

Drying Kinetics of Cellulose-Triacetate Films

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Introduction

Solvent-cast cellulose-triacetate film has traditionally been used as a substrate for photographic films, but now is also a key component in the manufacture of thin-film polarizers for the optical display industry. In this new application, the optical and physical property requirements of the cellulose-triacetate (TAC) sheet are stringent as are the specifications for defect levels. The primary means of preventing many common defects during manufacture is to maintain the solvent content and temperature of the TAC sheet within empirically determined ranges during each processing step. Consequently, optimization and troubleshooting of the TAC manufacturing process is greatly facilitated by a model that accurately predicts the drying kinetics. There are, however, some noteworthy features of TAC drying that could complicate model development. First, TAC coatings are strongly skinning. Second, it has been reported that the two major solvents in the TAC formulation, MeCl₂ and MeOH, exhibit non-ideal vapor-liquid equilibrium behavior. And third, since TAC coatings are relatively thick (~400 μm wet) compared with many commercial coatings, the effect of solvent diffusion on drying rates is accentuated.

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Experiment

In this work, an experimental apparatus was built to gather requisite data to enable the development of an accurate drying model for TAC. This apparatus enabled the application of 150 to 900 μm thick (wet) TAC coatings to a temperature controlled glass plate. Surrounding this plate was an enclosure with an exhaust damper that could be adjusted to control the air speed parallel to the coating surface within the range of 38 to 220 m/min. The apparatus also included an interferometer, a gas chromatograph/mass spectrometer, and an IR pyrometer to measure the film thickness, individual solvent vapor concentrations, and coating surface temperature with time. The interferometer was of a novel design that allowed the probe to be placed more than 5 cm from the coating surface and provided measurement of thickness and index of refraction independently. The precision of this instrument was 2 nm when measurements were averaged for 1 second.

An experiment was performed to determine the effects of plate temperature, initial film thickness, and air velocity on individual solvent evaporation rates. Figures 1 and 2 show plots of film thickness and solvent vapor concentration vs. time for a one set of process

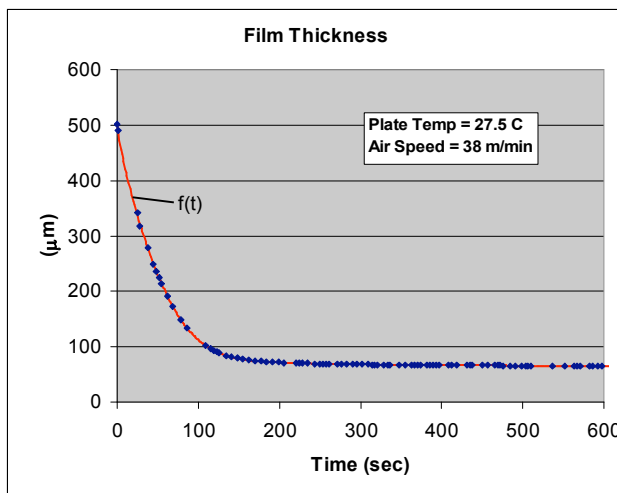


Figure 1

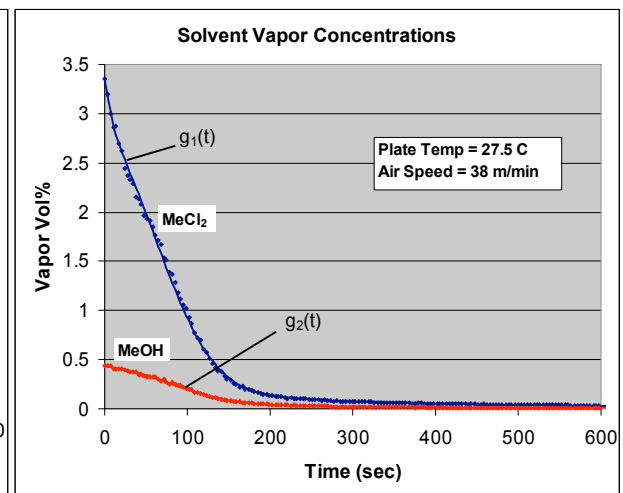


Figure 2

conditions. The solid curves on these plots are the best fits to the data that could be obtained using a non-linear regression technique. From these curve fits individual evaporation rates were calculated using the following relationships:

$$\dot{m}_1 = \frac{-\left(\frac{df(t)}{dt}\right)}{\left(\hat{V}_1 + \left(\frac{g_2(t)}{g_1(t)}\right)\hat{V}_2\right)}$$

$$\dot{m}_2 = \dot{m}_1 \left(\frac{g_2(t)}{g_1(t)}\right)$$

where \dot{m} and \hat{V} are the solvent evaporation rate and mass specific volume, respectively. The subscripts specify the solvent.

Results

Predictions of MeCl₂ and MeOH evaporation rates from a multi-solvent capable drying model were compared to measured trends. This model utilized the Flory-Huggins theory for estimation of the activity coefficients and the Free Volume theory for estimation of the temperature and concentration dependent Fickian based diffusion coefficients. No attempt was made to account for the skin that formed almost immediately at the TAC coating surface. For a base case set of drying conditions, the predictions of the model were made to match the observed behavior as closely as possible by varying some of the parameters in the physical property relationships. Subsequently, comparisons of predictions to observations for other drying conditions were made to see how well the model captured basic drying process changes.

Figures 3 and 4 show the comparison for film thickness and solvent evaporation rates calculated from the data in Figures 1 and 2 and from the drying model. Although the agreement between the measured and predicted curves is not exact, it does appear that the overall method

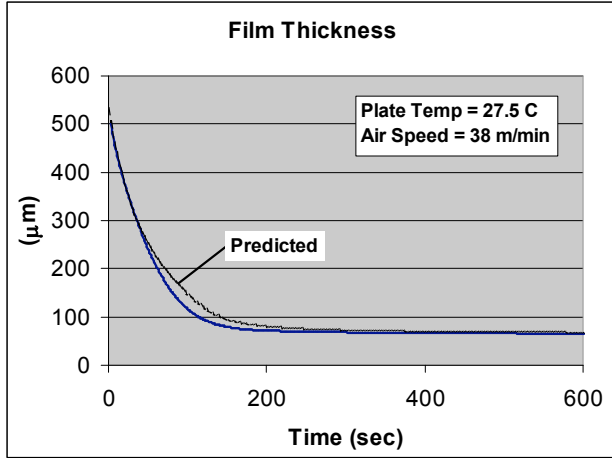


Figure 3

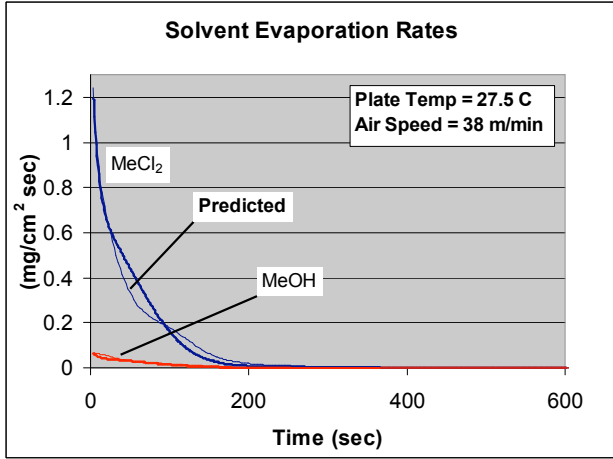


Figure 4

described here can be successfully used to calibrate a drying model for an industrial TAC manufacturing process. Furthermore, it appears that a Fickian model adequately captures solvent diffusion behavior within the film even with the presence of the skin. The presentation will describe these results in more detail as well as several additional interesting observations made about TAC drying behavior during the experiment.