Surface Measurement Systems
World Leader in Sorption Science

RSC INTEREST GROUP
FORMULATION SCIENCE & TECHNOLOGY

Quantifying the water content of hair using Dynamic Vapor Sorption (DVS)

Meishan Guo[1], Majid Naderi[1], Manaswini Acharya[1], Dan Burnett[2]
1: Surface Measurement Systems Ltd., Unit 5, Wharfside, Rosemont Road, Alperton, London, HA0 4PE, UK
2: Surface Measurement Systems Ltd., 2125 28th street SW, Suite 1, Allentown, PA 18103, USA
~ Email: mguo@surfacemeasurementsystems.com ~

BACKGROUND

It has been suggested that water should be considered an integral part of hair's complex structure due to its considerable influence on fiber properties. Yet this water content is not constant and varies with the relative humidity of the environment – and accordingly so do certain hair properties. These changing properties are behind the ability to create temporary so-called "water-set" hair styles – but they also represent the origin of eventual style failure. At the same time, consumer's worry greatly about the water content of their hair and the potential for "drying out" – where there is a demand for "moisturizing" or "hydrating products" if this perceived situation is realized. From a more-fundamental viewpoint, the interaction of hair and water can represent a probe in to the inner structure and provide information on altered protein chemistry. For all these reasons, there is need for a means of accurately measuring hair's water content.

MATERIALS AND METHODS

1. Material:

European human hair (International Hair Importers, USA) is the substrate used for all DVS experiments with water as the probe molecule for sorption and desorption processes.

2. Dynamic Vapor Sorption (DVS):

A schematic of the DVS Adventure instrument is given in Figure 1. The DVS technique is a gravimetric vapor sorption method where experiments involve monitoring the weight of a sample as a function of the relative humidity.

1) Interval Sorption: The target relative humidity is set to increase at a step size of 10%RH starting from 0%RH (800 minutes) then each step taking at intervals of 400 minutes until 90%RH, then for the desorption the same manner is followed to return back to 0%RH, as shown in Figure 2.

2) Integral Sorption: The relative humidity is increased from a starting point of 0%RH without any interval steps to a final specific humidity and back to where it started from before continuing to the next step, as shown in Figure 4.

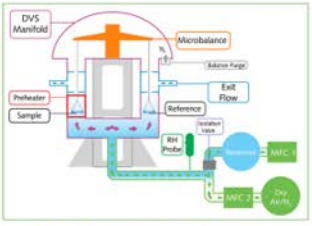

Figure 1. Schematic of DVS Adventure

RESULTS

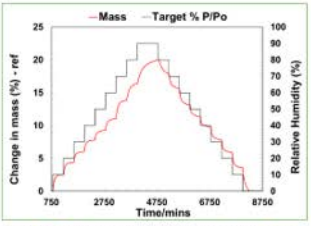

Figure 2. Water sorption kinetics of hair sample at 25 °C with Interval Sorption method

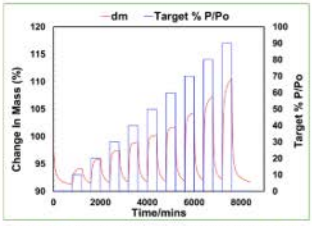

Figure 4. Water sorption kinetics of hair sample at 25 °C with Integral Sorption method

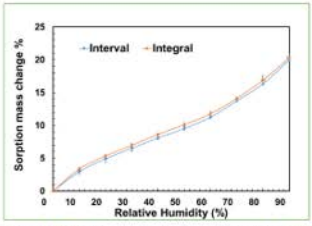

Figure 5. Water sorption isotherms of hair sample at 25 °C with both methods

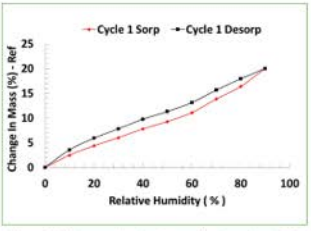

Figure 3. Water sorption isotherm of hair sample at 25 °C with Interval Sorption method

The equilibrium water content of hair sample fluctuates in a predictable and reproducible manner in accordance with the relative humidity. Figure 3 shows the water sorption / desorption isotherms, calculated from the equilibrium water content values in the kinetic plots. The presence of hysteresis, which is the gap between sorption and desorption isotherms, indicates that water molecules are not only adsorbed on the surface, but also go to the bulk of hair sample, resulting in different kinetics for desorption with a diffusion-limited process.

Figure 5 shows a 20% moisture uptake by hair when using both integral and interval sorption methods, which indicates the impact of sample history was not as anticipated in hair samples. This is probably due to the structure of hair, as partially amorphous sample with crystalline fibrils and extensive crosslinking, which is expected to significantly reduce molecular scope for relaxation [1].

Not withstanding, the shape of the water isotherm for hair sample is remarkably consistent and is influenced only slightly by temperature. Instead, it is the adsorption kinetics that are strongly impacted by temperature with water adsorption rates being around six times faster in hotter climates [2].

CONCLUSIONS

The DVS system provides a well-established method for the determination of water sorption and desorption properties. It has been used successfully in the past to determine the moisture content and moisture sorption kinetics for a wide range of materials, including hair and skin. DVS could also be applied to study the adsorption kinetics and water diffusion at different temperatures.

REFERENCES

[1] Naima Ali, The Effect of Hydration and Chemical Treatments on Ntural Fibres, PhD Thesis, Imperial College London, UK, 2018.
[2] T.Evans, Studies to understand the rates of moisture adsorption and desorption in hair, H&PC Today, 11(2), 2016, 18-20.
[3] F.J.Wortmann, A.Hullman and C.Popescu - Water management of human hair – IFSCC Magazine, Vol 10(4), 2007, 317-320
[4] T.A.Evans, Adsorption Properties of Hair, in Practical Modern Hair Science, Ed. Trefor Evans & R.Randall Wickett, Allured Books, 2012.