Investigations of Hygroscopic Growth and Phase Transitions of Atmospheric Particles by Noncontact Atomic Force Microscopy

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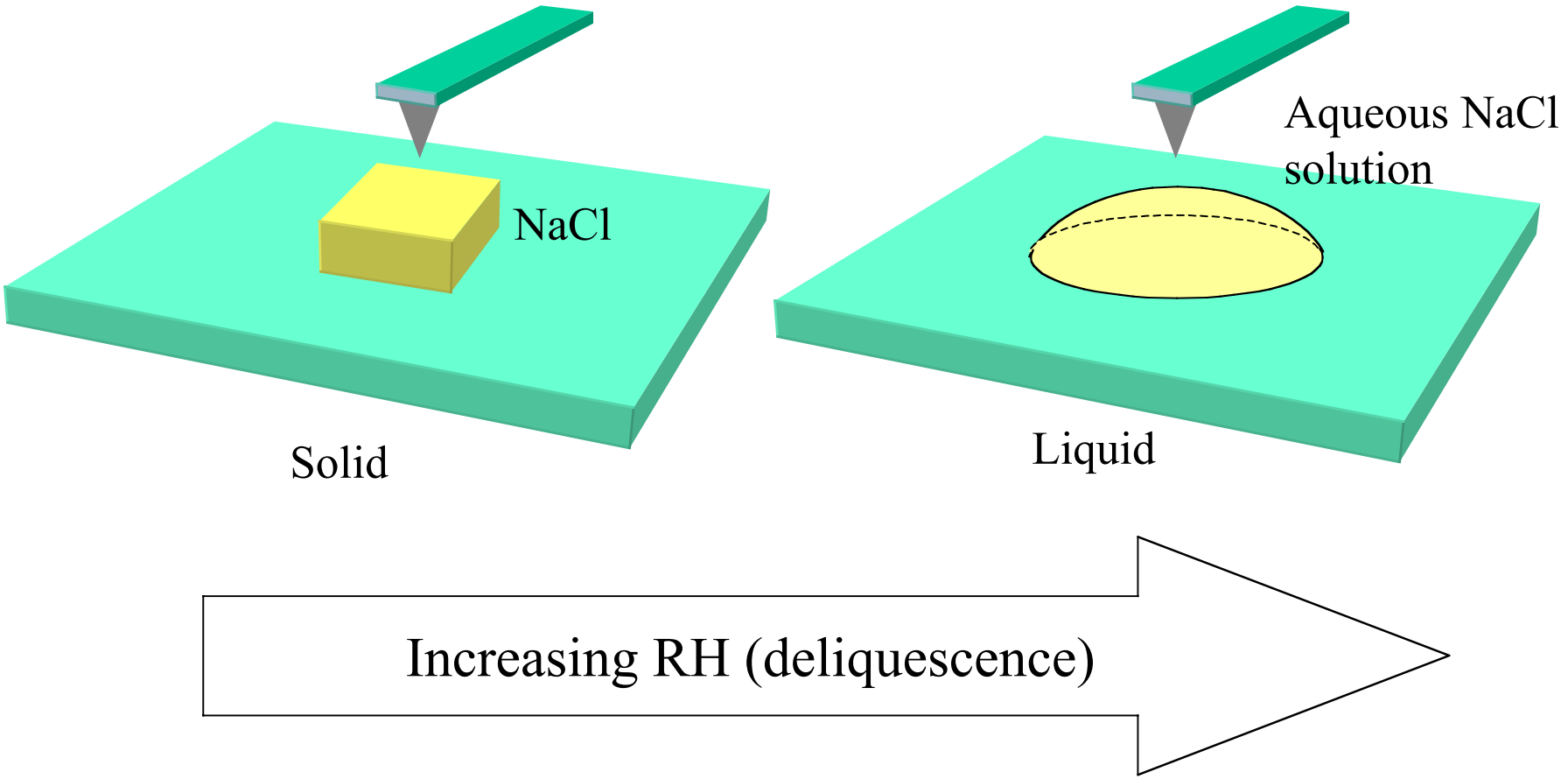
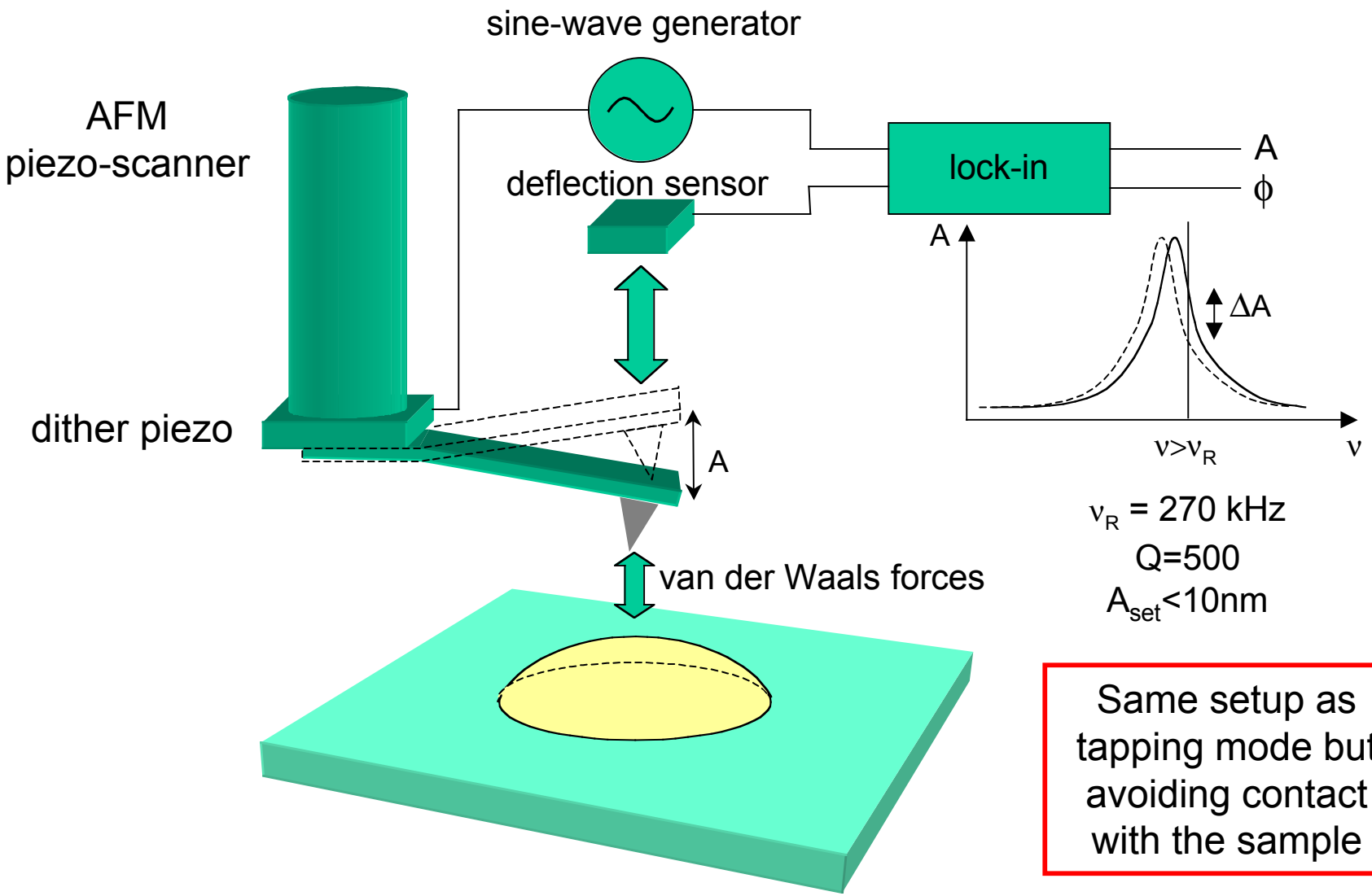
Motivation: Improve understanding of ***particle deliquescence, hygroscopic growth, and "aging"*** pertinent to climate influence of atmospheric aerosols.

Approach: Non-contact Atomic Force Microscopy under controlled environmental conditions

Atomic Force Microscopy under controlled environmental conditions



Non-contact AFM imaging of liquids



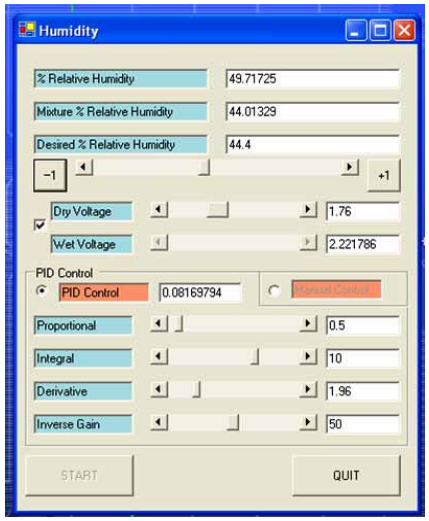
ν_R = 270 kHz

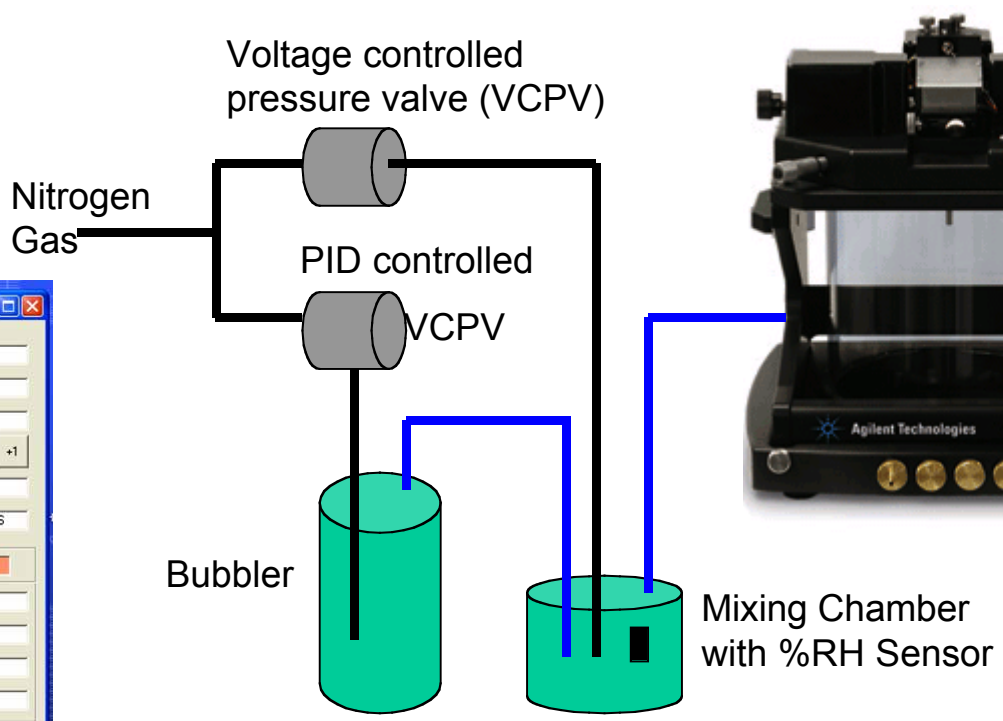
Q=500

A_{set}<10nm

Same setup as tapping mode but avoiding contact with the sample

Environmental AFM with humidity/vapor control



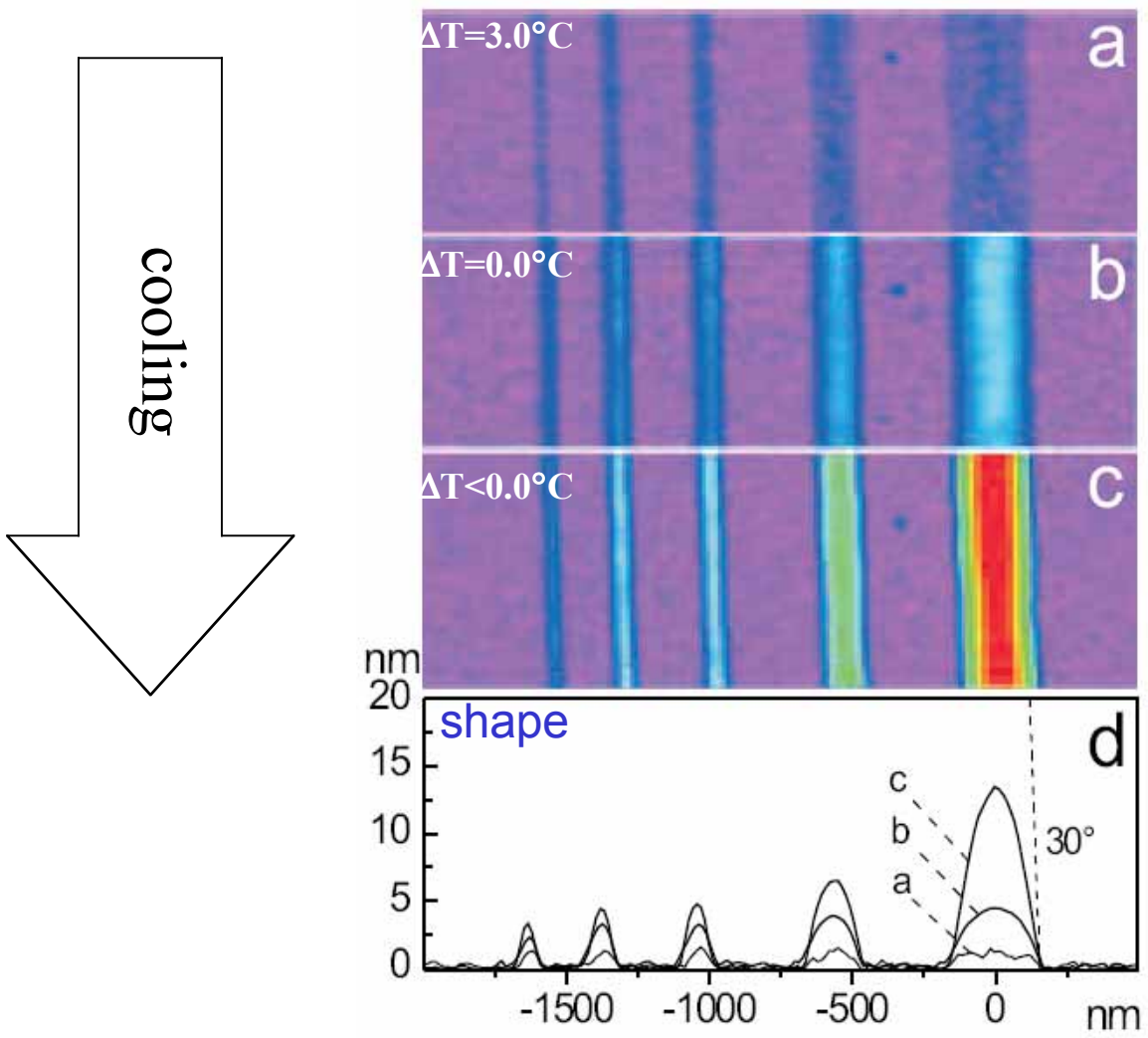


AFM Chamber with
%RH Sensor

PID software control of solenoid pressure valves
Error signal provided by IC humidity sensors

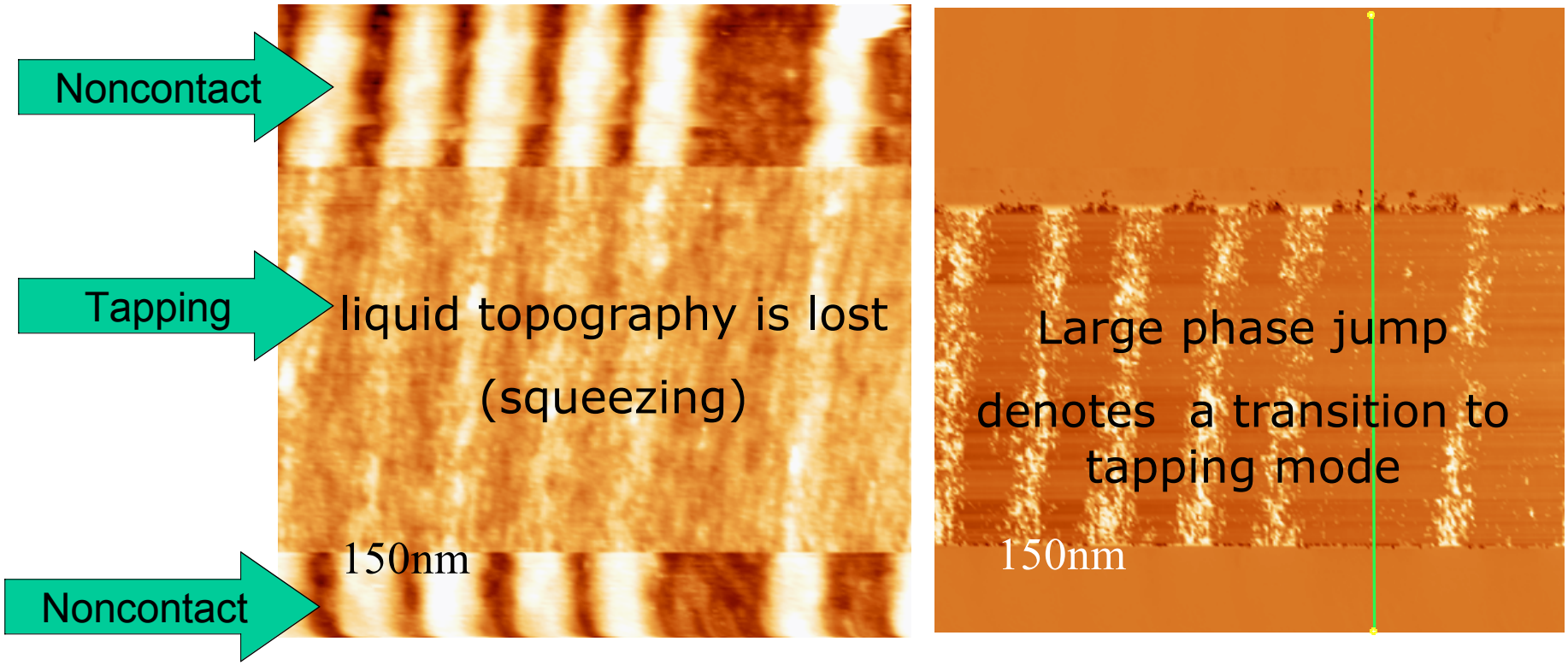
Humidity is controlled within ± 2% in the range 5% < RH < 98%.

Condensation of ethanol nanodrops on chemical patterns



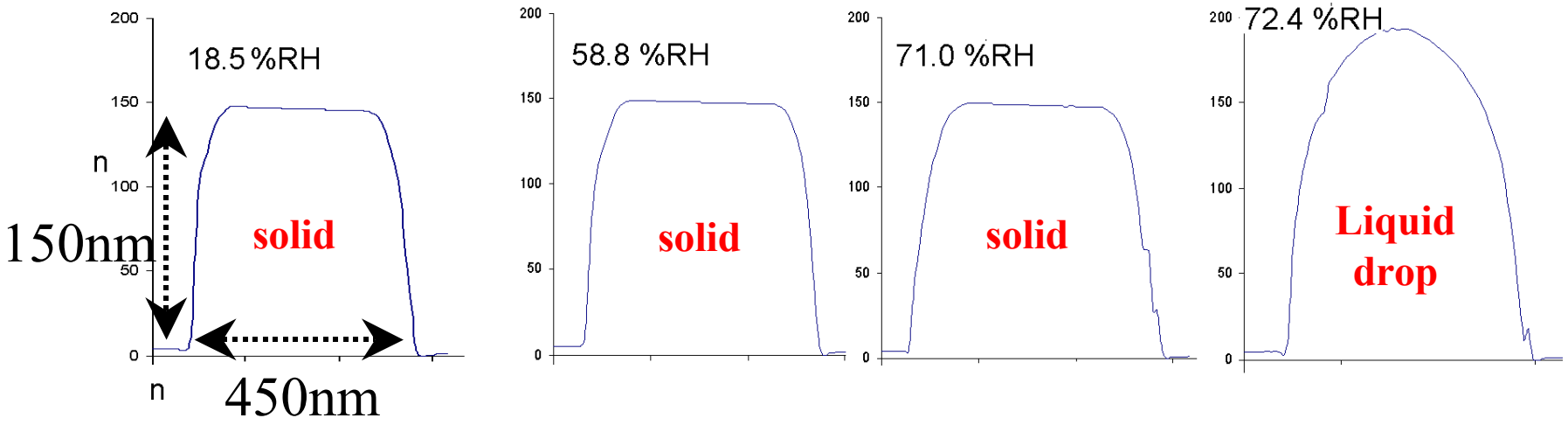
Checco, Ocko, Gang, Phys. Rev. Lett. 96, 056104 (2006)

Avoiding tip-sample contact is paramount !!



Checco, Cai, Gang, Ocko, Ultramicroscopy **106**, 703, 2006

Phase behavior of NaCl nanocrystals on (neutral) SiO_2 surface

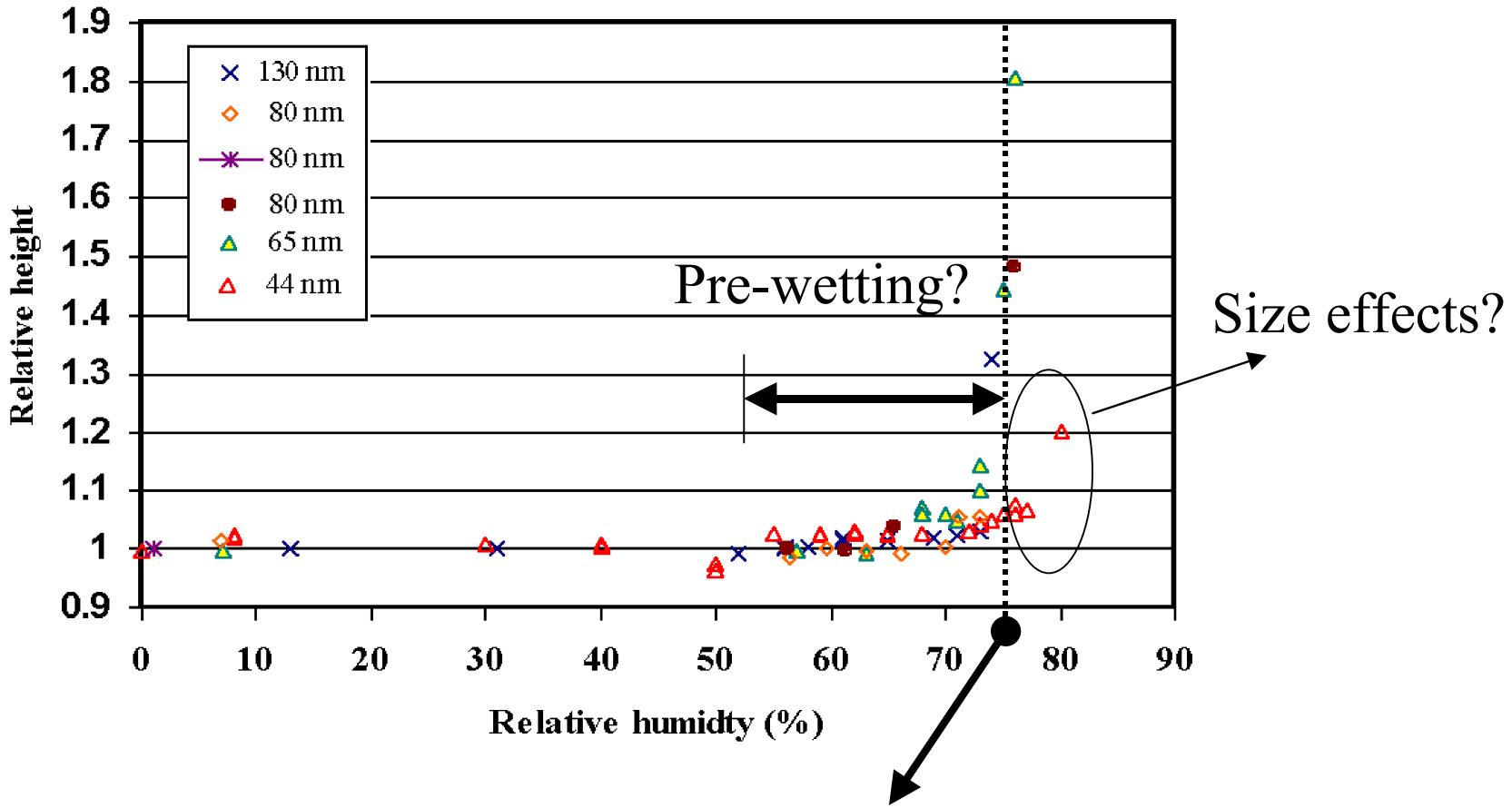


NC-AFM profiles of NaCl crystal (height ~100-150 nm) at increasing values of RH

Salt nanocrystals are generated using an atomizer.

Deposited on flat silicon oxide terminated surfaces at 65% RH.

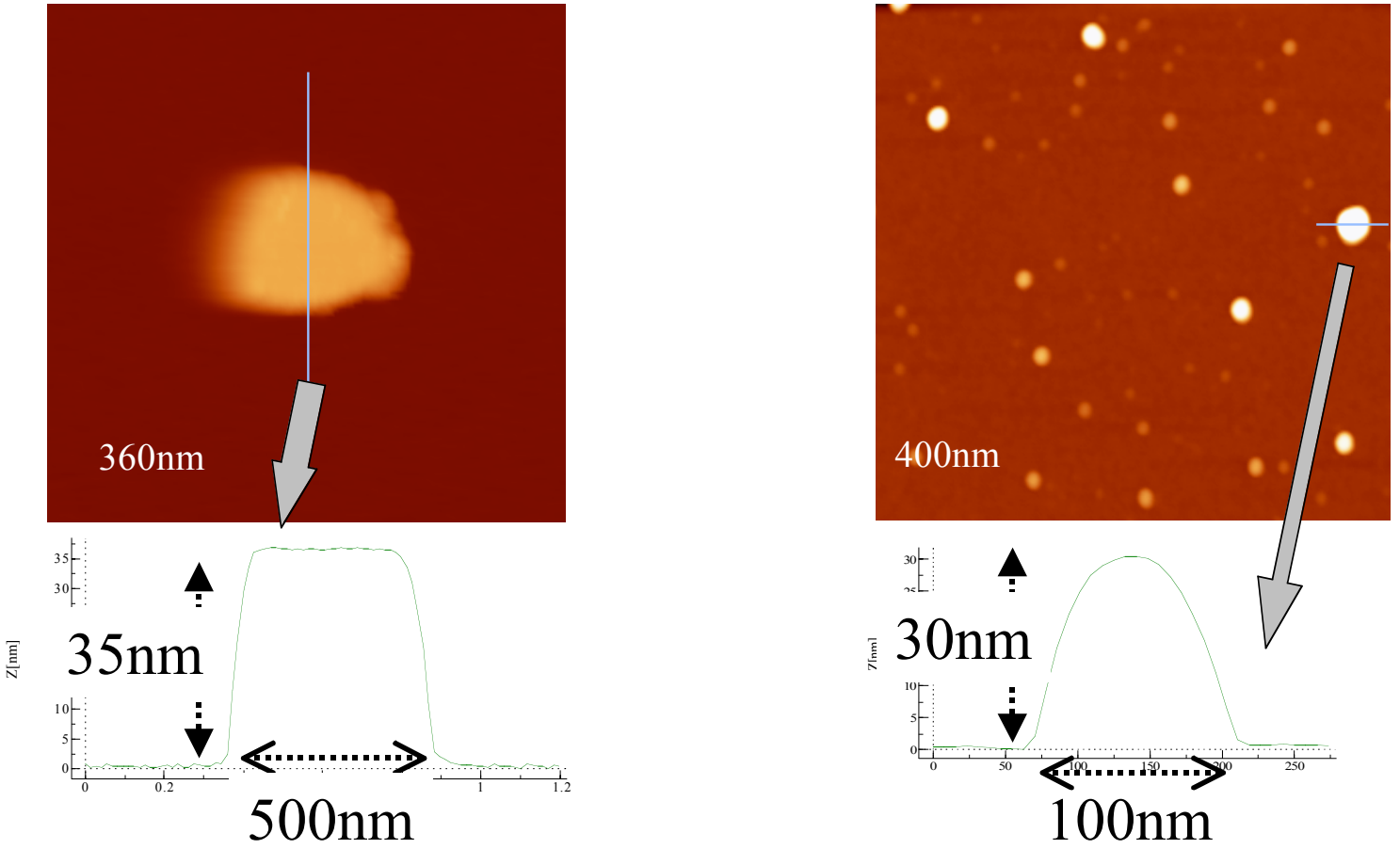
Phase behavior of NaCl nanocristals on SiO_2 surface: preliminary results



Expected deliquescence threshold (RH=75%) for diameter > 100 nm

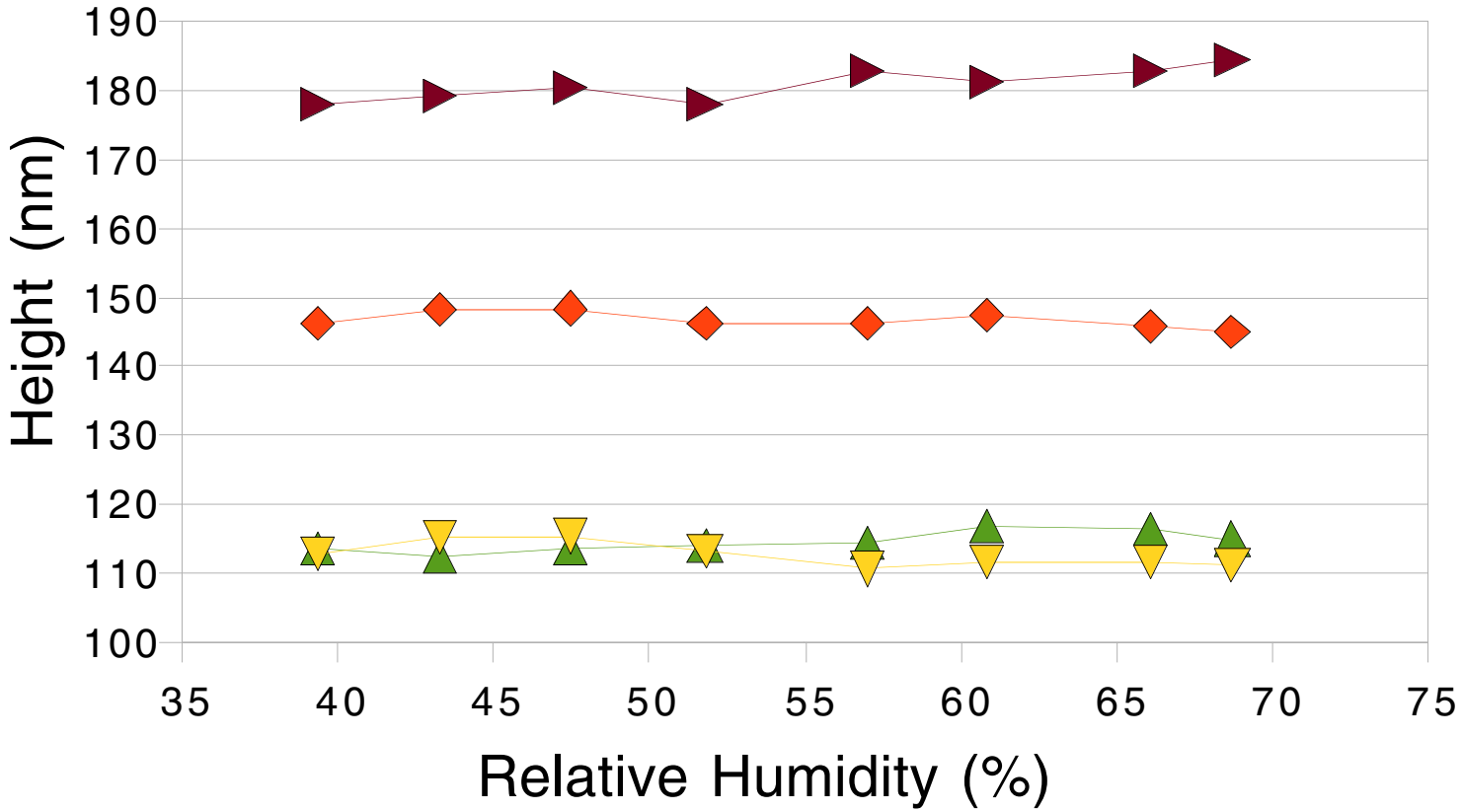
Additional data required to test size effect, pre-wetting and efflorescence

Synthesis of more regular and smaller crystals

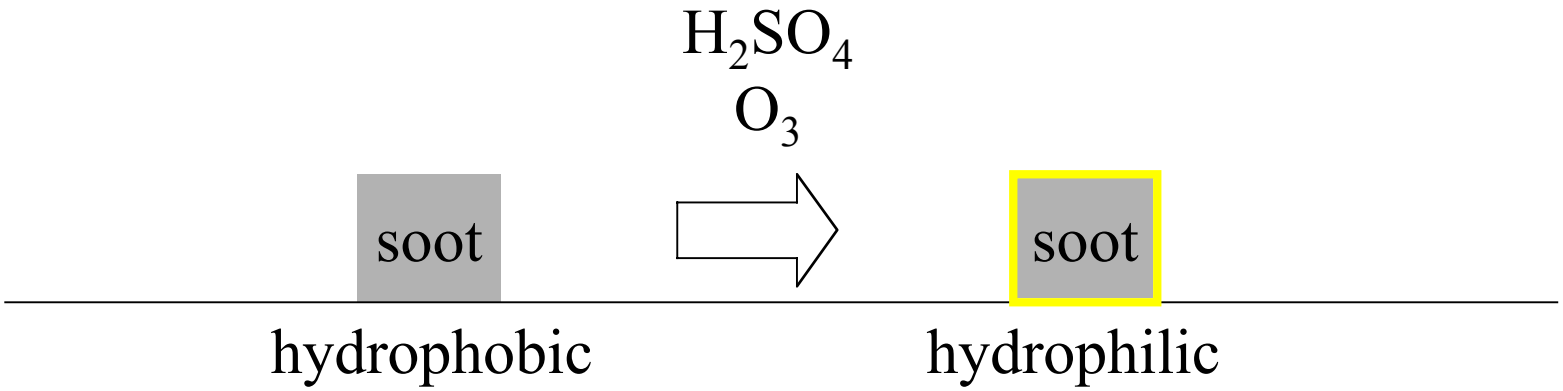


- By using perfectly flat crystals it is possible to accurately measure pre-wetting.
- Crystals smaller than 50 nm are expected to deliquesce at RH value higher than that of larger crystals (curvature effect).

Prewetting of flat NaCl crystals



Study of aerosol “aging”



- Carbonaceous aerosol (organic, soot) which are initially hydrophobic are believed to become hydrophilic upon adsorption of salt or sulfuric acid from the atmosphere (“aging”) and/or by oxidation.
- Examine effect of adsorbed H_2SO_4 or ozone exposure in modifying the wettability of prototypical organic surfaces.

Summary

- Demonstrated novel experimental approach with potential impact on environmental science.
- Validate preliminary results, demonstrate particle size effects on deliquescence/efflorescence thresholds.
- Extend to single- and multi-component aerosol particles of composition more directly relevant to ambient atmospheric aerosols.
- Initiate work on coated aerosols to simulate “aging.”