Modeling of Infrared drying of Polymer Solution

Md Zia-ul, Ramadhane Dhib, and Yaser Dahman
Department of Chemical Engineering , Toronto, M5B 2K3

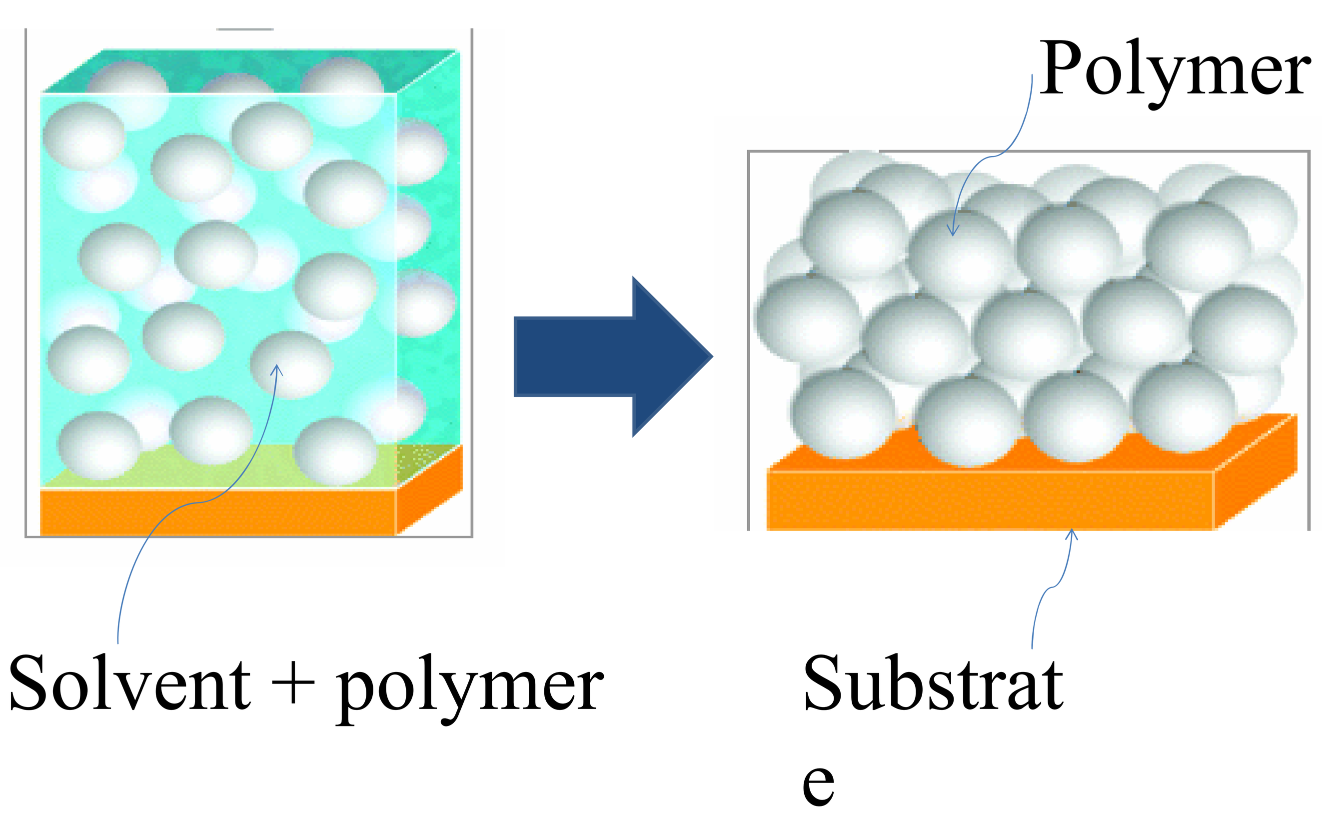
Introduction

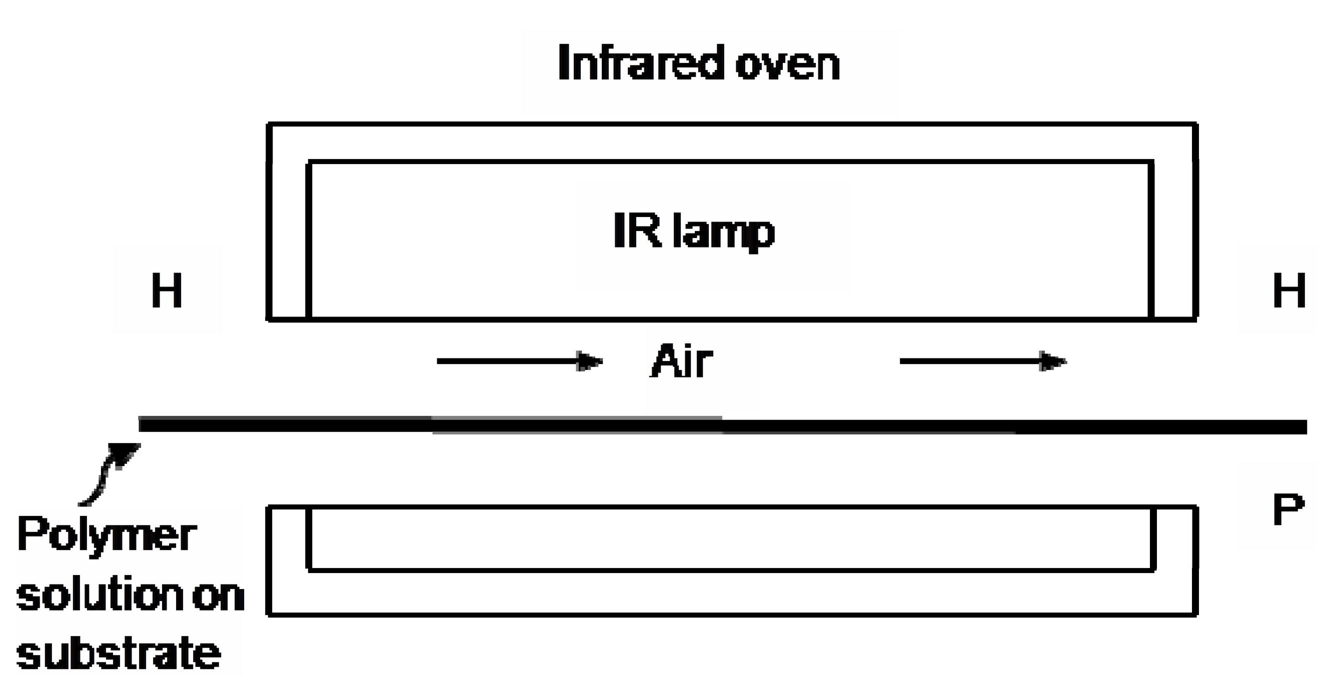
The manufacturing of adhesive tapes, photographic films, paints, protective coatings, magnetic media etc. involves the coating and drying of thin polymeric films. Here we discuss continuous drying of such film in an Infrared-convective oven.

Objective

To investigate the effect of following physical parameters on drying:

- ❑ Air velocity & temperature
- ❑ Polymer thickness
- ❑ Substrate velocity
- ❑ Heat flux





Major Advantages of IR drying

- ❑ High thermal efficiency, shorter response time
- ❑ High degree of process control
- ❑ Cleaner working environment
- ❑ Low maintenance cost

Model of Continuous IR Drying

Assumptions

- ❑ Binary polymer solution
- ❑ Uniform temperature of polymer film
- ❑ Heat & mass transfer in one dimension
- ❑ No chemical reaction in the solution
- ❑ The polymer film is opaque

Simple mass balance between the air the polymer gives us the following equations

$$\frac{\partial H_p}{\partial t} + V_p \frac{\partial H_p}{\partial x} = -\frac{W_p V_p}{M_p} \dot{m}_{evap}$$

$$\dot{m}_{evap} = k_m (H_{sat} - H_a)(H_p / H_c)^{\beta}$$

$$\frac{\partial H_a}{\partial t} + V_a \frac{\partial H_a}{\partial x} = \frac{W_p V_a}{M_a} \dot{m}_{evap}$$

Following two PDEs describe the radiative and convective heat transfer among the polymer, air and IR heater

$$\frac{\partial T_p}{\partial t} + V_p \frac{\partial T_p}{\partial x} = \frac{V_p W_p}{C_{p_s} M_p} \frac{\dot{q}_{pr} - \dot{q}_{pa} - \dot{q}_{evap}}{(C_{p_p} / C_{p_s}) + (H_a / H_p)}$$

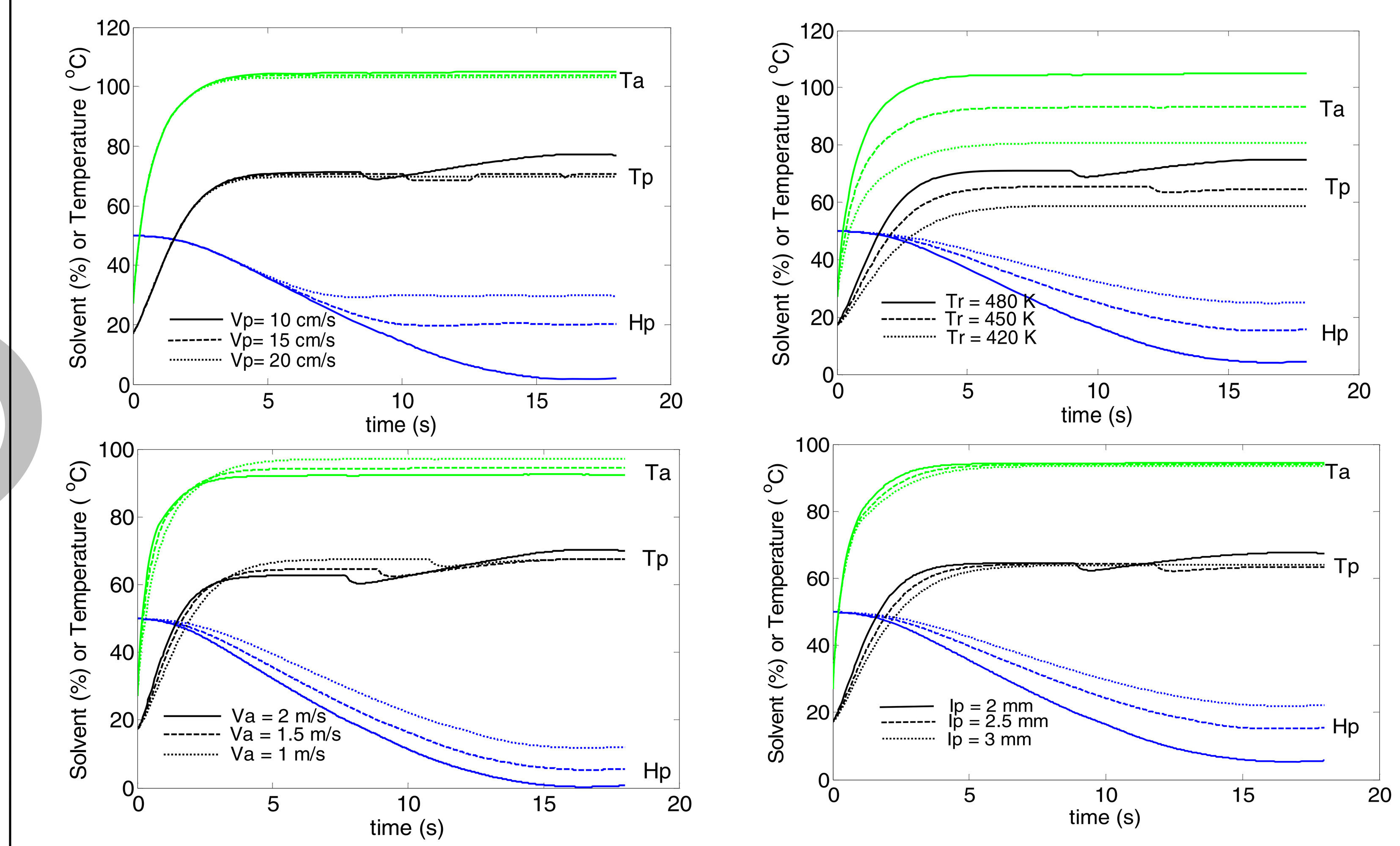
$$\frac{\partial T_a}{\partial t} + V_a \frac{\partial T_a}{\partial x} = \frac{V_a}{C_{p_v} M_a} \frac{W_r \dot{q}_{ra} + W_p \{\dot{q}_{pa} + m_{evap} C_{p_v} (T_p - T_a)\}}{(C_{p_a} / C_{p_v}) + H_a}$$

Where,

$$\dot{q}_{pr} = \Im \varepsilon_p \sigma (T_r^4 - T_p^4) \qquad \dot{q}_{evap} = m_{evap} (\Delta h_v + H_{des})$$

$$\dot{q}_{ra} = h_{ra} (T_r - T_a) \qquad \dot{q}_{pa} = h_{pa} (T_p - T_a)$$

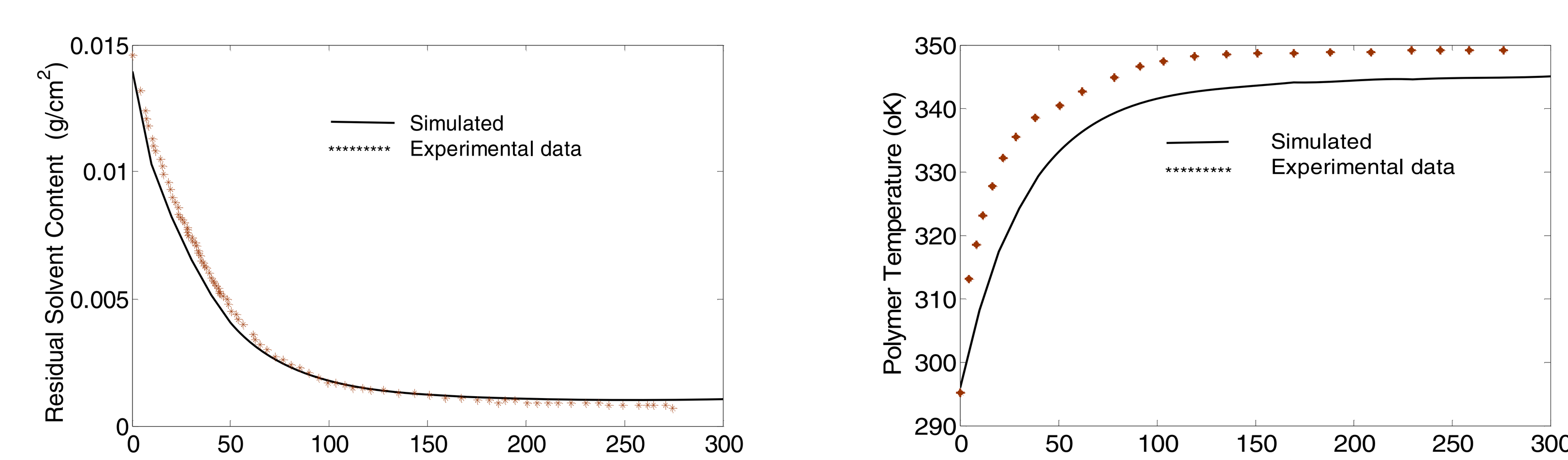
Results & Discussion



All the figures above demonstrate that solvent content (Hp) is a strong function of substrate velocity (Vp), heat flux (Tr), air velocity (Va) and polymer thickness (lp); whereas polymer and air temperatures mainly depend on heat flux.

Model Validation

Experimental data of convective drying of PVAC-toluene has been compared with the simulated result



Conclusions and Future Work

Simulation of only convective drying part of the model is in good agreement with the experimental data. However, the simulated results of IR-convective drying could not yet be validated due to lack of published data in the literature.