

Optimising the thickness determination of homopolymers and diblock copolymers using optical spectral reflectance during solvent vapour annealing

INM - RUC 2019 - Master's Thesis

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7/5/2019

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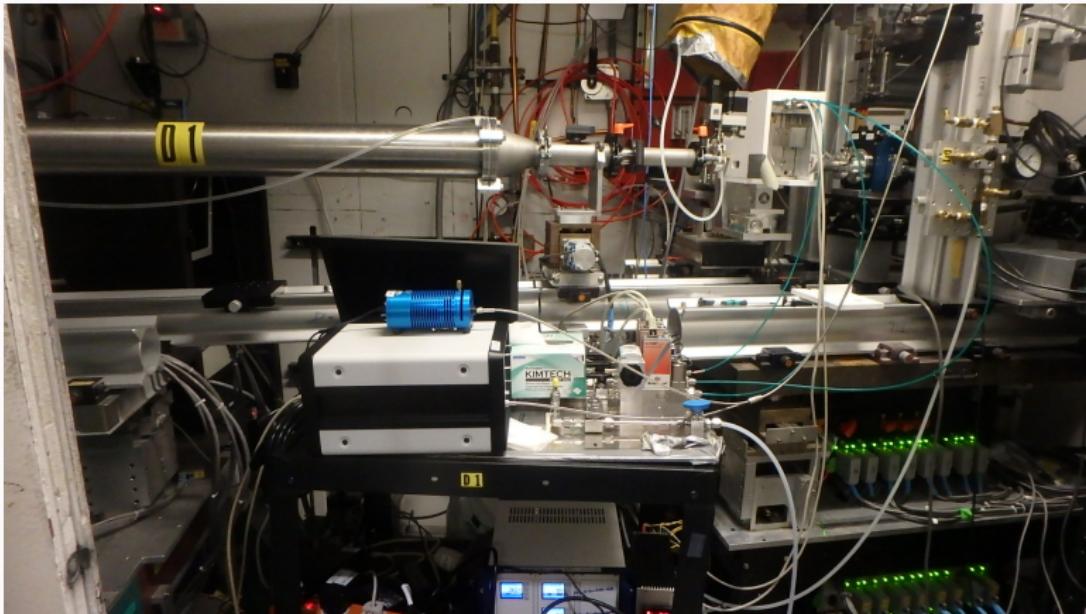
Table of contents

1. Master Thesis Prelude
2. Master Thesis Problem Formulation
3. Experimental Setup
4. Polymers
5. Fresnel Models
6. Solvent vapour Annealing
7. Preliminary Studies
8. Results - 1 polymer layer

Master Thesis Prelude

D-Line

December '17 and May '18



Problems with the reflectance measurements during swelling



Figure 1: Polystyrene - SVA run used in Master Thesis

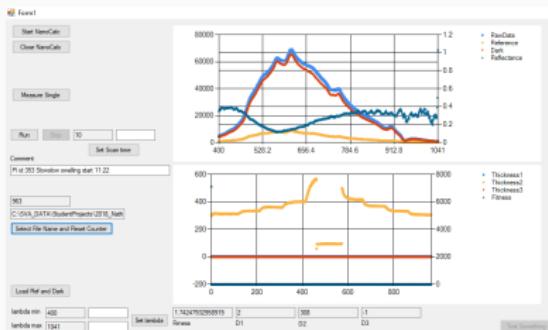


Figure 2: Polyisoprene - SVA run used in Master Thesis

Master Thesis Problem Formulation

Problem Formulation

What are the advantages and limitations when using optical spectral reflectance for determining the thickness of thin polymer films during solvent vapour annealing?

What is the optimal modelling and fitting method for the optical spectral reflectance measurements and thickness determination of the homopolymers, polystyrene and polyisoprene thin films during solvent vapour annealing?

Can the same thickness determination be used on thin films with a horizontal nano scale structure such as the diblock-copolymer Polystyrene-b-Polyisoprene?

Experimental Setup

Experimental Setup Overview

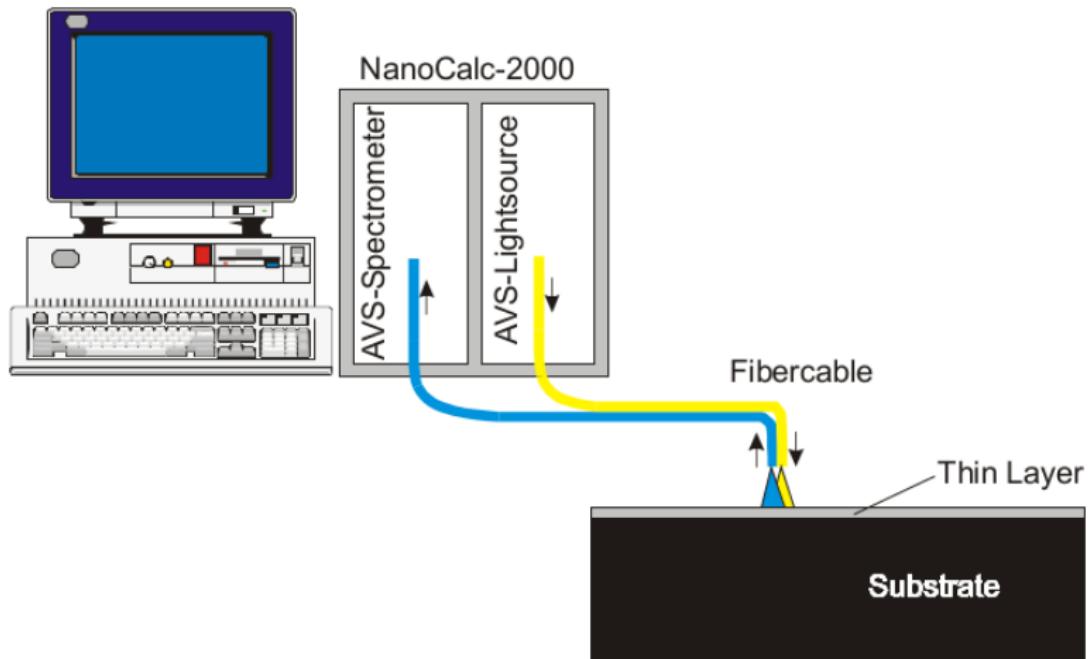
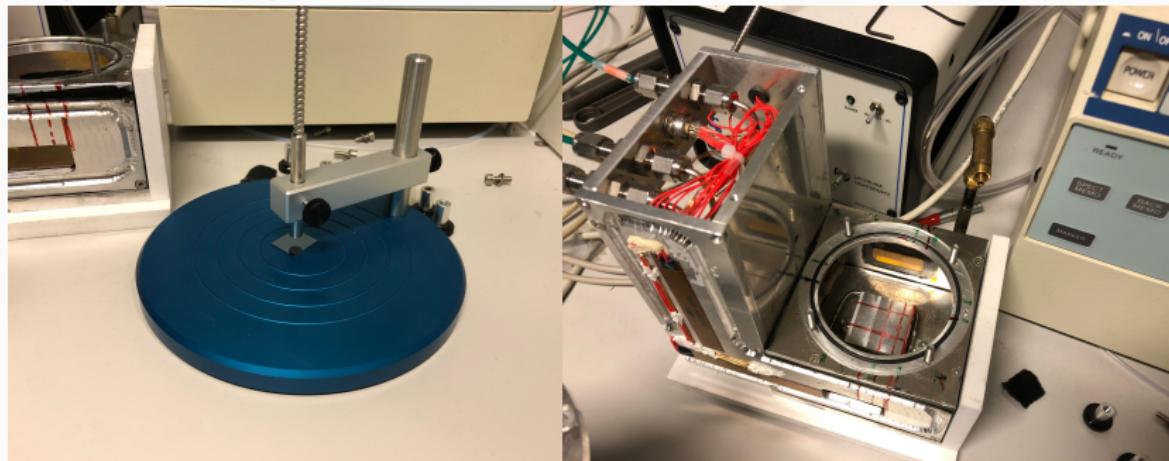


Figure 3: Taken from NanoCalc Software Manual v.4

Experimental Components

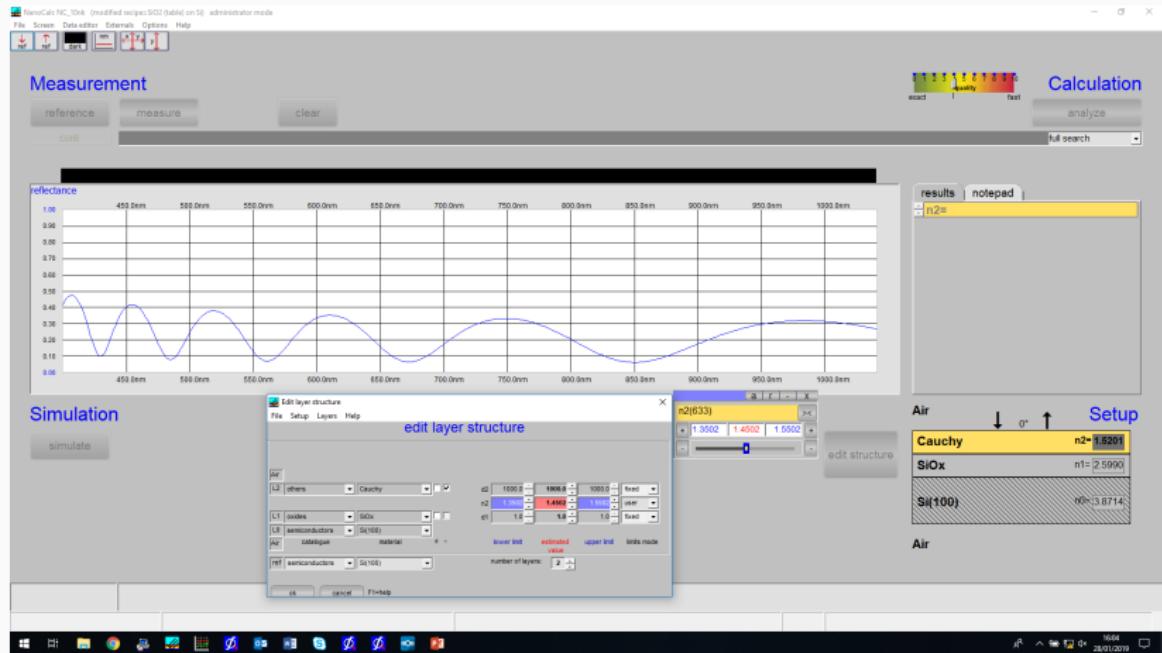
Single Point Stage and SVA test chamber.



Step Wafer



NanoCalc Software



Taking Measurements

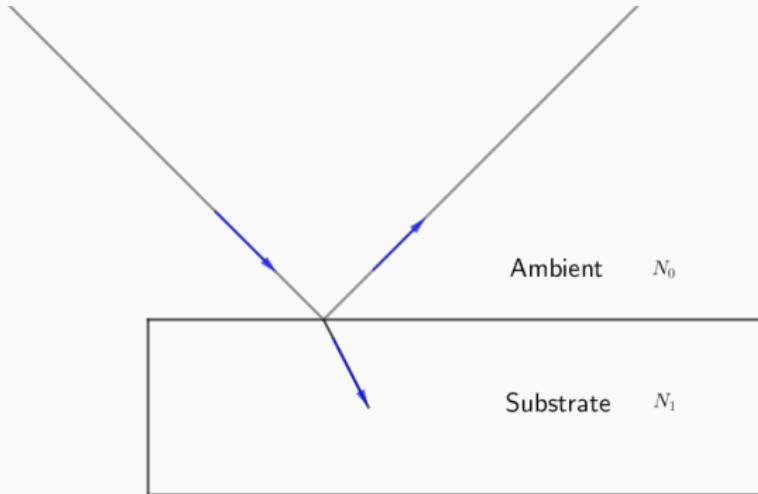
$$\text{Reflectance} = \frac{\text{Meas} - \text{Dark}}{\text{Ref}} \cdot R_{\text{sub}}$$

- Dark Measurement - *Dark*
 - Measuring stray light.
- Reference Measurement - *Ref*
 - Measuring light from blank wafer - SiO_x/Si
 - Ref data - minus dark
- Wafer Measurement - *Meas*
 - Wafer with spin-coated polymer
- Reflectance from ambient/substrate model - *R_{sub}*
 - Calculation - Fresnel model

Polymers

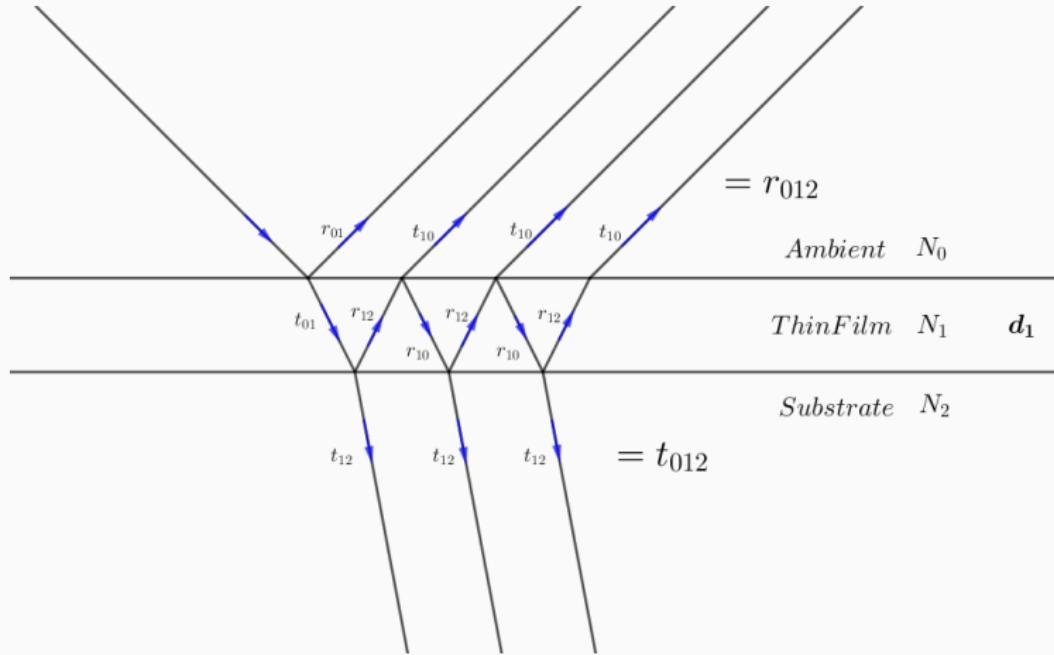
Fresnel Models

Fresnel Equations - Substrate



$$r_p = \frac{E_{r,p}}{E_{i,p}} = \frac{N_1 - N_0}{N_0 + N_1}$$
$$R_p = | r_p |^2$$

Fresnel Equations - One layer



$$r_{012} = r_{01} + t_{01}t_{10}r_{12} \exp(-i2\beta) + t_{01}t_{10}r_{10}r_{12}^2 \exp(-i4\beta) + \\ t_{01}t_{10}r_{10}^2r_{12}^3 \exp(-i6\beta) + \dots$$

Fresnel Equations - One layer

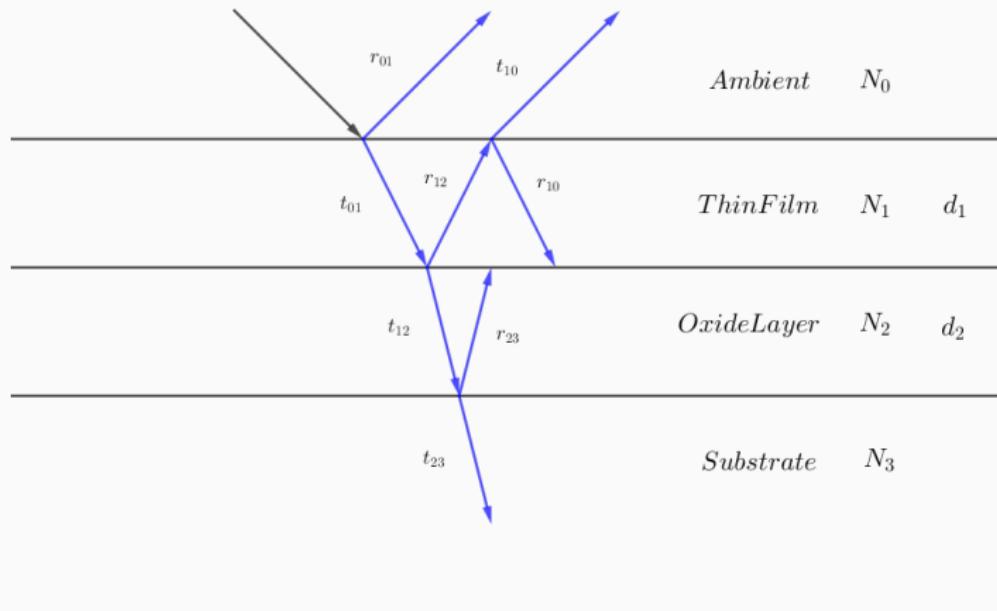
$$r_{012} = \frac{r_{01} + r_{12} \exp(-i2\beta)}{1 + r_{01}r_{12} \exp(-i2\beta)}$$

$$r_{jk} = \frac{N_k - N_j}{N_j + N_k}$$

$$\beta = \frac{2\pi d_1}{\lambda} N_1$$

$$R_{012} = |r_{012}|^2$$

Homopolymer Fresnel Model



Homopolymer Fresnel equations

$$r_{0123} = \frac{r_{01} + r_{123} \exp -i2\beta_1}{1 + r_{01}r_{123} \exp -i2\beta_1}$$

$$r_{123} = \frac{r_{12} + r_{23} \exp -i2\beta_2}{1 + r_{12}r_{23} \exp -i2\beta_2}$$

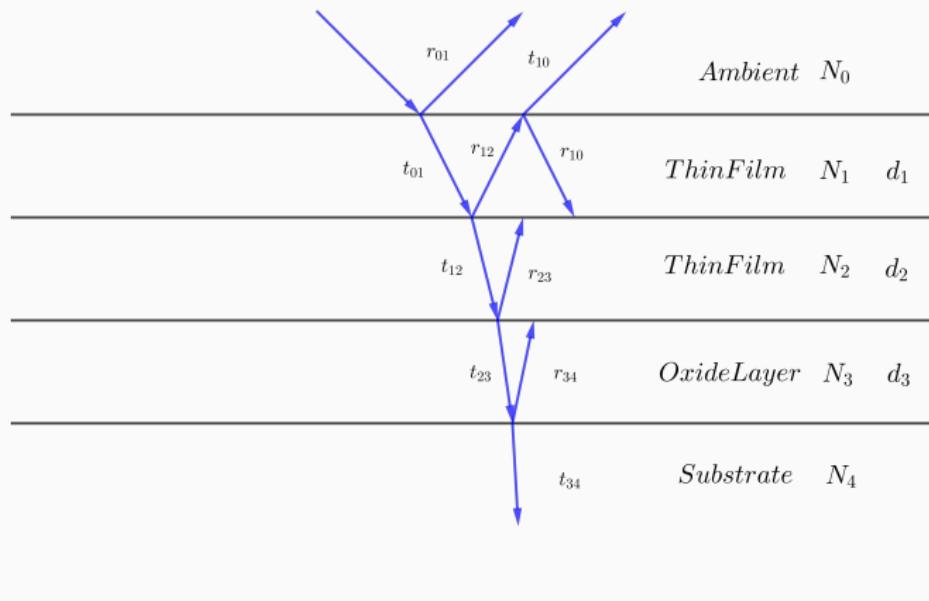
$$r_j k = \frac{N_k - N_j}{N_j + N_k}$$

$$R_{0123} = | r_{0123} |^2$$

$$\beta_i = \frac{2\pi d_i}{\lambda} N_i$$

N_0, N_1 and d_1 fitted during solvent vapour annealing.

Diblock copolymer Fresnel model



Diblock copolymer Fresnel Equations

$$r_{01234} = \frac{r_{01} + r_{1234} \exp(-i2\beta_1)}{1 + r_{01}r_{1234} \exp(-i2\beta_1)}$$

$$r_{1234} = \frac{r_{12} + r_{234} \exp(-i2\beta_2)}{1 + r_{12}r_{234} \exp(-i2\beta_2)}$$

$$r_{234} = \frac{r_{23} + r_{34} \exp(-i2\beta_3)}{1 + r_{23}r_{34} \exp(-i2\beta_3)}$$

$$r_{jk} = \frac{N_k - N_j}{N_k + N_j}$$

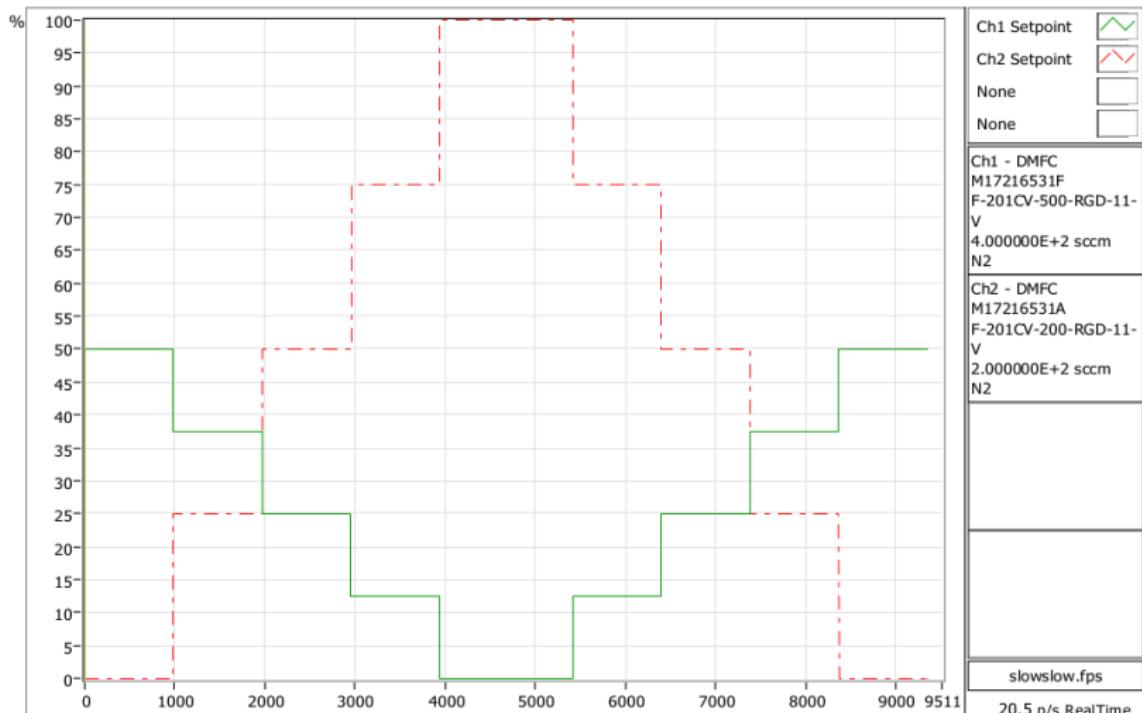
$$\beta_i = \frac{2\pi d_i}{\lambda} N_i$$

N_0, N_1, N_2, d_1 and d_2 fitted during solvent vapour annealing.

Plotted Fresnel models

Solvent vapour Annealing

SVA protocol



Preliminary Studies

Light Fluctuation

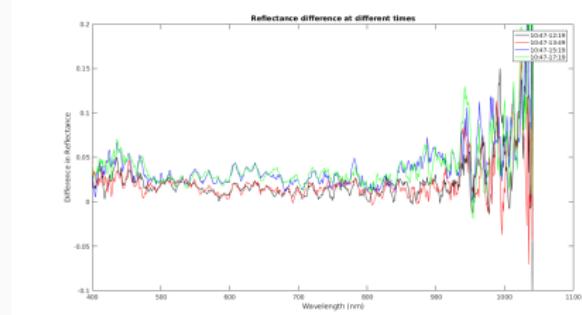


Figure 4

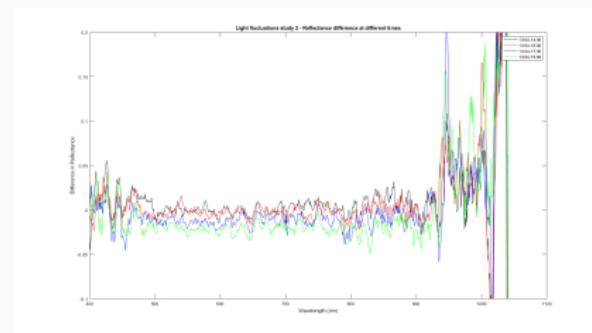


Figure 5

Solvent vapour annealing ambient study

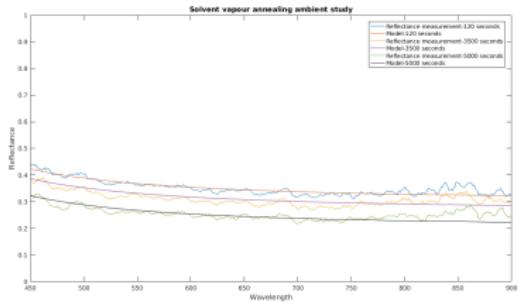


Figure 6

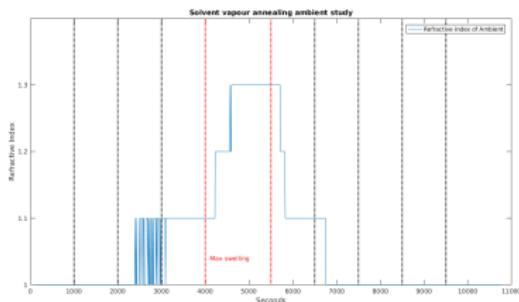


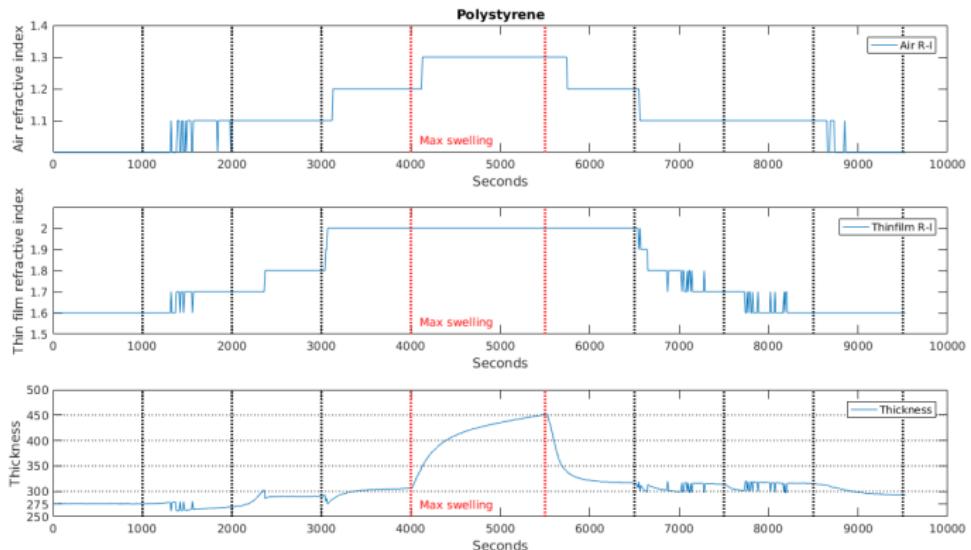
Figure 7

Results - 1 polymer layer

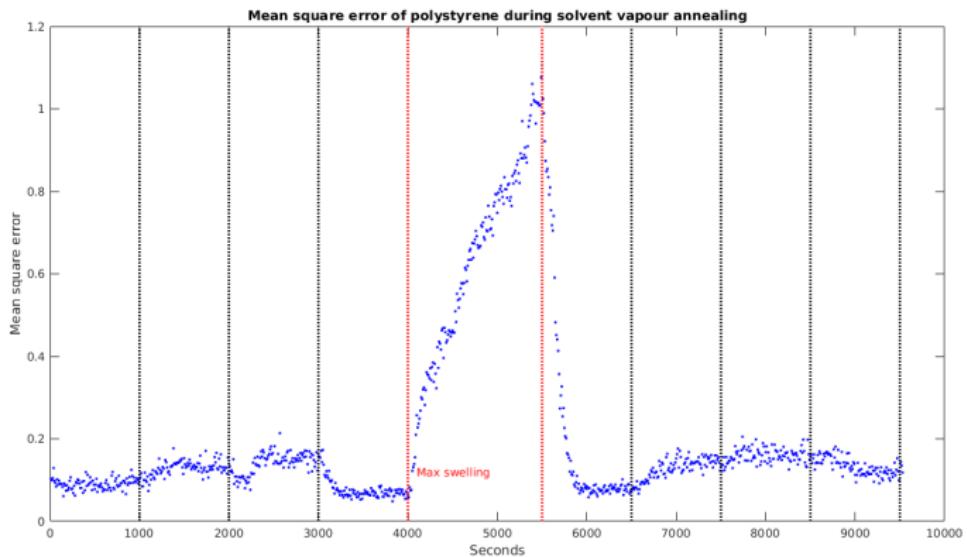
Polystyrene

Movie: PSsva.avi

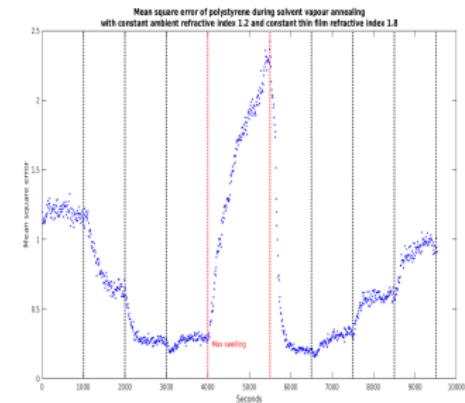
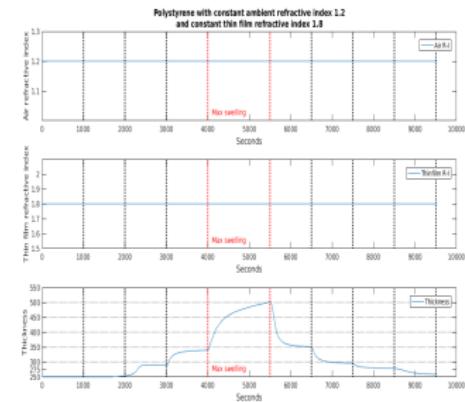
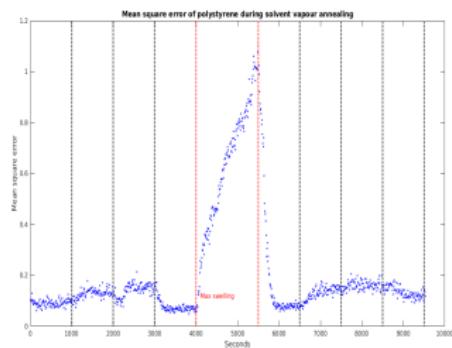
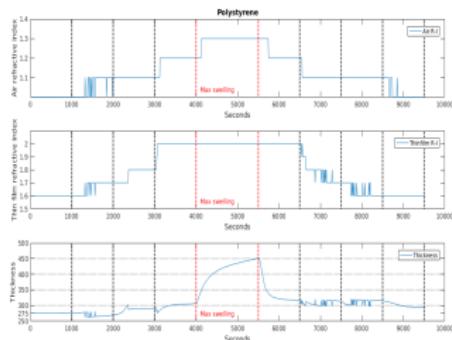
Polystyrene Results



Polystyrene MSE

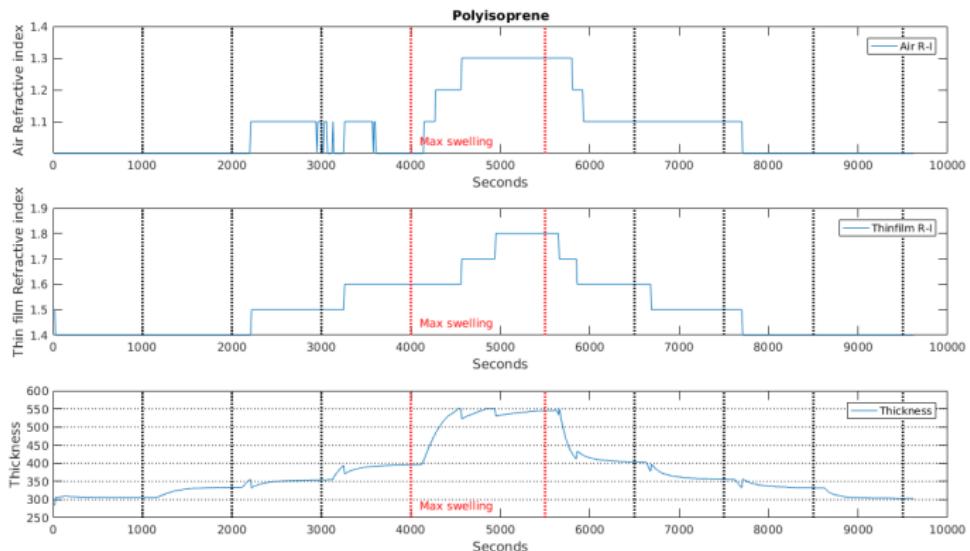


Polystyrene comparison

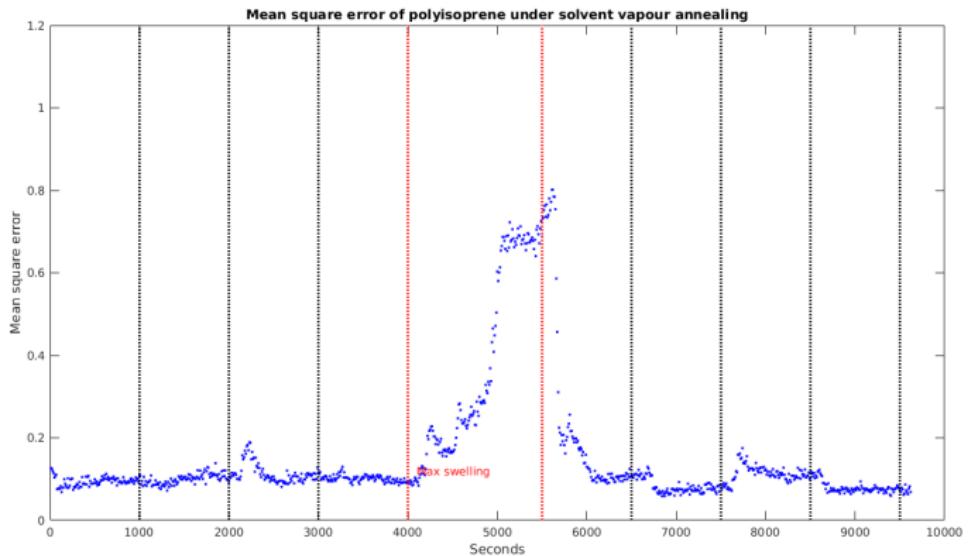


Movie:PIsvalframevalue2.avi

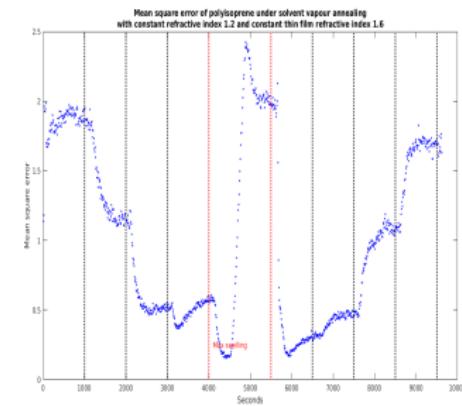
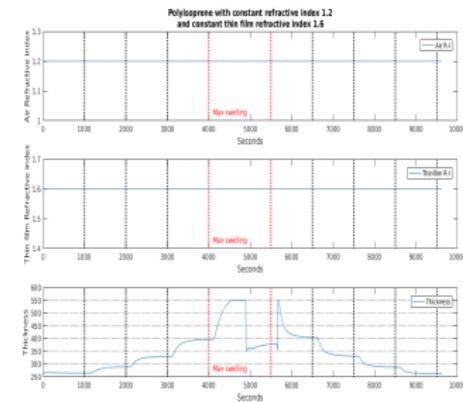
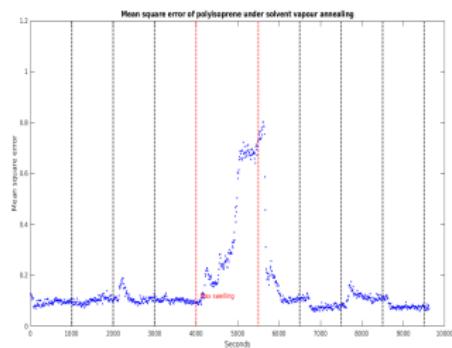
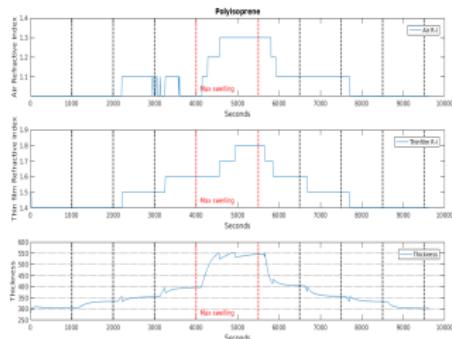
Polyisoprene Results



Polyisoprene MSE



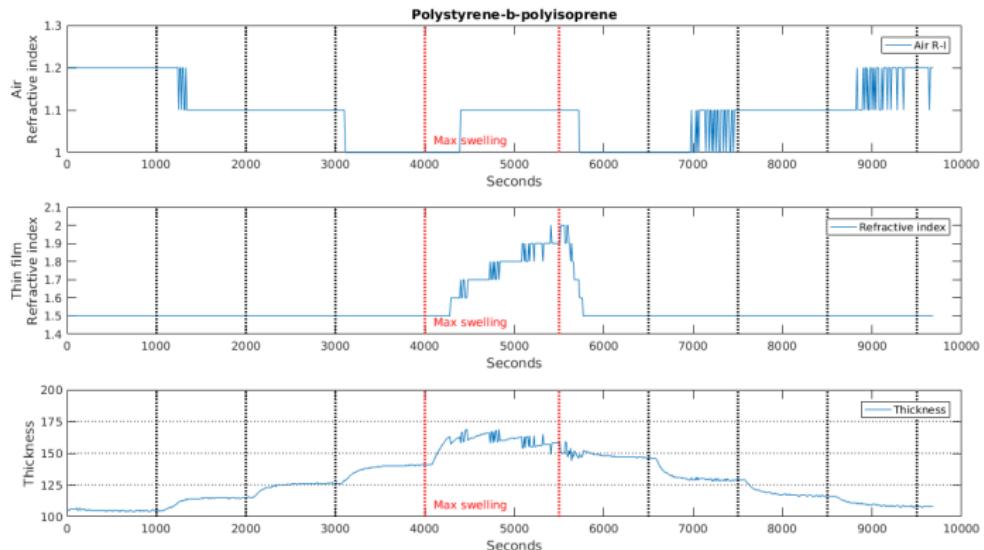
Polyisoprene comparison



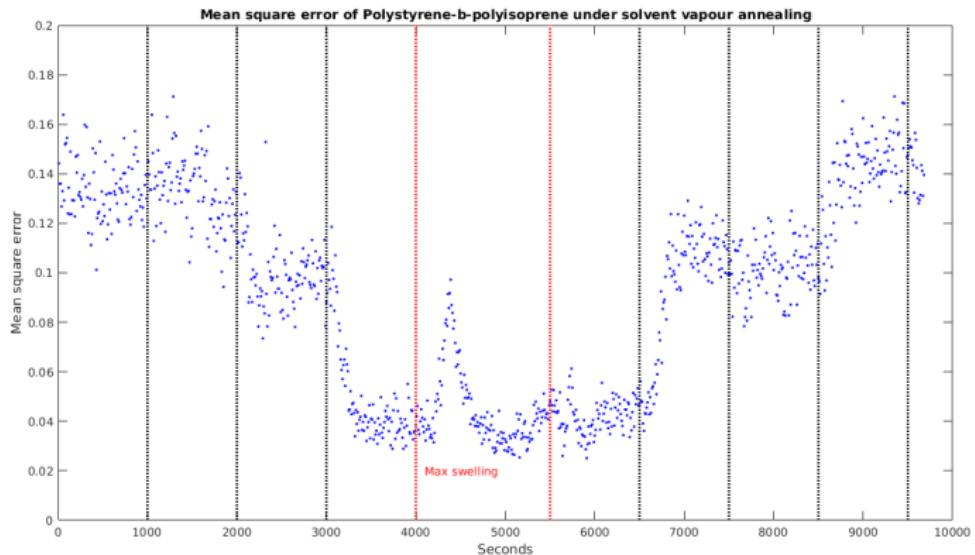
Polystyrene-*b*-polyisoprene

Movie: PSbPIsinglemodel.avi

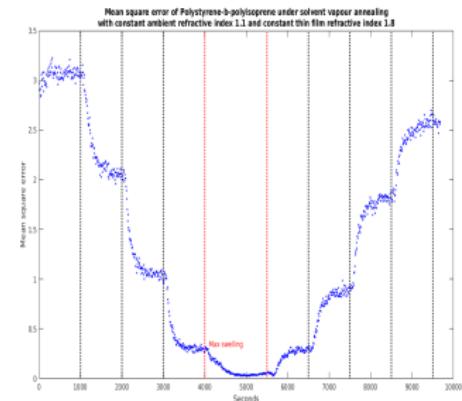
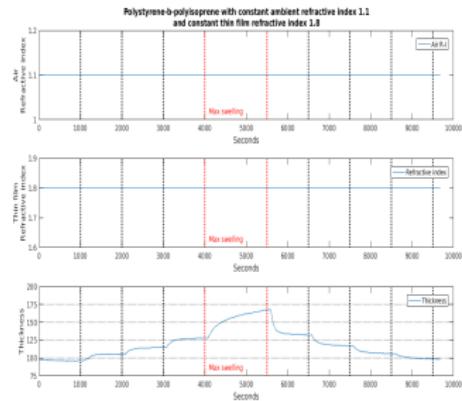
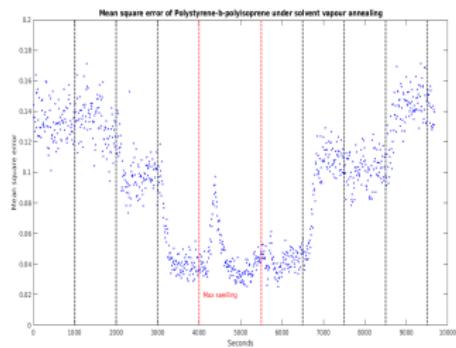
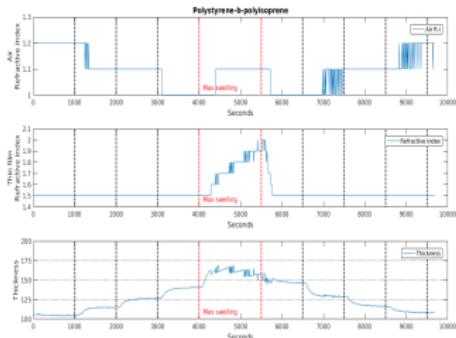
Polystyrene-b-polyisoprene Results



Polystyrene-b-polyisoprene MSE



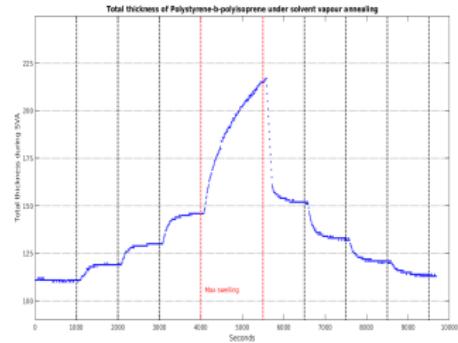
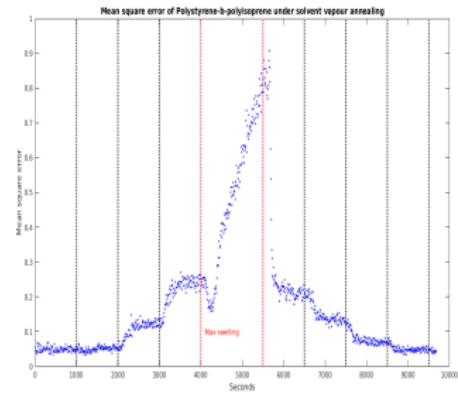
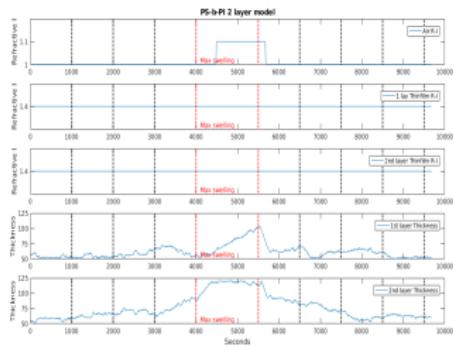
Polystyrene-b-polyisoprene comparison



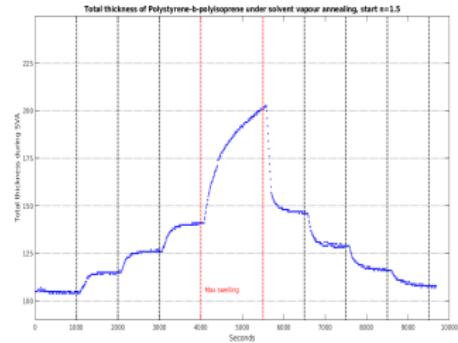
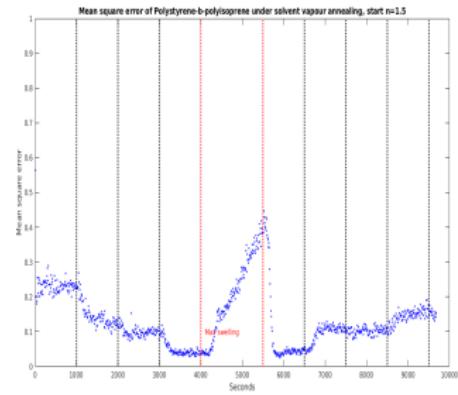
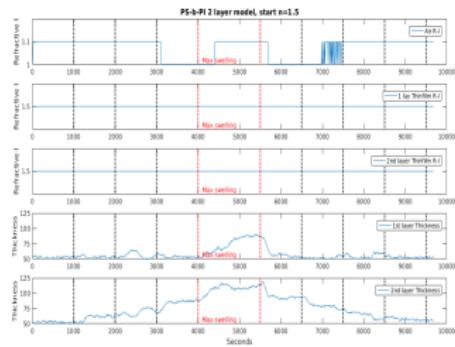
Results - 2 polymer layers

Movie: PSbPIfit2layermodel.avi
(Might Delete)

PS-b-PI - 2 layer model



PS-b-PI - 2 layer model



Using a 3rd party apparatus and software

content...

Missing
