Surface Measurement Systems
World Leader in Sorption Science

GenRH Application Note 501

Environmental Microscopy using the GenRH-A Humidity Generator and Mcell Accessory

Dan Burnett, Teri Hope, and Jan Gorgol | Surface Measurement Systems Ltd

Humidity can have a dramatic effect on the formulation, development, and performance of a wide range of materials. Therefore, it is important to study material physical properties over a range of real-world humidity and temperature conditions. This note utilizes the GenRH and Mcell accessory for light and FT-IR microscopy applications.

Introduction

Without suitable protection, all solid and liquid substances on the surface of the Earth are subjected to atmospheric moisture or humidity. In some cases the presence of atmospheric humidity can have significant consequences for the stability or performance of particular materials. In the case of solid materials and in particular powders, these humidity-induced changes often occur at the microscopic level. A classic example would be the caking of a free flowing powder such as table salt stored for a long time in an open container in a humid environment such as a kitchen. In order to study the effect of humidity at the microscopic level, it is necessary to be able to accurately and reproducibly control the humidity above a sample on a microscope stage. The GenRH-A accessory with combination of the Mcell has been developed by Surface Measurement Systems to provide such control for light microscopy, as well as NIR, FT-IR and Raman microscopes. This short paper describes the operation of the GenRH-A with MCell and shows the application to some real life examples.

Method

The GenRH-A consists of; a programmable digital controller with full time closed-loop control, temperature monitoring display, temperature and humidity probe, and a rotameter to control flow volume. A picture of the GenRH-A shown in Figure 1.

Figure 1. Surface Measurement Systems GenRH-A humidity generator.

To use the GenRH-A efficiently with a microscope, Surface Measurement Systems has developed the Mcell. The sample is mounted into the Mcell, which is fixed to the microscope stage as shown in Figure 2. This stage has double-glazed top and bottom windows, allowing both transmission and reflection illumination of the sample while minimising heat loss through the windows when being used under non-ambient conditions.

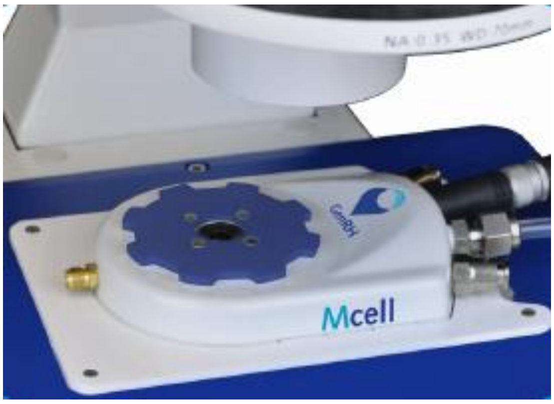
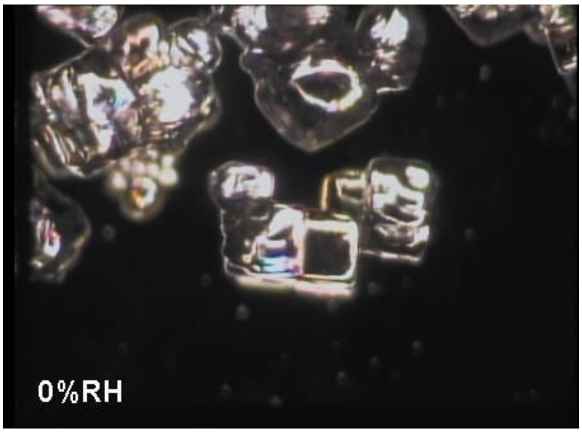
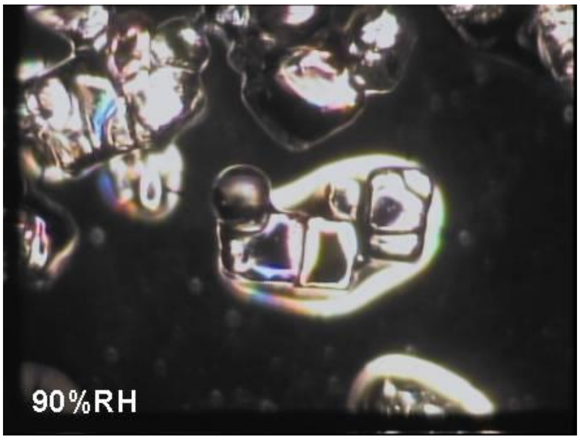


Figure 2. SMS Mcell microscope accessory for the GenRH line of products.



(a.)



(b.)

Figure 3. KBr images (100X magnification) at 0% RH (a.) and 90% RH (b.) collected at 25 °C.

Results

Deliquescence of Ionic Salts

One of the most common moisture-induced changes in solid materials is a phenomenon known as deliquescence. This occurs in many ionic solids, where above a critical humidity, the solid takes up moisture to form a solution. Often this phenomenon is associated with the caking of powders during storage. In Figure 3, a sample of potassium bromide (KBr) was subjected to 0% RH (a.) and 90% RH (b.) using the GenRH-A and Mcell at 25°C. The critical humidity for KBr at this temperature is 80.9% RH, therefore the sample readily dissolves at 90% RH which shows as a halo around the crystals in this transmission microscopy picture at 100x magnification.

Crystallization of an Amorphous Drug

One technique often used to study the formation of crystalline materials by microscopy is darkfield polarisation. In this case the optical properties of the crystalline material under polarised light are exploited to produce an image highlighting the crystalline regions of the sample. In Figure 4, an amorphous drug was subjected to a constant humidity of 80% RH at 25 °C and the evolution of the microscope image was recorded under dark field polarising conditions at intervals of 2 minutes. The sequence of images clearly show the initial fluffy powder, becoming at a first ‘glassy’ or liquid-like in appearance, followed by the formation of individual crystallites until the whole sample has crystallised. This type of behaviour has previously been characterised gravimetrically by Dynamic Vapor Sorption (DVS) studies but this provides additional evidence for the transient glassy state that is formed prior to the formation of the crystalline material.

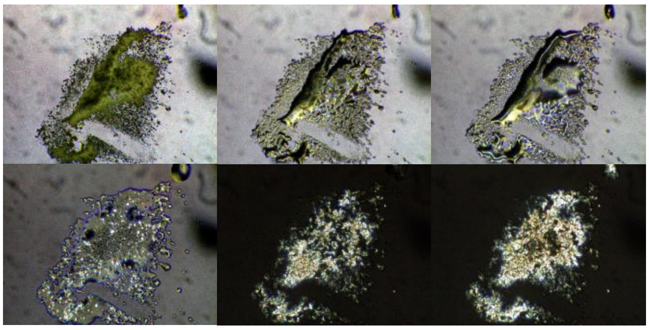


Figure 4. Glass transition and crystallisation of an amorphous drug studied at 80% RH and 25 °C.

Deliquescence of NaCl by FT-IR Microscopy

The GenRH-A and Mcell may also be used with microscopes adapted for FT-IR spectroscopy, by changing the window material used. Replacing borosilicate glass windows with replaced by BaF_2 windows, allows both transmission and reflection modes of the instrument to be used.

In this first example, the deliquescence of a single sodium chloride (NaCl) crystal was measured by FT-IR microscopy in transmission mode. In this case the sample was also mounted on a polished BaF_2 sample mounting slide. Figure 5 shows the evolution of the FT-IR spectrum ratioed with a background spectrum taken at 0% RH, as the sample is ramped from 70% RH to 79% RH at a rate of 0.1 %/min. Below 75% RH, the spectra show remarkably few features, apart from some variation in the background CO_2 peak at ~2400cm^{-1}. It is worth noting that this experiment also demonstrates that there is no discernible change in the IR signal due to absorption by the humidity atmosphere in the cell.

The spectra show that above 75% RH two bands grow steadily at 3000-3500 cm^{-1} and 1500-1600 cm^{-1} until above 76% RH they have saturated completely. These bands can be attributed to the OH stretching and OH deformation modes of liquid water molecules on the surface of the NaCl crystal and are indicative of the deliquescence phenomenon described previously.

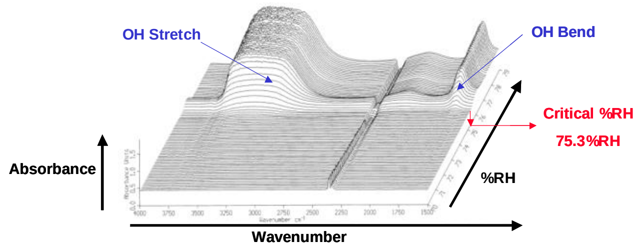


Figure 5. FT-IR Spectra of a NaCl crystal exposed to a humidity ramp between 70% RH and 79% RH.

Figure 6 shows the peak areas of the OH stretch peak as a function of % RH, clearly demonstrating the onset of deliquescence around 75.2% RH. This method is potentially a straightforward validation of the humidity generation in the Mcell, since the deliquescence points of a number of ionic salts have been well recorded in the literature. In this case the literature value for NaCl at 25 °C is 75.3% RH and is therefore in very good agreement with this experimental data.

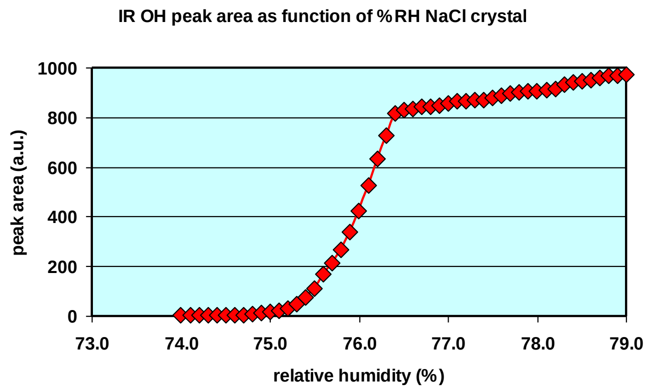


Figure 6. Variation of OH peak area with % RH for single NaCl crystal studied at 25 °C.

Hydration of Naloxone HCl by FT-IR Microscopy

In this second example using FT-IR microscopy, the hydration behaviour of Naloxone hydrochloride (Naloxone HCl), a well characterised anti-narcotic substance, has been characterised by reflection mode FT-IR microscopy. In this case, the sample was mounted on a polished stainless steel mounting plate. The hydration behaviour of Naloxone HCl has been studied previously by DVS and the equilibrium moisture content as a function of % RH at 25 °C is shown in Figure 7. Essentially, the material hydrates between 10% RH and 30% RH to form a monohydrate and between 30% RH and 60% RH to form a dehydrate. The dehydrate is relatively stable and will not dehydrate until the humidity drops below 10% RH. This kind of hysteresis phenomenon is often observed for the reversible formation of stoichiometric hydrates under typical ambient temperatures.

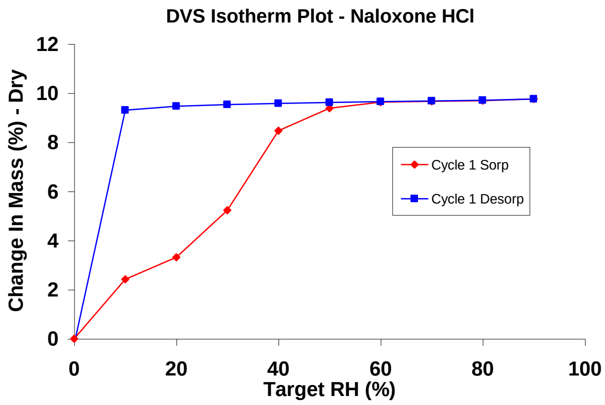


Figure 7. Moisture adsorption and desorption isotherms for Naloxone HCl at 25 °C.

The same experimental conditions for the hydration of Naloxone HCl were simulated in the Mcell by equilibrating the sample for 1 hour at 0% RH and then increasing the humidity in steps of 10% RH. The resulting spectra for each humidity step are shown in Figure 8. The most important features are the growth of two bands in the OH stretching region between 3300cm^{-1} and 3700cm^{-1} which are most probably due to the water of hydration within the solid. The presence of two bands probably indicates an asymmetric hydration interaction with the solid probably via hydrogen bonding. A plot of the IR peak heights for these two peaks (Figure 9) shows a remarkably similar variation in intensity to the moisture adsorption data obtained by DVS.

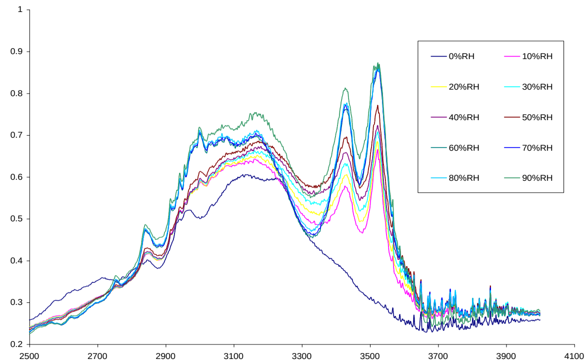


Figure 8. FT-IR Spectra for Naloxone HCl exposed to 0-90% RH in steps of 10% RH.

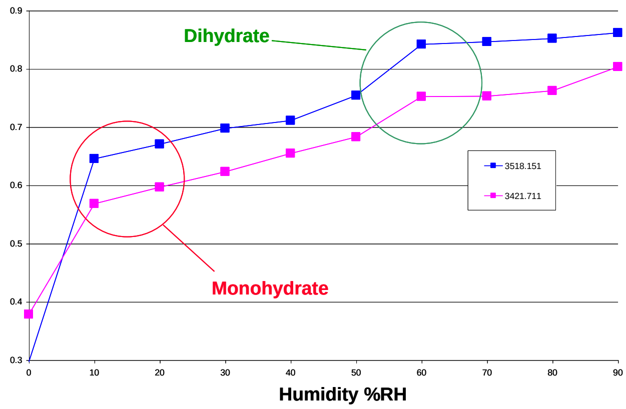


Figure 9. Variation of OH peak heights versus % RH for Naloxone HCl at 25 °C.

Conclusion

This short paper demonstrates the principle of operation of a new humidity generator, the GenRH-A, and Mcell accessory for controlling the humidity over samples mounted on a microscope stage. In addition a few representative examples of the application of GenRH-A and Mcell in light microscopy and FT-IR microscopy have been presented. The potential for a very wide variety of applications from pharmaceuticals, biosciences, foods and polymers is evident, and the same principles may equally be applied to NI-IR and Raman microscopy techniques. The data obtained is also to some extent complementary to that obtained by other techniques such as DVS and may be used to enhance the understanding of some quite complex interactions between humidity and solids which often occur in real life situations.

Acknowledgement:

Special thanks to C.L. Levoguer, J. Booth, and J. Davies for their contributions and supplying the experimental data.

Head Office:
Surface Measurement Systems, Ltd
5 Wharfside, Rosemont Road
London HA0 4PE, UK
Tel: +44 (0)20 8795 9400
Fax: +44 (0)20 8795 9401

United States Office:
Surface Measurement Systems, Ltd, NA
2125 28th Street SW, Suite I
Allentown PA, 18103, USA
Tel: +1 610 798 8299
Fax: +1 610 798 0334

Email: science@surfacemeasurementsystems.com