Proof of DRY IMAGING: Imaging in vacuum with a DRY SMAL lens

Purpose of the experiment: LIG Nanowise has developed SMAL lens which allows the imaging of small features down to 50 nm. In the first place, the SMAL lens were only working in oil immersion. Recently we have developed DRY SMAL lens which allow to observe the same small feature but without using any immersion liquid. The development and the imaging of such structure were performed successfully (as show bellow. (Figure 1)

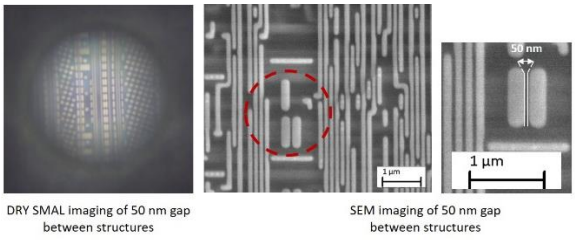


Figure 1: DRY SMAL and SEM images of a semi-conductor sample.

Since it is very difficult to get rid of the humidity on either both the sample surface and the front lens of the SMAL lens, we have conducted the experiment in the vacuum at a temperature were no water can exist in the liquid state (i.e. triple point of water) in order to prove the imaging occurs when no liquid is present between the microsphere and the sample.

Experimental set up: The set-up is show Figure 2. The sample is place in a vacuum chamber. An aperture was drilled in the chamber in order to put the objective lens go through. The sample is placed on a heating plate to raise the temperature of the sample up to 70 °C. A Z stage placed inside the chamber allows to bring the sample into focus. Silicon is used to seal the aperture created to let pass through the wall the lens and the different wires used to connect the heating plate and the z stage.

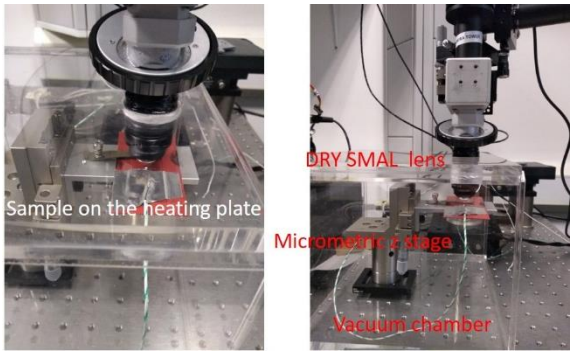


Figure 2: Vacuum chamber experimental set-up

We used a manual stage for the first experiment. This stage was then replaced by an automatic stage since the focus must be tuned when the vacuum is achieved.

Vacuum and temperature measurement:

The pressure inside the chamber is given by a gauge. The thermocouple attached to the sample allow us to monitor the temperature (Picture 3).

Figure 3: Vacuum and temperature measurement inside the chamber

The pressure inside the chamber during the experiment was 55 mbar and the temperature 66.4.

Triple point of water: (source: https://en.wikipedia.org/wiki/Triple_point)

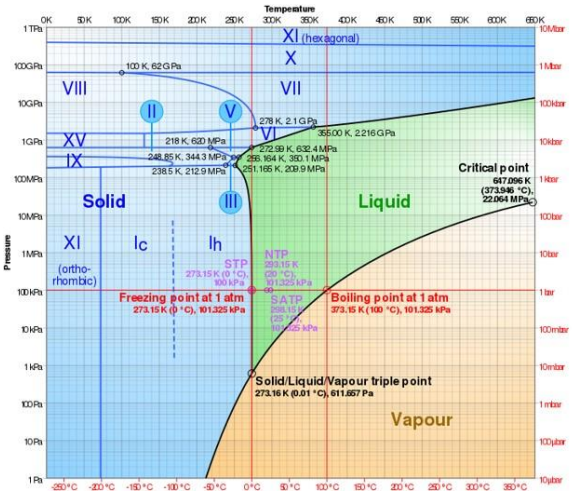


Figure 4: Triple point of water

Pressure measurement: The gauge give -0.960 bar. The pressure inside the chamber (p)= atmospheric pressure (1.015 bar) – value of the gauge (-0.960). We measure a value of pressure inside the chamber of p=0.055 bar. The figure 5 shows that at room temperature, the water is still in the liquid state. However, the plot tells us that increasing the temperature of the sample to a temperature around 65°C we allow us to reach the part of the triple point curve where the water is in the vapor state.

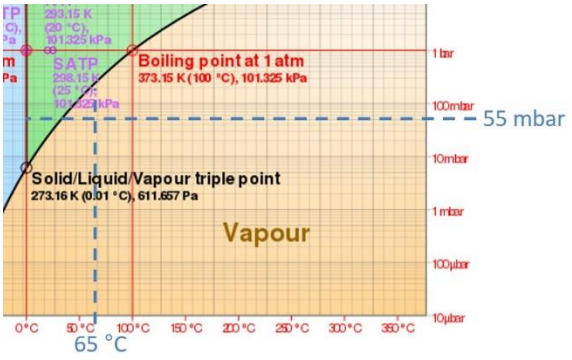


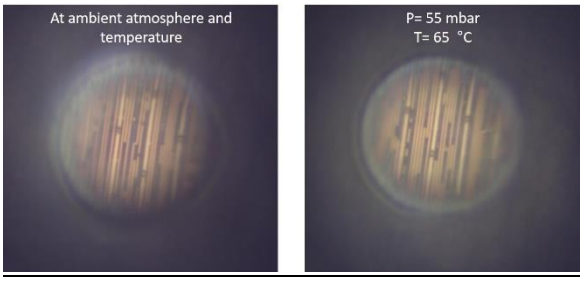
Figure 5: Triple point of water with our experimental parameters

Imaging in vacuum: The SMAL lens we want to test is used inside the vacuum chamber at the experimental condition describe above. We used an automatic z stage to approach the sample in focus after the vacuum is achieved inside the chamber. We also measure the humidity inside the chamber (h=12%). (Figure 5)

Figure 6: Imaging in the vacuum chamber

Results: Comparison imaging in normal condition VS imaging in vacuum

Figure 7 exposed the images obtained in normal condition (left) and under the vacuum and temperature condition describe by the triple point of water.



Conclusion:

At ambient atmosphere, the obtained image is the same than the image obtained in the condition when no water could be present at the liquid state.

Our SMAL DRY lens are DRY lens as long as no humidity contaminate the lens or the sample.