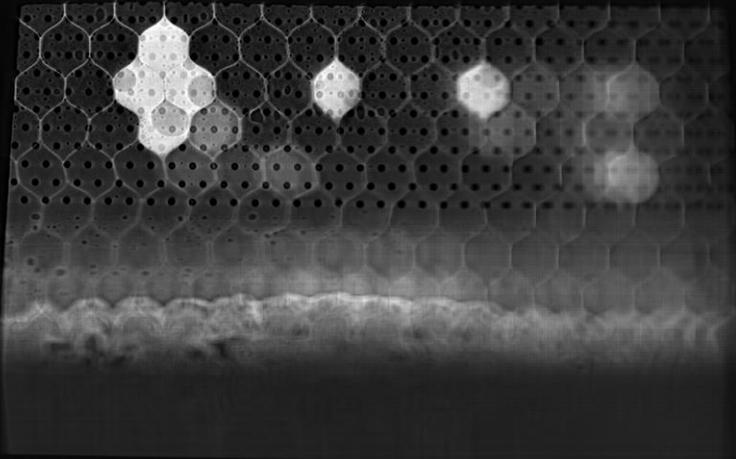


The view cuts through the thickness of the object revealing structures inside.

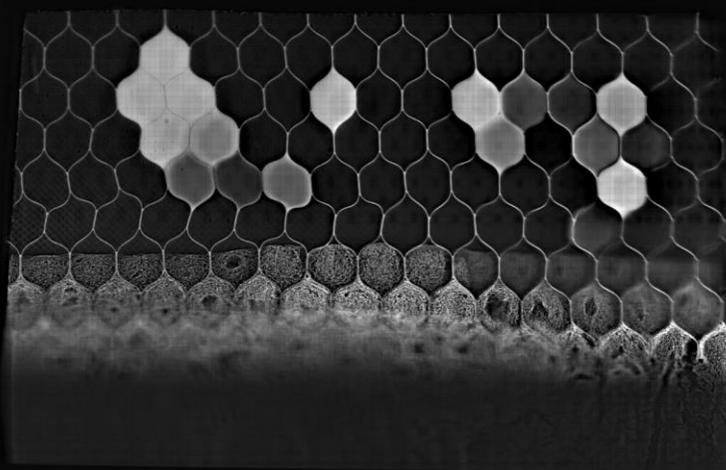
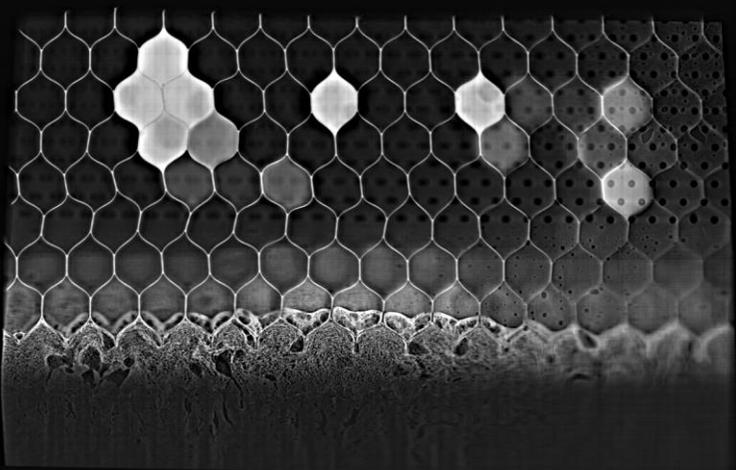


The water level and potting thickness can be read directly.

3D X-RAY SCAN: TOMOSYNTHESIS



- Tomosynthesis “**focuses**” the X-ray image into selected depth of sample.



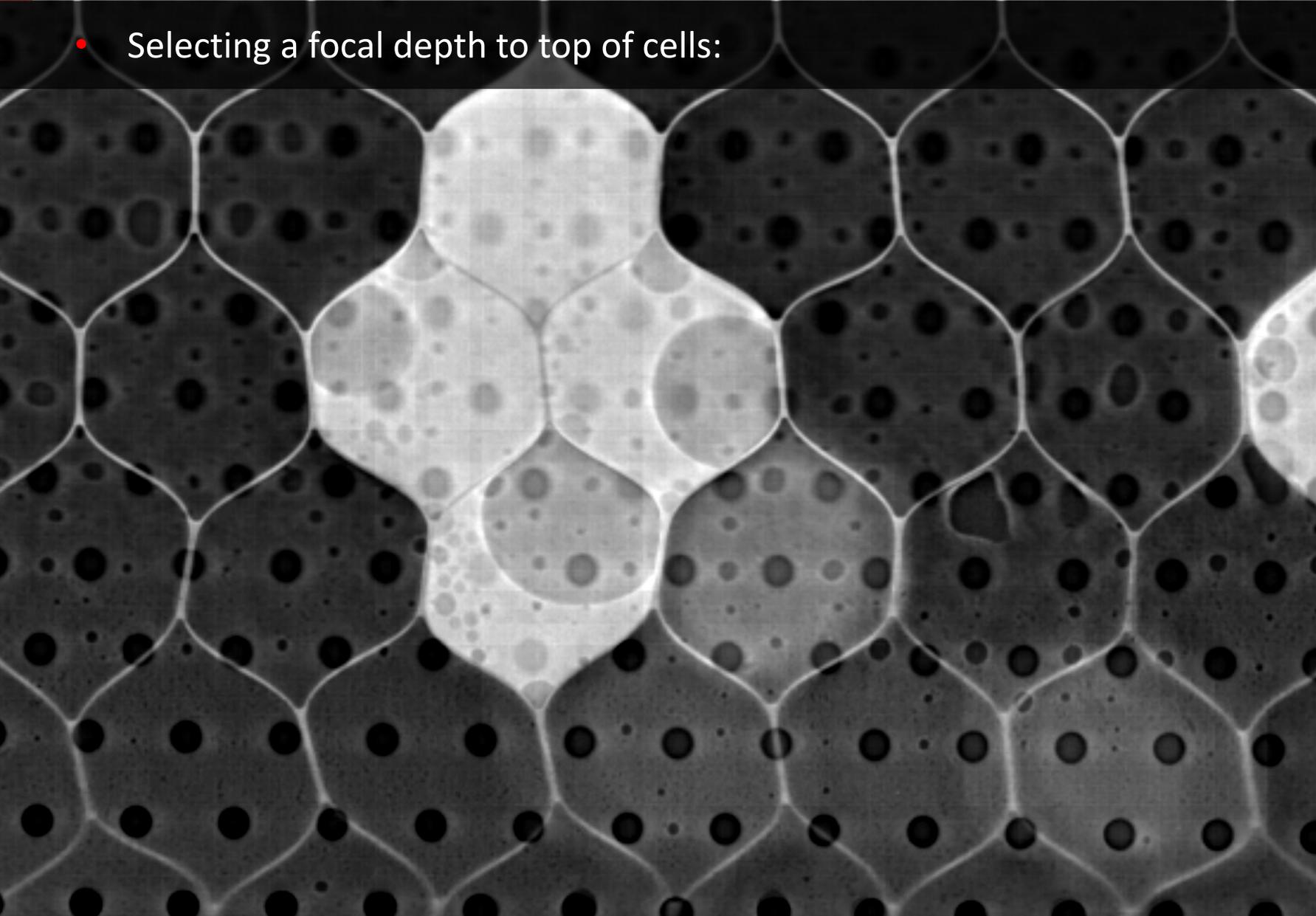
The view cuts through the thickness of the object revealing structures inside.



The water level and potting thickness can be read directly.

3D X-RAY SCAN: TOMOSYNTHESIS = FOCUS TO SELECTED DEPTH

- Selecting a focal depth to top of cells:

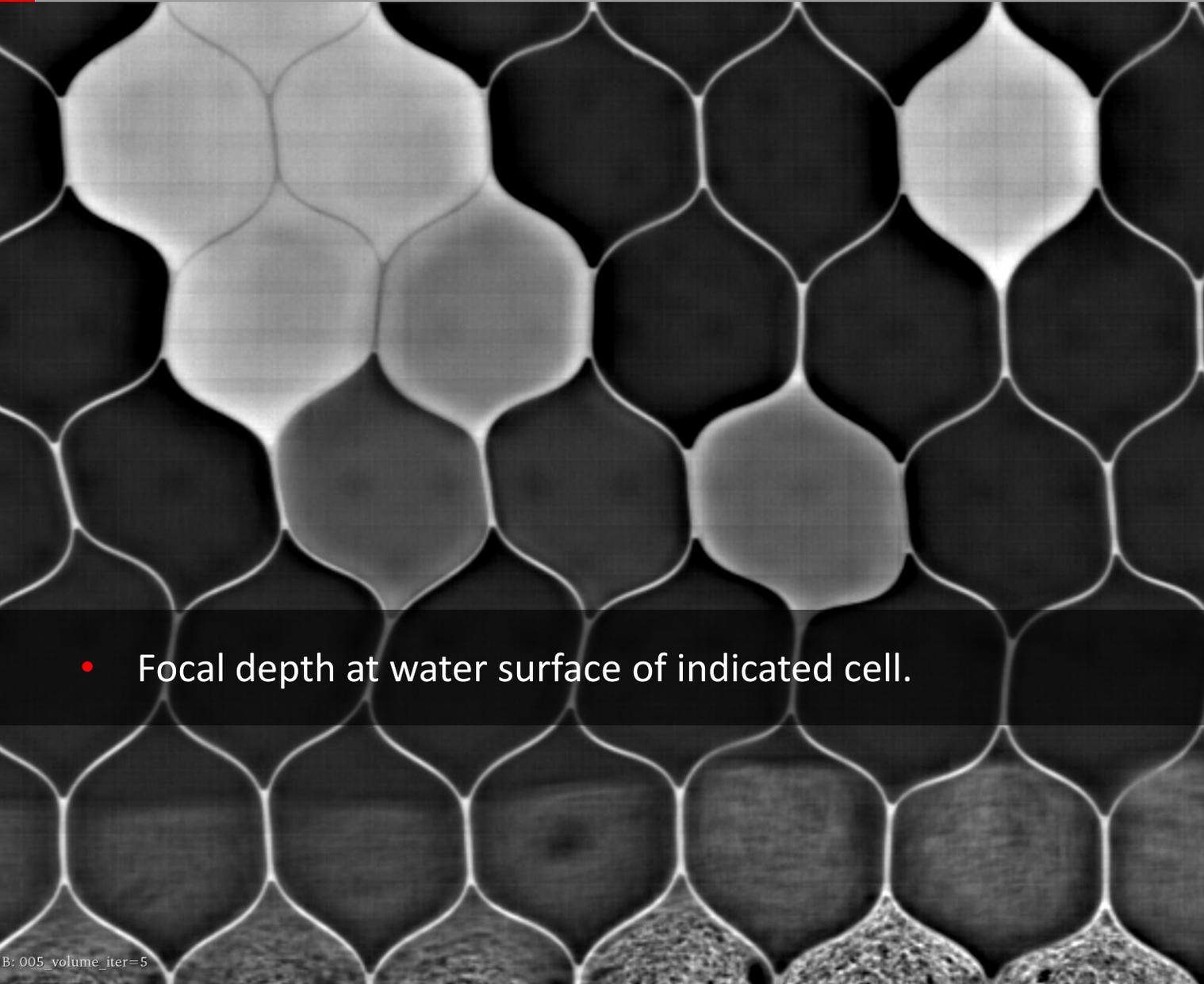


Cells full of water or with small bubbles are easily seen.



Only partially filled cells have significantly less contrast and are therefore well identified.

3D X-RAY SCAN: TOMOSYNTHESIS = FOCUS TO SELECTED DEPTH



- Focal depth at water surface of indicated cell.



Cells with less water have blurred water edges. Only cells where the focal plane cuts the water are sharp.



*A simple **quantitative estimate** of water ingress in honeycomb panels can be obtained by determining the total volume of cells containing water e.g., by multiplying the visible cell area (occupied with water) by the known panel thickness.*

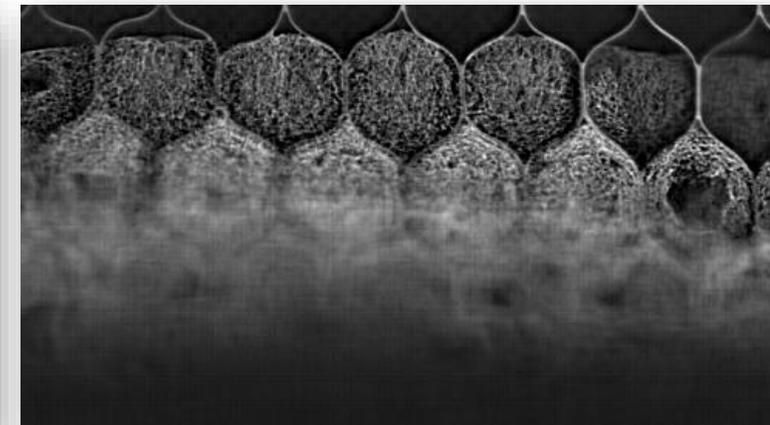
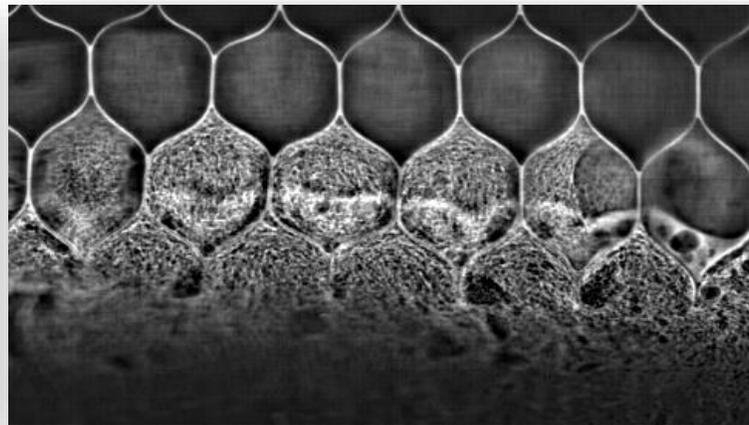
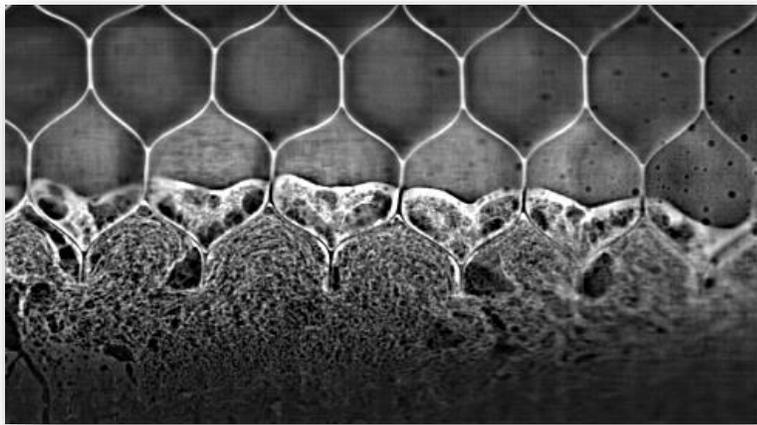
3D X-RAY SCAN: TOMOSYNTHESIS = FOCUS TO SELECTED DEPTH

- **Inspection of potting**

Potting layer close to the top skin

Potting layer in the middle

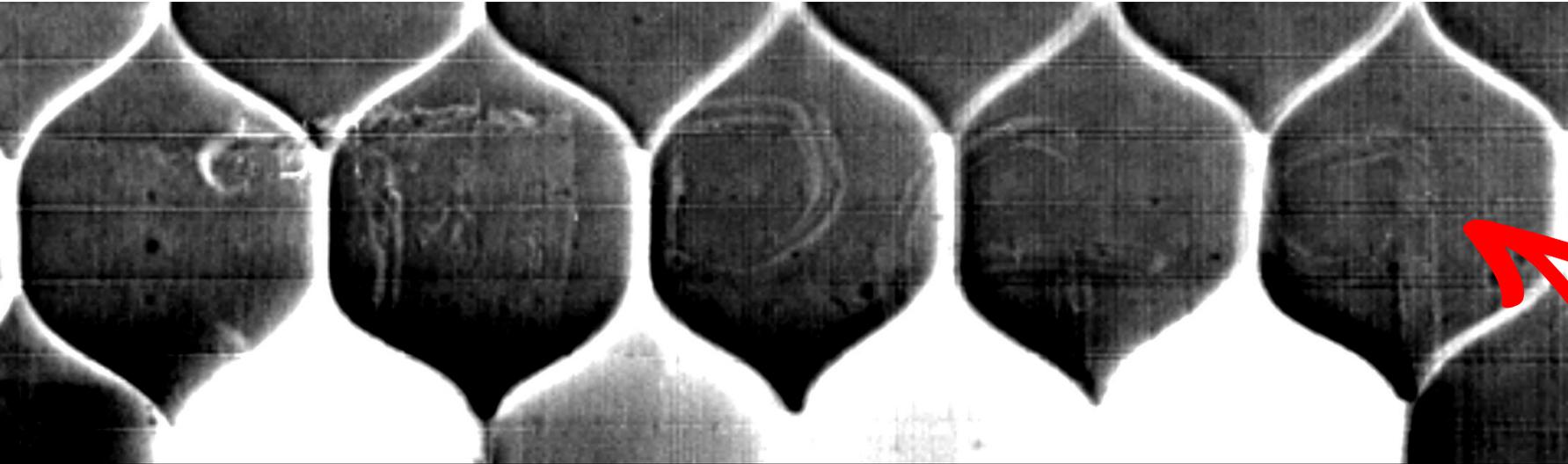
Potting layer close to the bottom skin



- The potting in this sample does not fully fill the cells.

- Focusing the X-ray image to different depths **resolves** level of cell filling.

3D X-RAY SCAN: TOMOSYNTHESIS = FOCUS TO SELECTED DEPTH



- Sample description is visible in the appropriate focal depth as well



X-ray image provide enough contrast and depth resolution to detect and localize even vague structures such as marker handwriting.