The Effect of Temperature on Moisture Sorption Kinetics in Microcrystalline Cellulose

Manaswini Acharya, Meishan Guo, Majid Naderi, Sabiyah Ahmed and Dan Burnett, Surface Measurement Systems Ltd.

Dynamic Vapour Sorption (DVS) allows a fast and accurate determination of solid-vapour interactions over a wide range of temperature and humidity conditions. The aim of this study is to investigate the moisture sorption kinetics of Microcrystalline Cellulose (MCC) at different temperatures.

Introduction

To improve the performance of the oral dosage form of pharmaceutical drugs and develop the processing, an understanding of the physical properties of the active and excipient components like Microcrystalline Cellulose (MCC) is crucial. MCC is widely used in the pharmaceutical industry as an excipient in combination with active pharmaceutical ingredients. MCC has special properties such as inactivity, the absence of toxicity, and considerable hygroscopicity. The moisture sorption by MCC has been reported to cause stability problems in tablets, affecting their potency and effectiveness due to the moisture exposure[1],[2]. This study was undertaken to measure the water sorption behaviour and kinetics of the MCC (PH-101 as standard material) over 0% to 95% relative humidity range at 5°C – 60°C by using Dynamic Vapour Sorption (DVS). Additionally, the diffusion constants were calculated over a temperature range of 10°C – 60°C.

Method

The DVS technique uses a saturated carrier gas flow over a sample. As the sample is exposed to the vapor molecules, there will be a change in the mass. As the vapor concentration is increased there are more vapor molecules present and the sample shows an increase in mass. The sorption isotherms can then be plotted by using the equilibrium mass data against the relative vapour pressure of the solvent.

Microcrystalline Cellulose (PH-101) from Sigma Aldrich with a particle size of $50\mu m$ was used to minimize the effect of particle size. 6mg – 20mg of the sample was loaded into a DVS sample pan, and immediately placed into the sample chamber. The samples were first dried under a continuous flow of dry air as a carrier gas to establish the dry mass, m_0. The samples were then exposed to the following typical partial pressure profile: 0% to 90%RH in 10% steps, followed by a 5% step to 95%RH. The partial pressure was then decreased in a similar manner. Experiments were set in dm/dt mode with a fixed value of 0.002 % min^{-1} as the criteria. The same moisture sorption experiments were performed at 5°C, 10°C, 20°C, 25°C, 40°C, 50°C and 60°C on the MCC sample. The particle size of $50\mu m$ was used for the calculation of diffusion coefficients.

Results

The superimposed plots for moisture sorption and desorption kinetics for the MCC sample at different temperatures is shown in **Figure 1**. **Figure 2** shows comparison of sorption isotherms at 5°C – 60°C temperature range. The data are expressed as the percentage change in mass with reference to the sample mass after the drying stage. The data demonstrates that within the 5°C – 25°C temperature range, the moisture uptake at a particular relative humidity does not show a significant difference. However, the water sorption results at 40°C, 50°C, and 60°C indicate that the percentage water uptake decreases as the temperature increases. Higher temperatures would increase solubility and bulk absorption and should actually increase uptake, but the sample may be going through a structural re-arrangement, which causes the decrease in water sorption capacity at elevated temperatures.
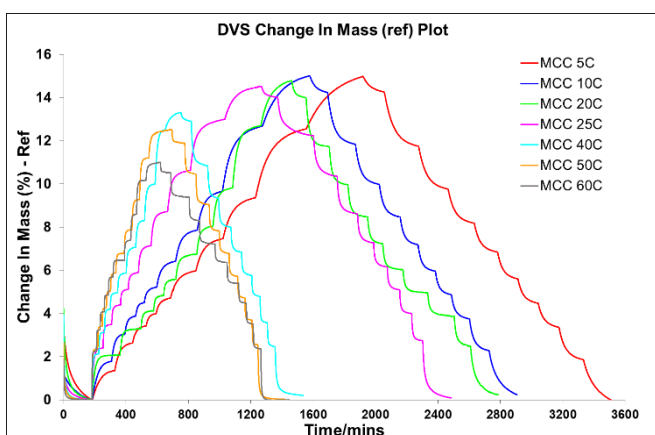

Figure 1: Water vapour sorption kinetics for MCC at 5°C – 60°C

Figure 1 shows that as the temperature increases, the moisture sorption kinetics of the MCC material are faster due to the increased diffusion through the powder bed as well as the particles. The hysteresis gap between the sorption and desorption isotherms at 60°C (**Figure 5**) is narrower as compared to 10°C (**Figure 3**). As the temperature increases, water molecules move more freely out of the bulk structure, which results

in a smaller hysteresis gap and an increase in the diffusion constants as shown in **Table 1**.

In a DVS experiment, the moisture sorption kinetics of particulate samples are determined by the speed of moisture delivery, average particle size, experimental temperature and sample size. In this study, the quick delivery of moisture to the sample at a particular relative humidity was optimised by the dynamic flow of the humidified carrier gas. The effect of particle and sample size was eliminated by using an average particle size of 50μm and a typical sample size of less than 20mg. The current data clearly demonstrates the effect of temperature on moisture sorption kinetics at a range of relative humidity conditions within the temperature stability of the material.
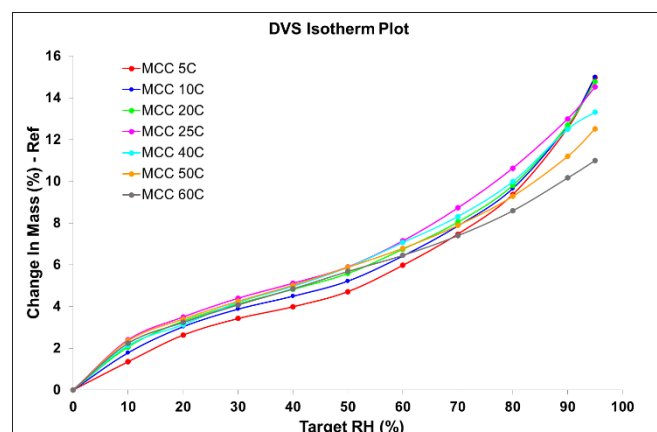

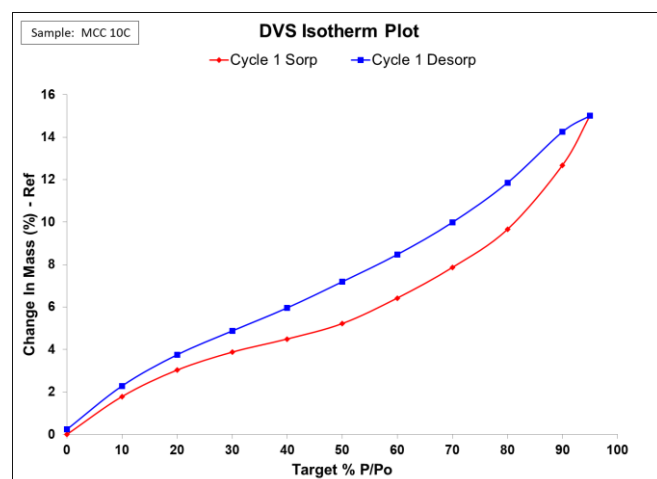*Figure 2: Water vapour sorption isotherms for MCC at 5°C – 60°C*
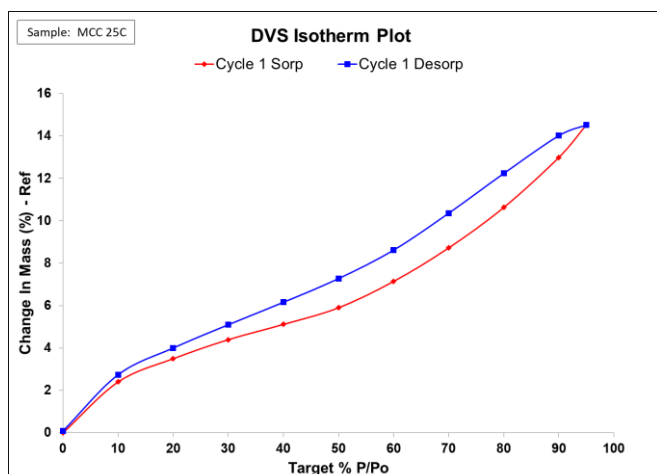

Figure 3: Water vapour sorption isotherm at 10°C

DVS Isotherm Plot

Sample: MCC 25C

— Cycle 1 Sorp — Cycle 1 Desorp

Figure 4: Water vapour sorption isotherm at 25°C

DVS Isotherm Plot

Sample: MCC 60C

— Cycle 1 Sorp — Cycle 1 Desorp
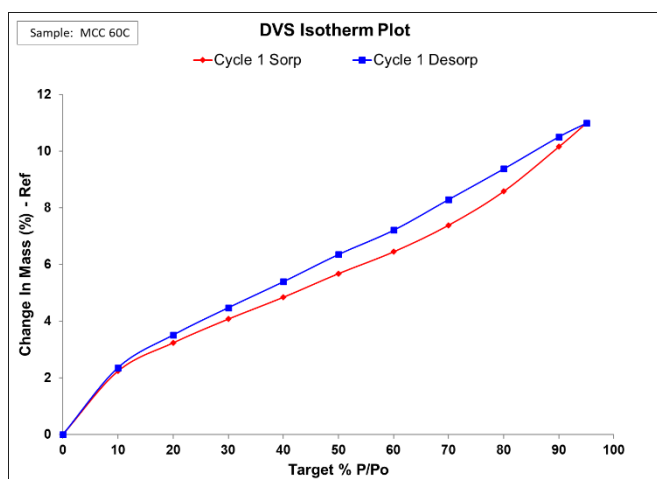
Figure 5: Water vapour sorption isotherm at 60°C

Conclusions

The physical properties of the active and excipient components like MCC are crucial in administering potent drug in the pharmaceutical products. The effect of temperature on moisture sorption kinetics of MCC shows an increase in the molecular mobility of water which results in faster equilibrium time, but decreases the overall moisture uptake at elevated temperatures due to structural re-arrangement in the material, which causes the decrease in water sorption capacity.

References

[1]. Sahputra, I.H., Alexiadis A., Adams, M.J., J. Polymer Sci., 2019, 10.1002/polb.24801.
[2]. Mihranyan, A., Llagostera, A.P., Karmhag, R., Strømme M., Int. J. Pharm., 2004, 269(2).

Table 1: *Bulk Diffusion constants at 10°C, 25°C, 40°C, 50°C, and 60°C*

Previous RH [%]	Target RH [%]	Diffusion Coefficient [cm²/s]				
		10°C	25°C	40°C	50°C	60°C
70	80	3.98E-11	2.67E-10	5.40E-10	8.97E-10	1.94E-09