# Monitoring the Drying of Paint Under Controlled Humidity

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## ABSTRACT

When applying paint on a surface, its drying process is significantly affected by the environment to which it is exposed, such as temperature and humidity conditions. The relative humidity accessory on the TA Instruments Discovery Hybrid Rheometer (DHR) is a powerful tool that provides the capability of controlling both temperature and humidity at the same time. In this paper, we studied the drying process of paint under different controlled humidity environments. The changes of viscoelastic properties of the paint surface were quantitatively monitored by using a specially designed surface diffusion geometry. Our results have highlighted the sensitivity and effectiveness of this technique in understanding paint's response to a changing humidity environment.



*Figure 1: TA Instruments Discovery Hybrid Rheometer with the relative humidity accessory (DHR-RH)*

## INTRODUCTION

In addition to temperature, the amount of water content in materials such as water-based liquids, pastes, gels and hygroscopic solids, has a significant impact on their rheological properties. When exposed to a humid environment at certain temperatures, the viscoelastic properties of these materials may undergo significant changes, which can affect their processing and/or end use. For example, the drying process of paints, inks or coatings is extremely sensitive to the environmental surroundings. Leveling, sagging and cracking of a coating are also affected by drying kinetics. Therefore, quantitative characterization of the rheological properties during drying under controlled humidity conditions is critically important.

TA Instruments has introduced a Relative Humidity (RH) accessory that can be attached and used with a Discovery Hybrid Rheometer (Figure 1). This accessory provides the ability to control both temperature and humidity simultaneously. Test geometries used in combination with this DHR-RH accessory have been specially designed and optimized for testing different types of samples varied from low viscosity liquids and pastes to solids. The operating temperature range of this accessory is 5-120 °C, and the controllable relative humidity range is 5-95% depending on the set temperature. The specifications of this humidity accessory are shown in Figure 2.

In this study, the relative humidity accessory with the surface diffusion ring geometry was used to monitor the drying process of a water-based latex paint under a controlled humidity environments.

| | |
|---|---|
| Temperature Range | 5 °C – 120 °C |
| Temperature Accuracy | ±0.5 °C |
| Heating/Cooling Rate | Maximum ±1 °C/min over entire range |
| Humidity Range | 5% to 95% RH (see chart below) |
| Humidity Accuracy | 5 – 90% RH: ±3% RH<br>>90% RH: ±5% RH |
| Humidity Ramp Rate | ±2% RH/min (fixed) both increasing and decreasing |

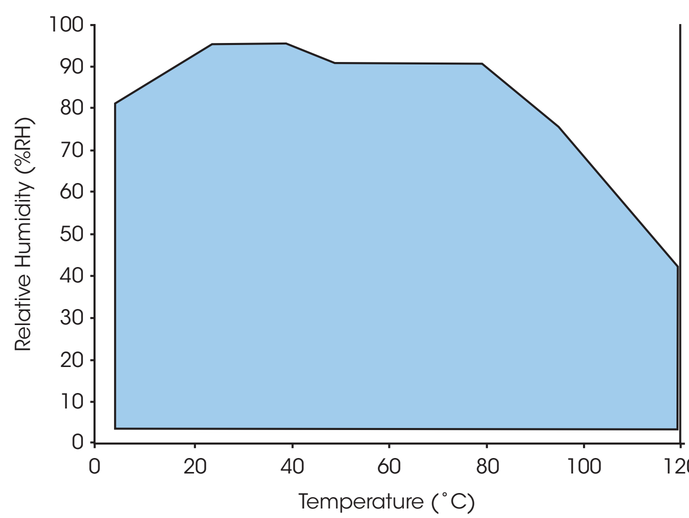


*Figure 2: DHR-RH Accessory operational specifications*

## EXPERIMENTAL

A commercial interior water-based latex white paint was used for all testing. In order to quantitatively monitor drying, a specially designed surface diffusion ring geometry (shown in Figure 3) was used with the relative humidity chamber on a DHR-3 rheometer. This geometry is designed similar to the double wall ring interfacial geometry as it is designed for measuring the surface viscoelasticity of low viscosity samples such as paint or ink. The bottom stage is an annular trough that holds the liquid sample. The upper geometry has a sharp-edge ring positioned right at the surface of the sample. Bulk rheology is limited by diffusion. This surface diffusion ring keeps the entire sample surface open to atmosphere, enabling it to exchange with chamber gas. Measurement at surface is not limited by internal diffusion time. The ring is designed to have low mass to minimize system inertia. It has sufficient sensitivity to monitor changes of viscoelasticity at the surface of a low viscosity liquid such as paint or ink.

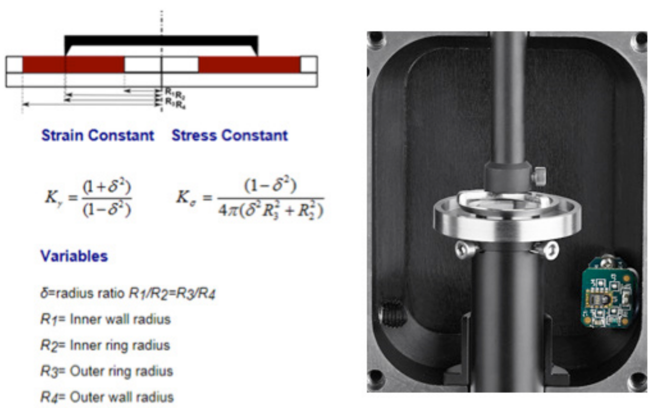


*Figure 3: Picture of surface diffusion geometry and its stress and strain constant equations*

A dynamic time sweep test was programmed for monitoring the drying process of paint. The measurement temperature was 30°C, and sample chamber relative humidity was set to 10%, 30% and 60%, respectively. Since the contact area between sample and geometry was small, a low oscillation torque (5.0 µN.m) and low frequency (1.0 rad/s) were used for the measurements in order to minimize the contribution of instrument and geometry inertia to the results. During the test, sample surface moduli ($G'_s$ and $G''_s$) and complex surface viscosity were monitored as a function of humidity and time.

## RESULTS AND DISCUSSIONS

Paint drying is limited by diffusion of water from the bulk. This diffusion process is slow since a boundary layer or skin is formed at the surface with a high solid content. The surface diffusion ring is designed to selectively monitor surface, rather than bulk rheology change. For this reason, the data obtained is selectively representative of the dried boundary layer. Figure 4 shows quantitative measurements of surface moduli and complex surface viscosity at 30 °C and 60% relative humidity. At the beginning of the test, the sample behaved liquid-like when $G''_s$ was greater than $G'_s$. Both moduli increased with time, which indicated a weak structure that was building over time with water evaporation. The $G_s$ crossover point can be used to correlate to the formation of surface skin. At this point, the paint surface underwent a liquid-to-solid transition. Beyond the crossover point, the storage modulus ($G'_s$) continuously increases at almost a constant slope, which indicates that the surface film structure increased in strength with further drying. The test was terminated before the sample lost a significant amount of volume.

Figure 5 shows the results collected under different humidity conditions (i.e. 10%, 30% and 60%, respectively). Comparative values of $G_s$ crossover time and modulus are summarized in Table 1. This paint sample was observed to dry or form the surface skin more slowly when it is exposed to a higher humidity environment. However, even though the $G_s$ crossover occurred at much longer time with higher humidity, the crossover modulus was at the same value (i.e. 0.057 N/m), which indicates that paint surface film processed the same rheological properties associated with the material's formulation and were independent of the surrounding humidity.

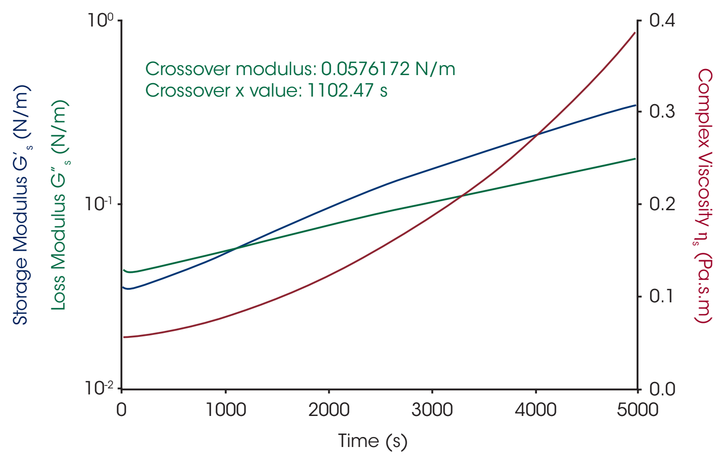


*Figure 4: Time sweep test at 30 °C and 60% relative humidity*

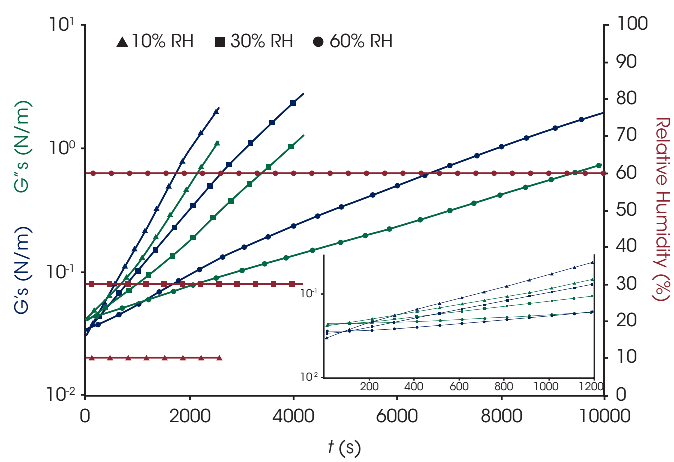


*Figure 5: Time sweep tests at 30 °C with relative humidity of 10%, 30%, and 60%, respectively*

*Table 1: Summary of modulus crossover under different humidity*

| Relative Humidity (%) | 10% | 30% | 60% |
|---|---|---|---|
| $G_s$ Crossover Time (s) | 338 | 485 | 1102 |
| $G_s$ Crossover Modulus (N/m) | 0.057 | 0.056 | 0.057 |

## CONCLUSIONS

The paint drying process is very sensitive to its application conditions such as temperature and humidity. TA Instruments' relative humidity accessory with the surface diffusion ring geometry on the DHR rheometer provides the capability of quantitative measurement of this drying process under both controlled temperature and humidity environment.

For more information or to place an order, go to http://www.tainstruments.com/ to locate your local sales office information.