Terahertz time-domain spectroscopy for the analysis of latex film formation

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***Abstract*— The subject of latex film formation has been studied for many years and it is known to be affected by many environmental conditions such as evaporation rate, polymer glass transition temperature, T_g, and particle size. Understanding latex film formation is particularly relevant to the paint industry, to ensure even coated films. In this study, THz-TDS was used to analyze various latex solutions with different polymer glass transition temperatures and particle sizes. 2D water distribution maps were produced, as a function of drying time, to monitor latex drying processes such as the 'coffee-ring effect'.**

I. Introduction

Latex consists of polymer particles dispersed in water. It has many commercial applications including paint, adhesives, sealants, and construction additives. The film formation process is of particular relevance in these industries to create thin, smooth, crack-free films. The process is often described in three sequential steps: firstly, most of the water evaporates and the polymer particles pack together. Afterwards, the particles deform above the minimum film formation temperature and the remaining water evaporates producing a homogeneous, transparent film. In the final stage, if the temperature is greater than T_g, the polymer diffusion between particles leads to the phasing out of the polymer particle interface. The properties of the polymers can affect this process [1].

Terahertz time-domain spectroscopy (THz-TDS) has been used successfully to measure the thickness of paint coatings [2-4]. Some attempt has been made to study the drying process, but this has been limited with THz-TDS [5].
In this study, THz-TDS was used in a reflection setup to analyze the effect of particle size and glass-transition temperature, T_g, on the film formation process of different latexes.

II. Methodology

THz-TDS measurements were taken using the K-15 THz spectrometer by Menlo systems in a reflection geometry with a 30° incident angle. For the calibration curves, 1 ml of latex sample, at various solids contents, were pipetted onto the quartz imaging window and a circular holder was used to maintain the sample height. 30 pulses, at 4 pulses per second, were acquired immediately after to mitigate the effect of evaporation. The average peak-to-peak (P2P) of the 30 pulses was calculated, and a calibration curve of P2P against latex solids content was determined.

To image the drying process, 0.05 ml of latex sample was pipetted atop of the quartz imaging window to form a circular droplet. The sample was left to dry until completely transparent. The reflection set-up moved in a x–y imaging stage, leading to the acquisition of 21×21 pixels images. Each image had an acquisition time of 4 minutes. The P2P of each pulse at each position was measured to produce the images shown in Figure 1.

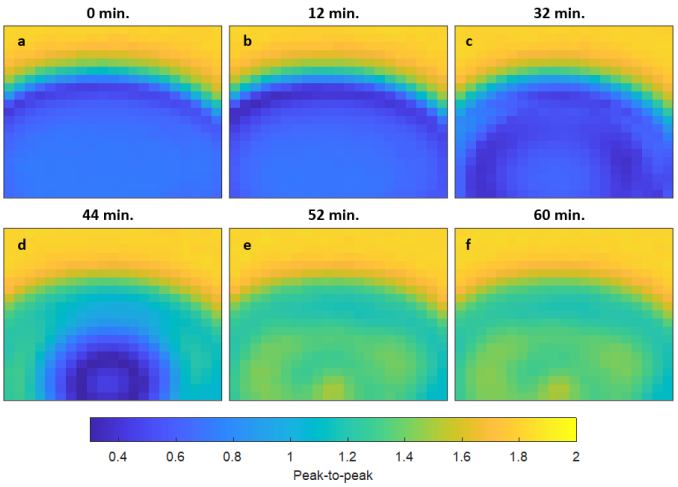

Fig. 1. 21×21 pixels 2D water distribution maps of a drying latex solution, demonstrating a decrease in the water content of the sample. The sample was dried over a period of 64 minutes, when full transparency was reached. The time in minutes at which the images were recorded is given above each image.

III. Results and Conclusions

Initial results show that the droplet experiences non-uniform drying. This is expected due to the 'coffee-ring effect' which exhibits faster drying at the edge of the droplet, and slower drying in the middle, due to particle movement outwards via capillary flow. Interestingly, the water distribution shows a depletion zone of particles (dry blue circle) moving inwards as the droplet dries. Using a calibration curve of P2P as a function of solids content it is possible to quantify the water content in the different drying sections. This allows further investigation into the effects of particle size and glass-transition temperature on the latex's drying process.

References

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