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DVS Application Note 55

Measurement of Moisture Uptake Capacity in Human Hair Using Dynamic Vapour Sorption Technique

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Dynamic Vapour Sorption (DVS) was used to investigate the water sorption performance of three types of human hair classified as; Asian (undamaged), Caucasian (undamaged), and bleached Caucasian (damaged) hair.

Introduction

Water content is one of the most important parameters controlling the condition of skin and hair fibres [1]. Under ambient conditions human hair can take up as much as 35% by weight of water before completely wet. Bleaching and exposure to temperature as well as light would damage the inner structure of the hair and cause detectable changes in the moisture uptake properties. Therefore, the determination of equilibrium water contents, water sorption isotherms and hysteresis is of fundamental interest for the hair condition [2, 3].

Method

The hair samples were taken from a few centimeters above the ends to avoid sampling the ends themselves as they may be damaged more severely. The samples were labelled Reference (undamaged Caucasian), A (undamaged Asian) and B (damaged / bleached Caucasian). A sample size of 12 - 41mg was used for each analysis.

The samples were analysed on a DVS moisture sorption instrument at 25°C, using the following typical partial pressure profile: 95, 20, 30, 40, 50, 60, 70, 80, 90, 95, 90, 80, 70, 60, 50, 40, 30, 20,10, 0, 10, 20 and 30% RH. For all the RH steps, the instrument was run in a dm/dt mode (mass variation over time variation). A fixed dm/dt value of 0.002 % min^{-1} was selected. This criterion permits the DVS software to automatically determine when equilibrium has been reached and complete a relative humidity step. When the rate of change of mass falls below this threshold over a determined period of time, the humidity will proceed to the next programmed level. A maximum stage time of 180 minutes and a minimum stage time of 60 minutes were selected for this experiment.

Results

The superimposed moisture sorption kinetic results for samples A, B and Reference are shown in Figure 1. All data was normalised to the "dry" sample mass as defined by the sample masses at the end of the 0% relative humidity step. Percentage mass changes are referenced to this mass. The water vapour isotherm plots for the experiments are shown in Figures 2 – 4 and the corresponding hysteresis plots are given in Figure 5.

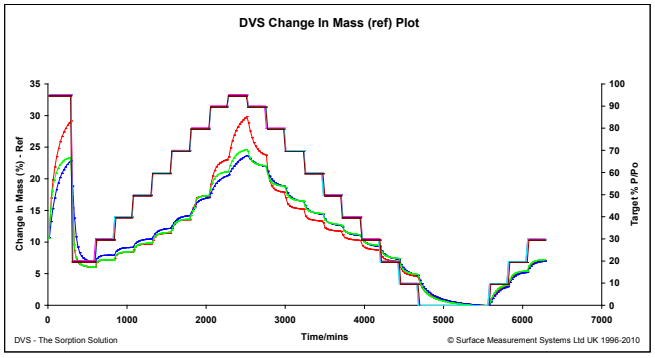

Figure 1. The superimposed moisture sorption and desorption kinetic results for samples A (red), B (blue) and reference (green) at 25°C.

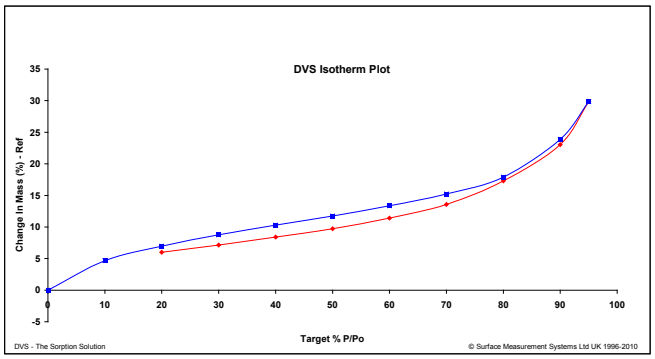

Figure 2. The moisture sorption (red) and desorption (blue) isotherms for sample A at 25°C.

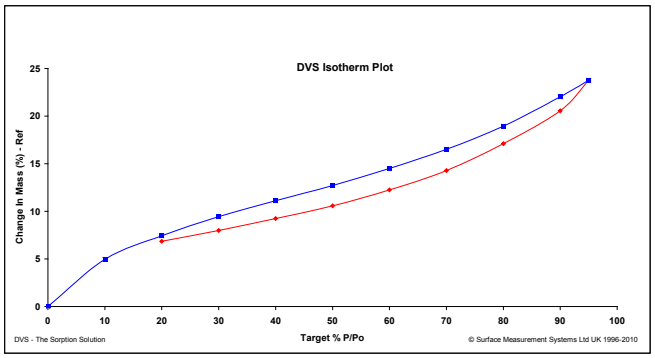

Figure 3. The moisture sorption (red) and desorption (blue) isotherms for sample B at 25°C.

From Figure 1 a number of differences in the samples can be noted, as well as a number of similarities. Sample A (undamaged Asian) showed the highest moisture uptake at 95% RH. The reference sample (undamaged Caucasian), gave an intermediate level of moisture uptake and sample B (damaged Caucasian) showed the lowest moisture uptake. After all samples passed from 95% to 20% through a 0% RH drying stage, the percentage moisture uptake for the three samples coincide at 5.5% of the dry mass at the final 20% RH step. Considering the uptakes at the initial and final 20% RH steps, the results show that the 0% RH drying step had a greater effect on sample B resulting in 1.5% decrease in the moisture uptake, whereas samples A and Reference showed a decrease of 1% in uptake during the final 20% RH step.

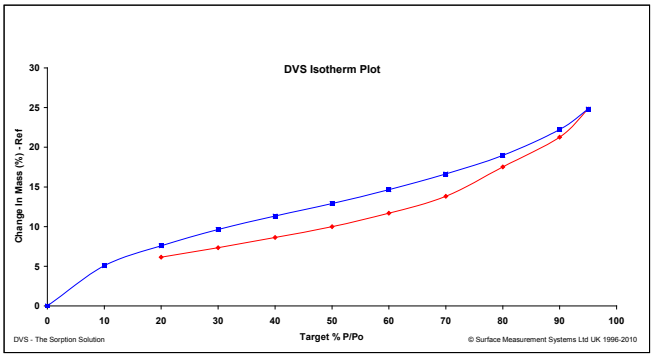

Figure 4. The moisture sorption (red) and desorption (blue) isotherms for Reference sample at 25°C.

From the isotherm plots (Figures 2 - 4) the reference sample and sample B show a much higher level of sorption/desorption hysteresis at 50% RH compared to sample A. The isotherm hysteresis plots (Figure 5) show that the trend for decreasing hysteresis at 50% RH is as follows: Reference > Sample B > Sample A, indicating that the moisture diffusion out of the bulk is more restricted for the undamaged Caucasian hair. Further work is in progress to investigate these differences.

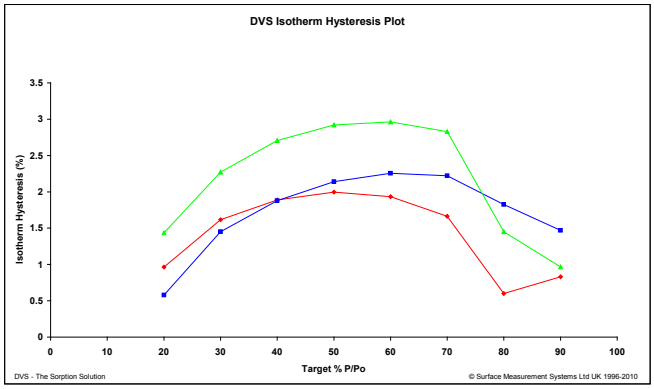

Figure 5. The superimposed DVS isotherm Hysteresis plots for samples A (red), B (blue) and reference (green) at 25°C.

The identical experimental conditions such as temperature and relative humidity would provide the most accurate level of sample to sample precision for hair samples, where small differences in sample moisture uptake would be very important. The DVS instrument allows mass changes of <0.03% to be measured and the use of an empty reference pan allows accurate baseline corrections for the instrument to be integrated into the experimental method. For the experiments reported here, which ran for nearly 5 days, active baseline subtraction would allow further precision in the experimental data.

Conclusion

Moisture uptake differences in hair samples were identified using the DVS instrument. Sample A showed the highest moisture uptake at 95% RH. The reference sample and sample B showed an intermediate and low levels of moisture uptake, respectively. After going through a 0% RH stage

the moisture uptake capacity of all three samples was found to be similar at 20% RH. The Reference sample displayed a much higher level of sorption/desorption hysteresis at 50% RH compared to samples A and B, indicating limited diffusion out of the bulk.

Active baseline subtraction using an empty pan as well as the fact that all samples were exposed to identical conditions of humidity and temperature would allow the best precision in the experimental data.

References

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