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Application note | ElastoSens™ Bio

Testing the Swelling of Superabsorbent Polymers (SAP) and Gel Formation using ElastoSens™ Bio

ELASTOSENS™ BIO

CHEMISTRY

BIOLOGICAL MATERIALS

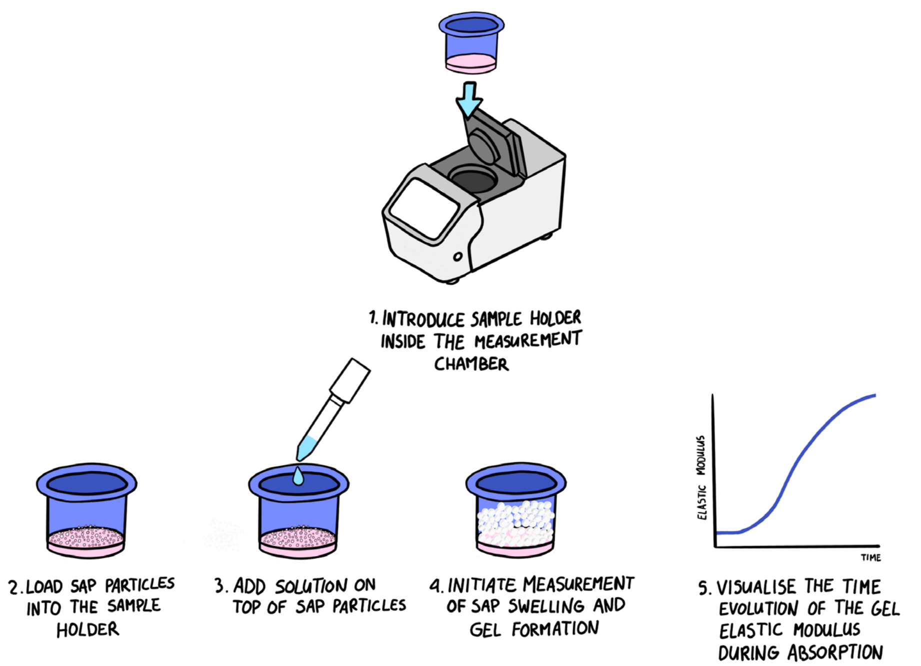
THERMO STIMULATION

INTRODUCTION

Testing the bulk mechanical properties of superabsorbent polymers (SAP) during swelling may be extremely challenging using traditional testing instruments such as rheometers and compressional testers. This analytical limitation reduces the ability to develop and formulate new superabsorbent polymers for specific applications and requirements. In this application note, we introduce the use of ElastoSens™ Bio to characterize the viscoelastic properties of SAP particles during swelling for applications in R&D and industrial quality control.

MATERIALS AND METHODS

In this study, SAP particles were weighted and dispensed into the sample holders of the ElastoSens™ Bio. A defined volume of demineralized water was then poured into the sample holder of the instrument and the test was immediately initiated in order to capture the swelling kinetics of the particles while the while the SAP absorbs water and forms a cohesive gel.



The precision of ElastoSens™ Bio to measure the swelling of SAP particles was first evaluated. For that purpose, the time evolution of the shear storage modulus G' and tan(δ) of three (03) different samples of the same SAP was measured using ElastoSens™ Bio during the absorption of demineralized water. The water-to-powder ration (swelling ratio) used for these repeatability tests was 200 g/g (i.e. there was 200 times more demineralized water than SAP powder). As it clearly appears in Figure 1, the repeatability of measurements was very high for the shear storage modulus G' and tan(δ). The variability of the shear storage modulus of the formed gel at the plateau was ±2%.

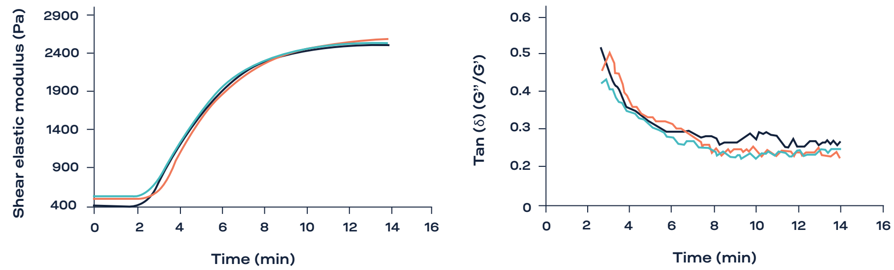


Fig. 1 Time evolution of the shear elastic modulus G' (left) and tan(δ) (right) of three samples of a SAP during the absorption of demineralized water (water-to-powder ratio was 200 g/g). The variability of measurements of G' at the plateau was ±2%.

The effect of the SAP water-to-powder ratio on the kinetics of absorption was then studied using the ElastoSens™ Bio. For this purpose, different water-to-powder ratios were tested by analyzing how different amounts of SAP powder absorbed the same quantity of water. The water-to-powder ratio was varied as follows: 100, 150, 200, 250, 300, 350 and 400 g/g. As it can be seen in Figure 2, the absorption kinetics is strongly affected by the water-to-powder ratio. The absorption was initiated more rapidly when the ratio was low. It also appears that the stiffness of the resulting gel was inversely proportional to the water-to-powder ratio.

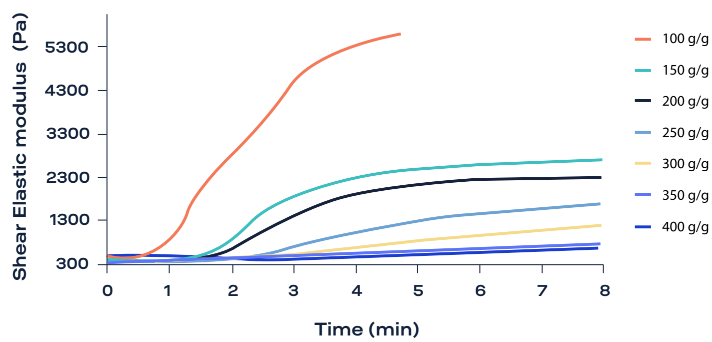


Fig. 2 Time evolution of the shear storage modulus (G') of SAP particles gels during swelling at different water-to-powder ratios. The swelling ratio was varied from 100 g/g to 400 g/g with increments of 50 g/g.

These data were processed in order to plot the stiffness (shear storage modulus, G') of the formed gels after 4 minutes of swelling as a function of the water-to-powder ratio. Similarly, the absorption initiation time was represented as a function of the water-to-powder ratio. Absorption initiation time was defined as the time the gel needs to reach a shear storage modulus G' of 700 Pa (see Fig. 2).

Figures 3 and 4 show the non-linear relationship between the gel firmness and the absorption initiation time from one hand and the water-to-powder ratio from the other hand. These non-linear, but still uniform, dependencies can be used as performance indicators when it comes to formulate new superabsorbent polymers.

The ElastoSens™ Bio was also used to measure how the pH of a solution affects the ability of a superabsorbent polymer to absorb the solution and swell. Figure 5 shows that an acidic solution tends to be absorbed more slowly by SAPs than a basic solution. Similarly, the stiffness (shear storage modulus, G') of the formed gel is also lower when an acidic solution is being absorbed by a SAP.

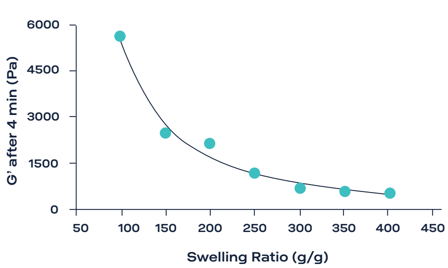


Fig. 3 Effect of the water-to-powder ratio on the shear elastic modulus (G') after 4 minutes of absorption.

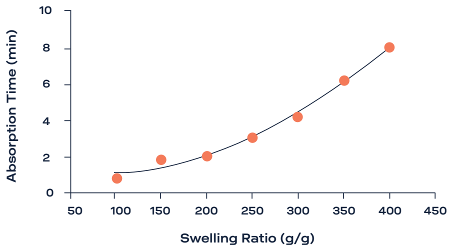


Fig. 4 Absorption initiation time (time needed by the formed gel to reach a firmness of 700 Pa) as a function of the water-to-powder ratio.

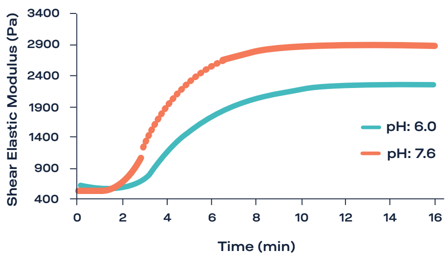


Fig. 5 Time evolution of the shear storage modulus of SAP gels while absorbing demineralized waters with two different levels of pH: 7.6 and 6. The water-to-powder ratio was maintained stable at 200 g/g.

The ElastoSens™ Bio was finally used to study the incremental swelling of SAP particles. The testing protocol consisted in successive additions of defined amounts of demineralized water on top of the SAP gel and to measure the time evolution of the shear storage modulus during absorption. The water-to-powder ratio was varied from 100 g/g to 400 g/g with increments of 100 g/g. Figure 6 shows the evolution of the shear storage modulus (G') as a function of time during the experiment. It is noticeable that the addition of water caused a sudden decrease of G' before the gel starts absorbing the extra volume of water. However, this behavior tended to decrease as the water-to-powder ratio increased and the maximum absorption capacity of the SAP was reached.

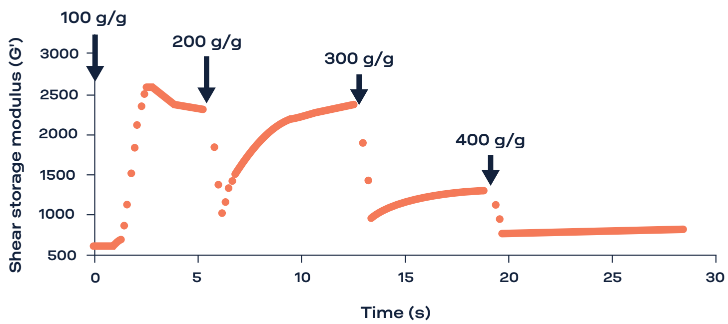


Fig. 6 Time evolution of the shear storage modulus (G') of a superabsorbent polymer during incremental absorption of demineralized water. Water was incrementally added to get a water-to-powder ratio of 100 g/g (added at 0 min.), 200 g/g (added after 5 min.), 300 g/g (added after 13 min.) and 400 g/g (added after 19 min).

CONCLUSION & PERSPECTIVES

This application note showed how the ElastoSens™ Bio can be used to characterize the swelling of SAP particles and the formation of a biphasic gel made of SAP gel and liquid. The time evolution of the shear storage modulus reflects key parameters that describe the quality and efficacy of a SAP:

Parameter	What question does it answer?
Absorption initiation time	How long does it take to the SAP to start absorbing the liquid?
Absorption speed	How fast does the SAP absorb the solution?
Total absorption time	How long does it take to the SAP to complete the absorption of the liquid?
Gel final stiffness	How strong (and stable) the formed gel is? What is the remaining absorption capacity of the SAP?

These measurements can serve to study how chemical and physical conditions affect the absorption of solutions by a SAP. One can, for example, change the chemistry of the solution to quantify how a given formulation of SAP will react. The ElastoSens™ Bio also proved to be convenient to study the incremental absorption of a solution. The instrument can be used to study, *in vitro*, the absorption of physiological liquids and to simulate real life conditions.

The ElastoSens™ Bio can be used in R&D to develop and qualify new formulations of SAPs. It can also be used in quality control to monitor the quality and performance of a product.

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