How to Use UV-Vis Absorption of PhIs to Monitor Inner Filter Effect in UV Curable Formulations

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Outline of Presentation

1. Introduction: Basic Problems in UV Curing Applications

2. What Is Inner Filter Effect?

3. Results and Discussion

   To use BPh UV absorption difference to study inner filter effect of PhI across depth of cured film

   Depth profile of BPh (PhI) consumption (photo decomposition) as a function of depth of cured film

   Influence of UV light intensity on reducing inner filter effect in model formulations

4. Conclusion

The Challenge of UV Curing

At the outmost part of UV cured films:

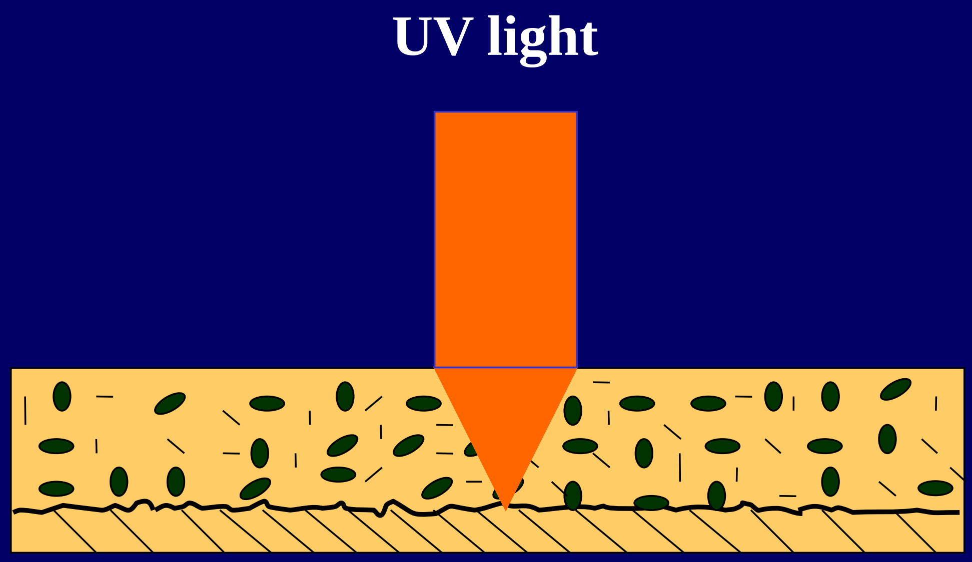
Oxygen Inhibition in Touch Screen Hard Coating

At the interface between UV cured films and substrates:

Inner Filter Effect in UV embossing Coating

On UV curing production line:

Un-stable UV Output and un-stable Spectra Distribution



Photoinitiators

Monomers or oligomers

Distribution of UV light intensity as a function of filter effect in formulation

What is inner filter effect for UV Light and how can we reduce it?

Filter effect: $I_a \cdot I_0$

Filter effect comes from monomers, oligomers, additives, PhIs and pigments, as well as laminated substrates, such as PET, PP / PE

Filter effect on UV light intensity has more influence on bottom part of cured film for Inks, relative thicker films, such as UV embossing coatings

PhIs and inner filter effect for UV curing applications

How to reduce inner filter effect in UV curing applications?

1. Formulation

Reduce amount of PhIs

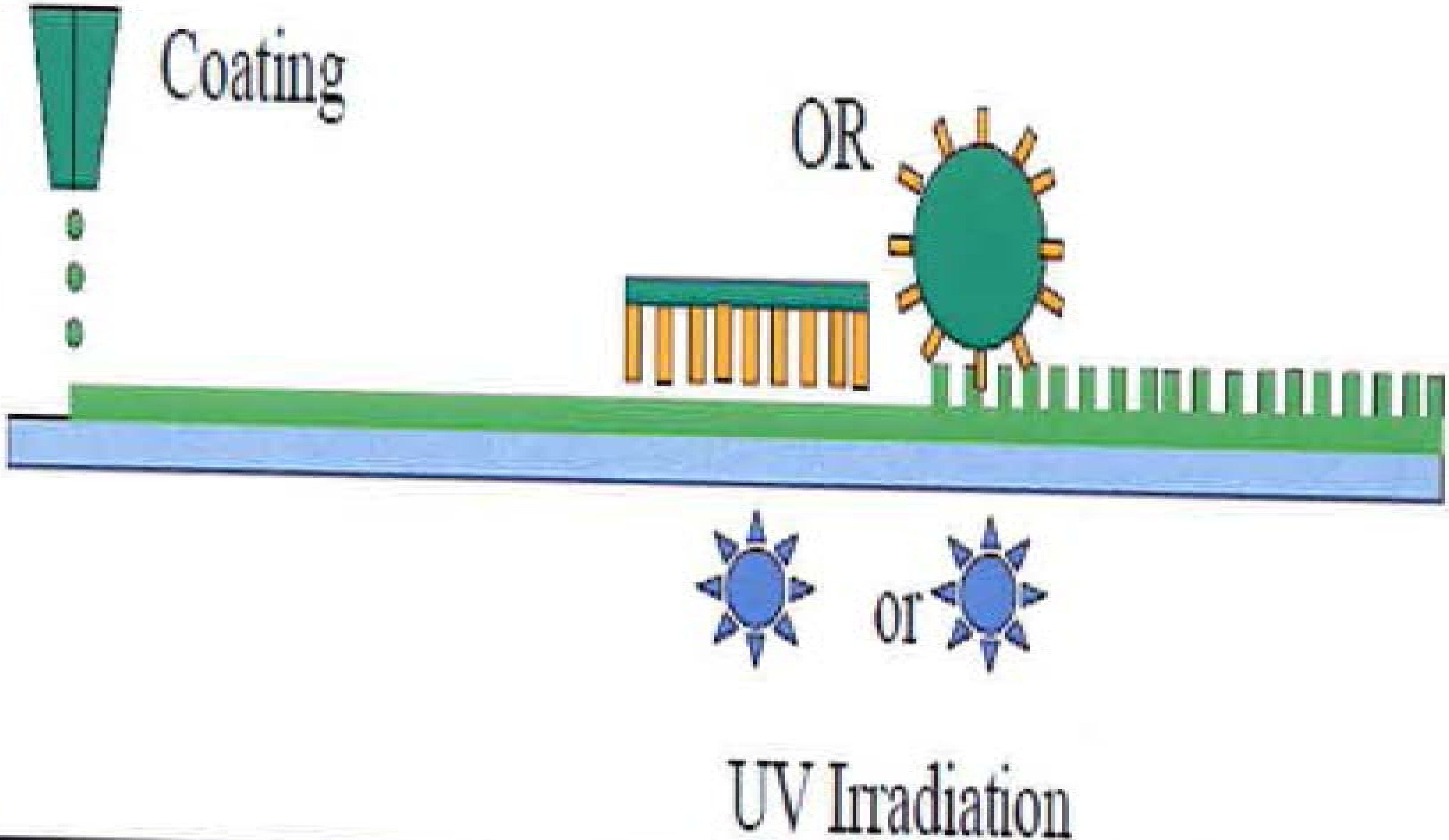
Use Photo Bleachable PhI

2. UV Lamp

Increase UV Energy(mJ/cm^2) by reducing cure speed or increasing the number of lamps

Increase I_0 (mW/cm^2) to increase penetration ability of UV light

UV Embossing



UV casting applications

- **150-200 microns depth and 50 microns wide in Prime EBF**
- **UV curing Efficiency is different at different depthes of coating**

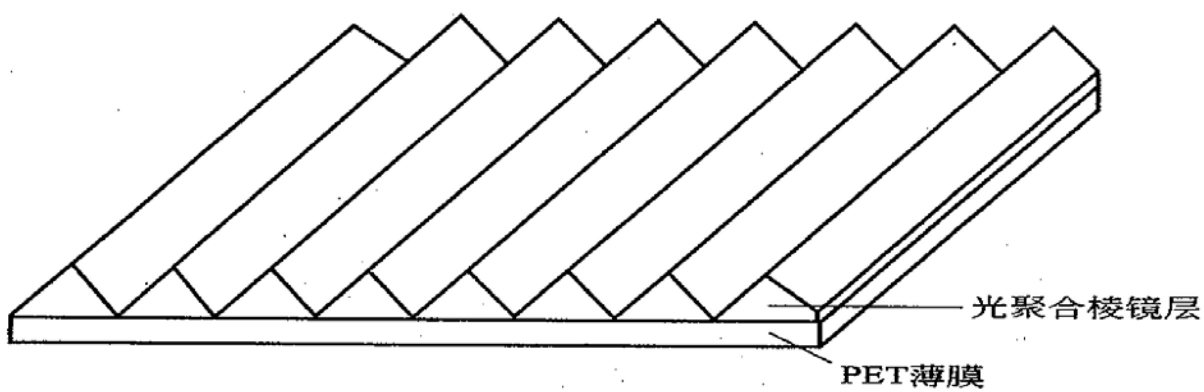


图 7-18　棱镜片结构示意

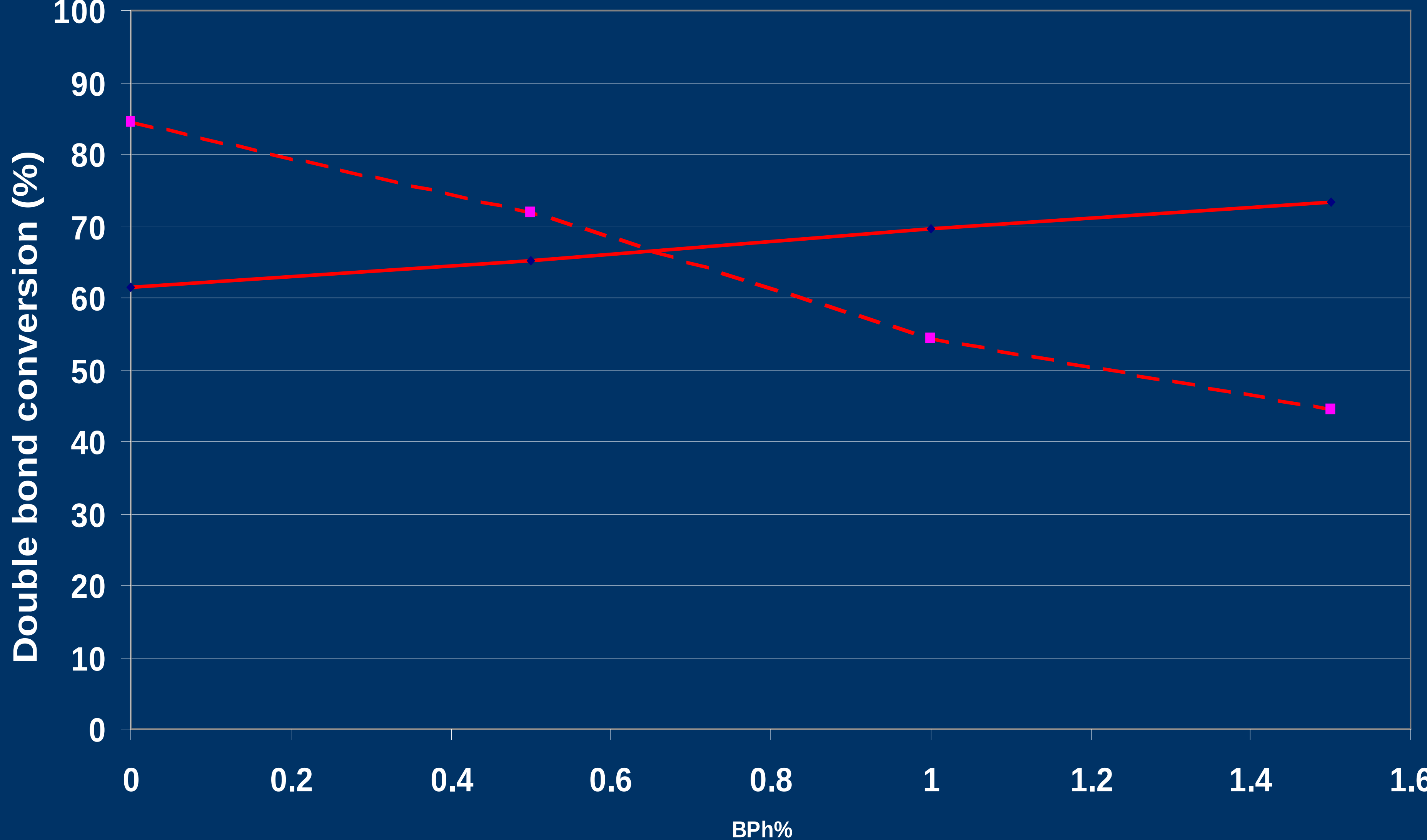


Fig. 9 Double bond conversion as a function of film depth and BPh, EB8402/SR506 (3:7), Irg. 184 1.94% and MDEA 1.5% in Air, 200 fpm

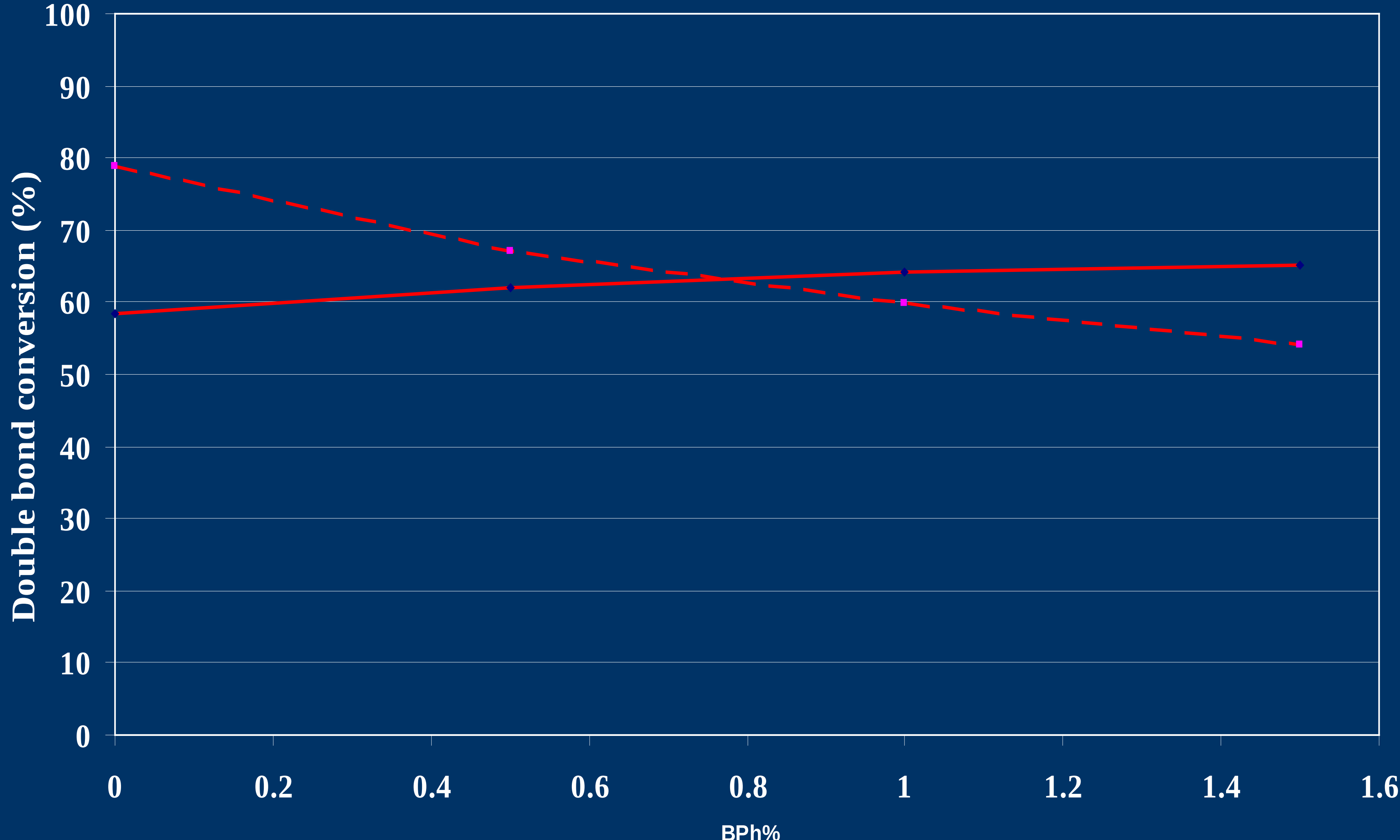


Fig. 14 Double bond conversion as a function of film depth and BPh, EB8402/SR506 (3:7), Darocur 1173 1.94% in Air, MDEA 1.5%, 200 fpm

To Study BPh (PhI) Photo Decomposition efficiency at different depth of cured film by Using UV-Vis spectra

$$A = \bullet . C. d$$

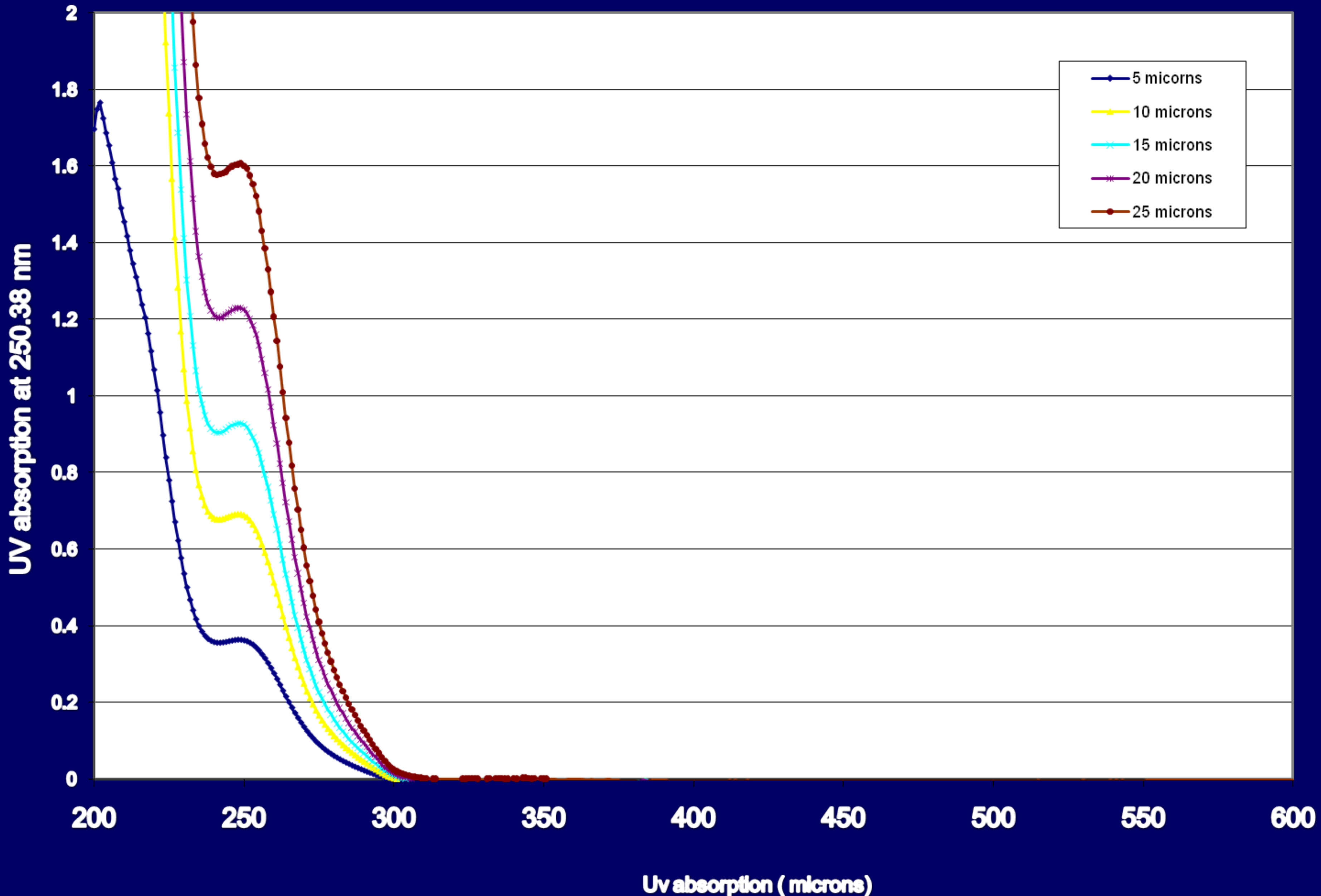


Fig. 2 UV absorption spectra as a function of film depth, EB 8402/SR506(7:3), BPH 0.5%, MDEA0.5% and BYK 348 0.75% nm (micorns)

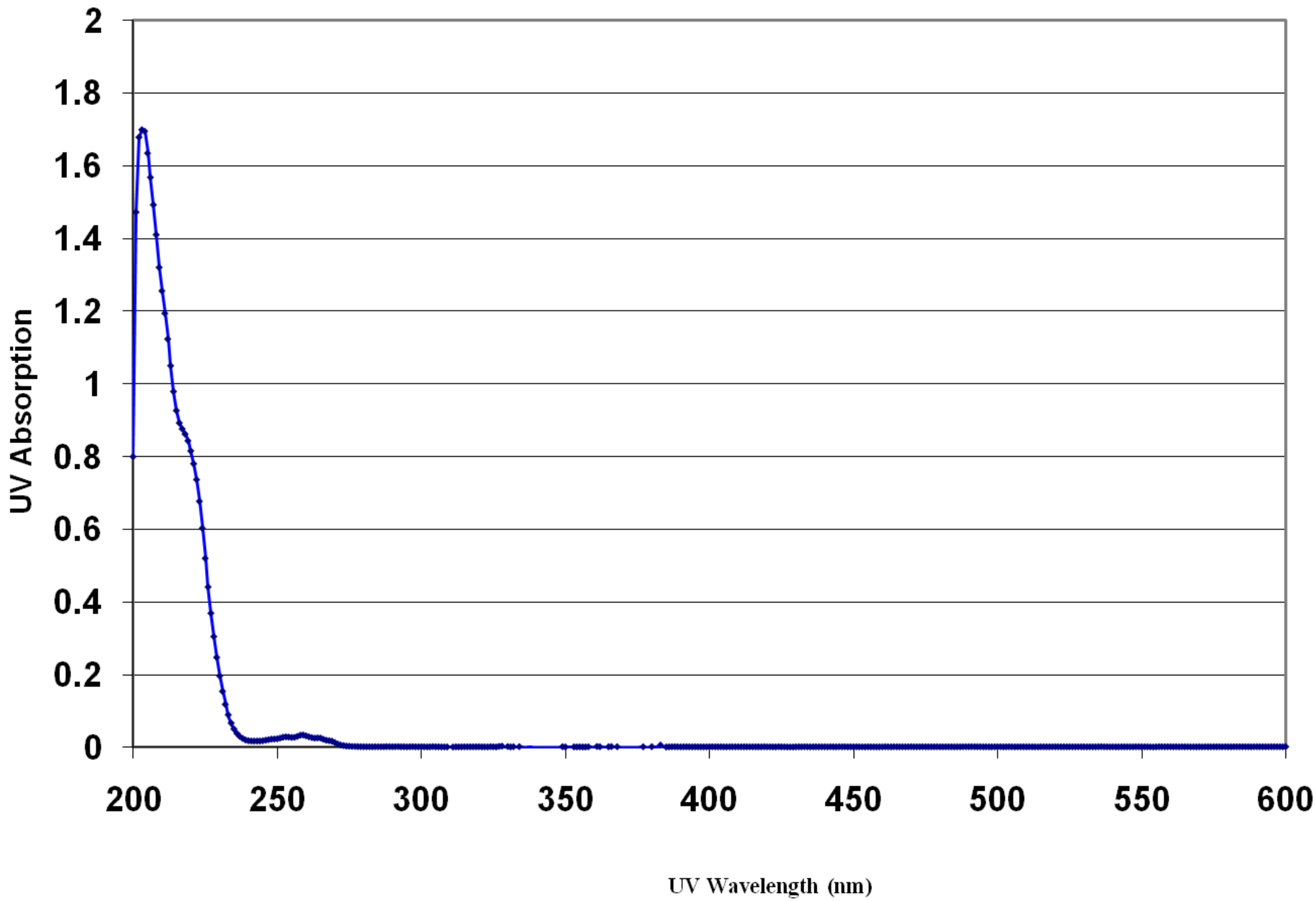


Fig. 3 UV absorption of Benzoin, 1 cm thickness, 0.005 g Benzoin in 500 g Methanol

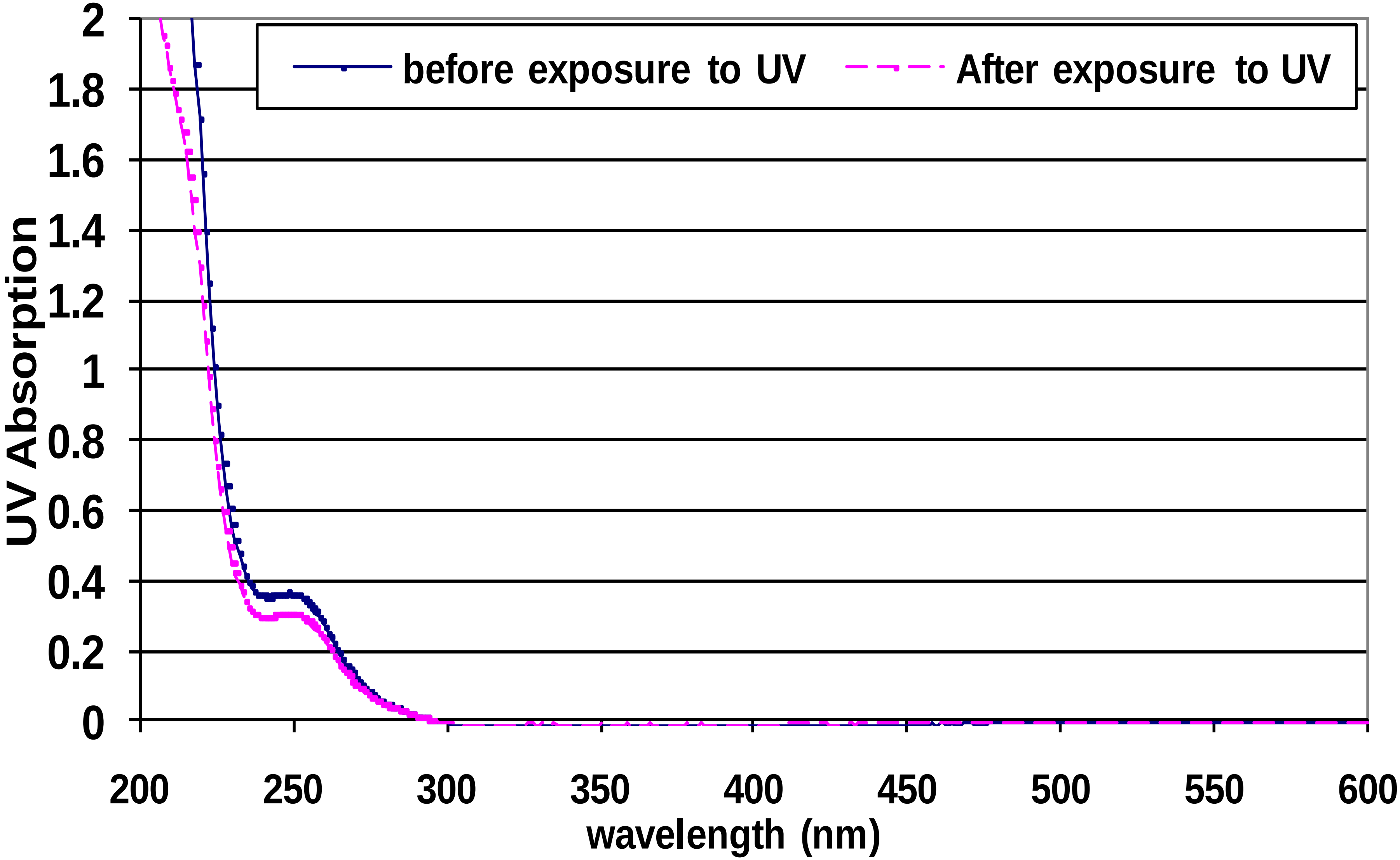
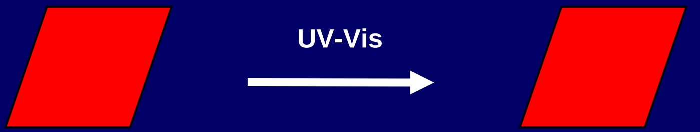


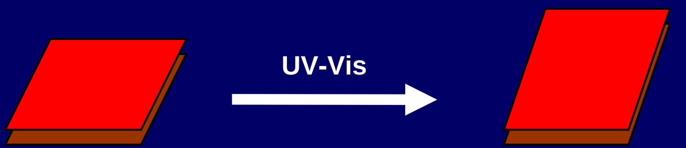
Fig. 4 UV absorption before and after UV exposure, EB8402/SR506 (7:3), with BPh 0.5%, MDEA, 0.5% BYK 348, 0.75% at 200 fpm

5 µm

X_1 = Consumption. of first 5 µm



$(X_1 + X_2 + X_3 + X_4 + X_5) / 5$ = Average consumption.



10 µm

Consumption. of second 5 µm (X_2) = ?

$(X_1 + X_2) / 2$ = Average cons.

First 5 µm(X_1) Cons. = Top 5 µm(X_1) cons. in 10 µm film

Table 1 Depth profile of PhI cons. as a function of film depth in air

Film Thick.	Ave. Cons.	Top 5	Sec. 5	Third 5	Fourth 5	Fifth 5
5 µm	30%	30%				
10 µm	21%	30%	12%			
15 µm	17%	30%	12%	10%		
20 µm	14%	30%	12%	10%	7%	
25 µm	12%	30%	12%	10%	7%	6%

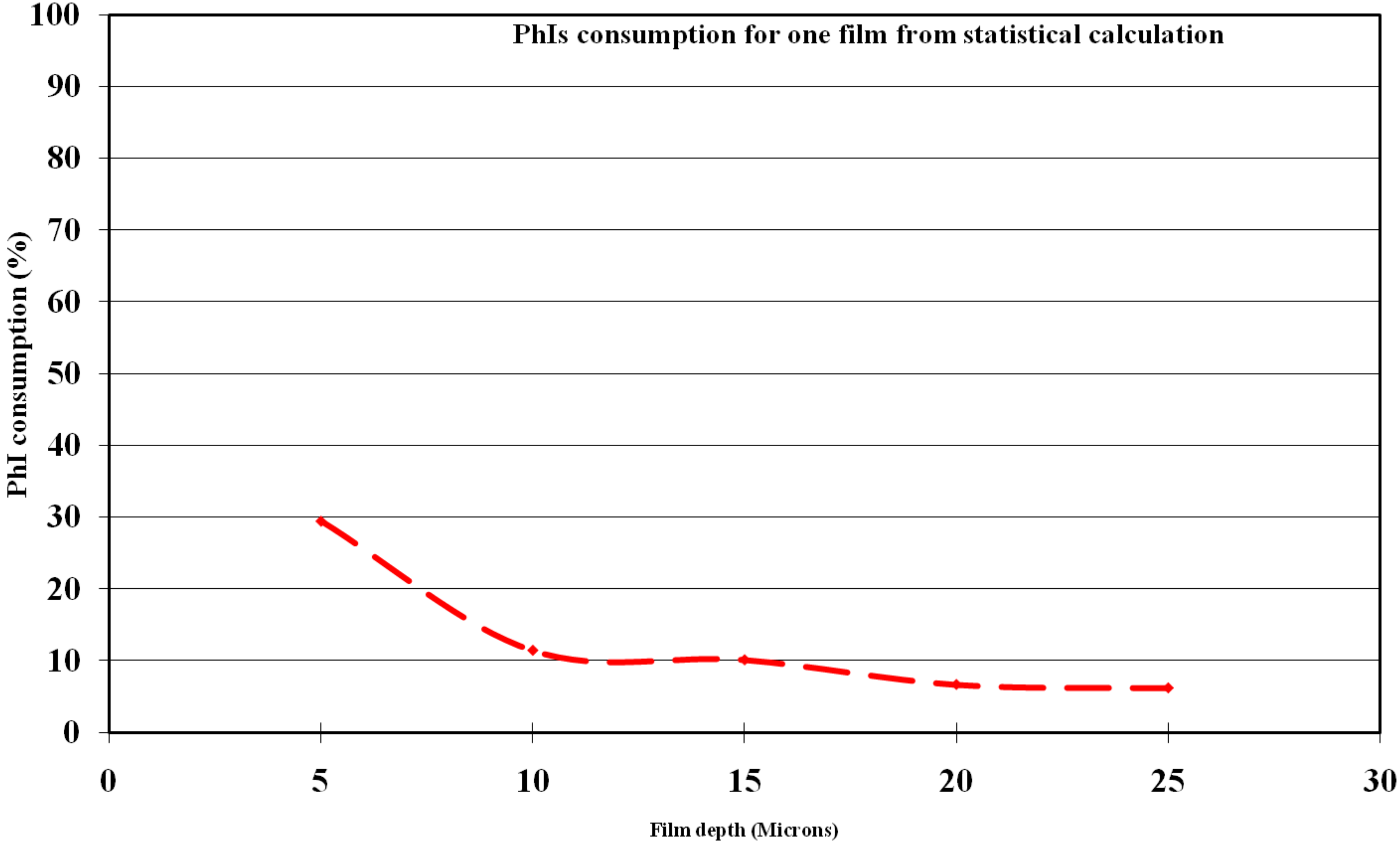


Fig.5 Depth profile of PhIs Consumption as a function of film depth, EB8402/SR506 (7:3) BPh 0.5%, MDEA 0.5%, and BYK 348 0.75%, LH6H, 100% power, 200 fpm

For five different films, average PhI consumption change from 30% to 12%

For one 25 microns film, PhI consumption at different depth change from 30% to 7%

PhI consumption at different depth is different due to inner filter effect

More Inner Filter Effect is Observed at Bottom 5µm film

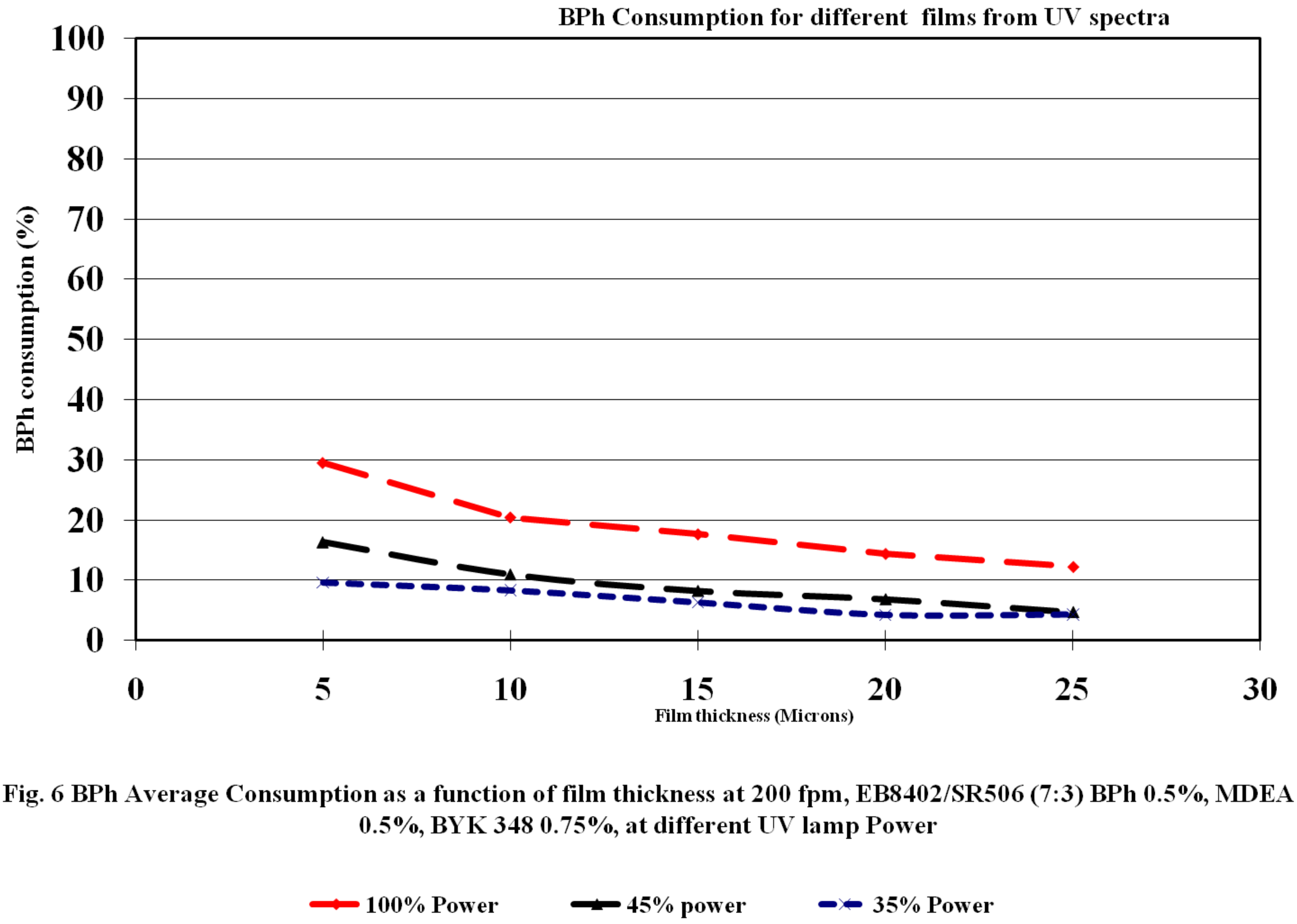


Fig. 6 BPh Average Consumption as a function of film thickness at 200 fpm, EB8402/SR506 (7:3) BPh 0.5%, MDEA 0.5%, BYK 348 0.75%, at different UV lamp Power

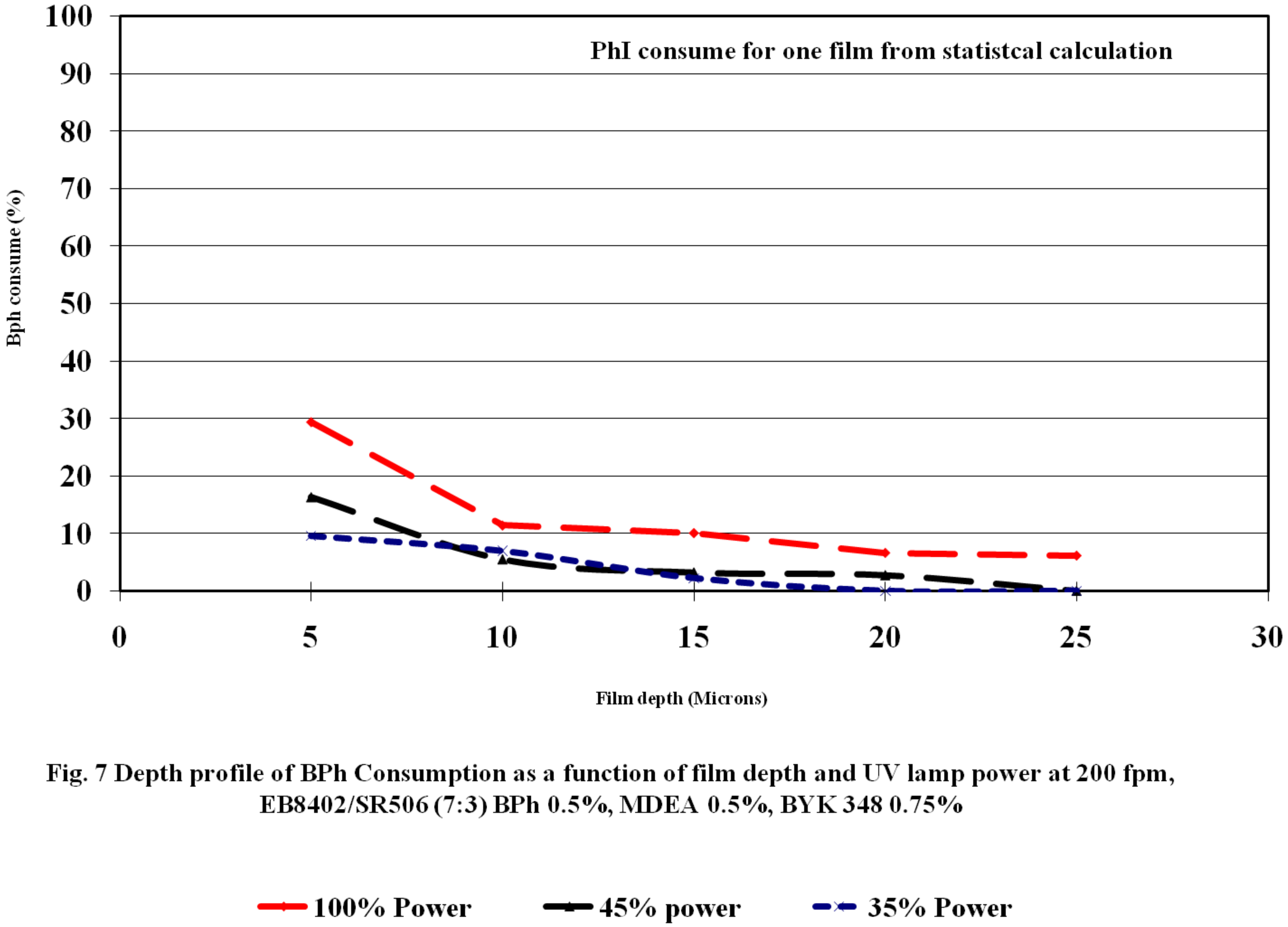


Fig. 7 Depth profile of BPh Consumption as a function of film depth and UV lamp power at 200 fpm, EB8402/SR506 (7:3) BPh 0.5%, MDEA 0.5%, BYK 348 0.75%

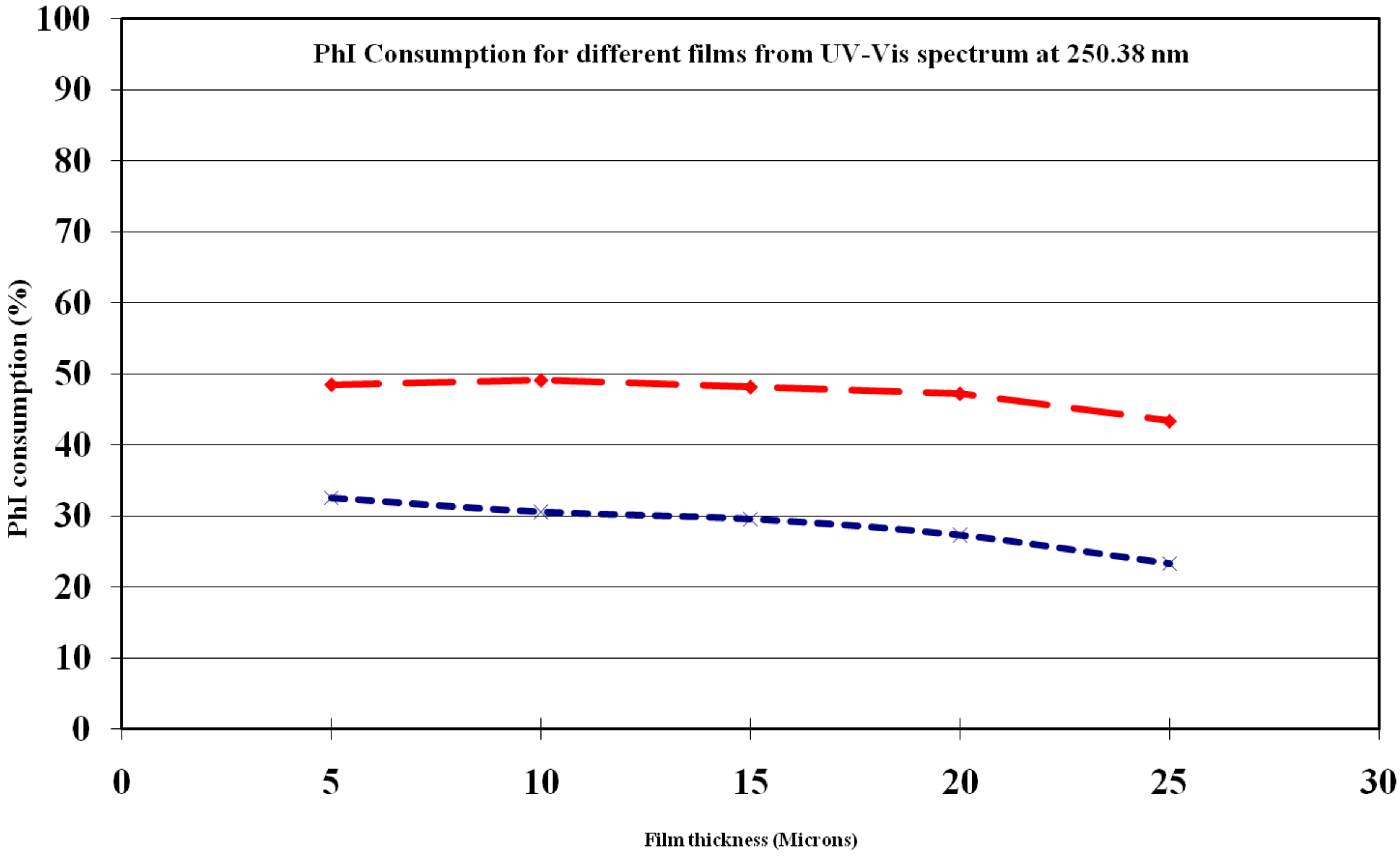


Fig. 8 PhI Average Consumption as a function of thickness and curing power at 50 fpm, EB8402/SR506 (7:3) BPh 0.5%, MDEA 0.5%, BYK 348 0.75% in air

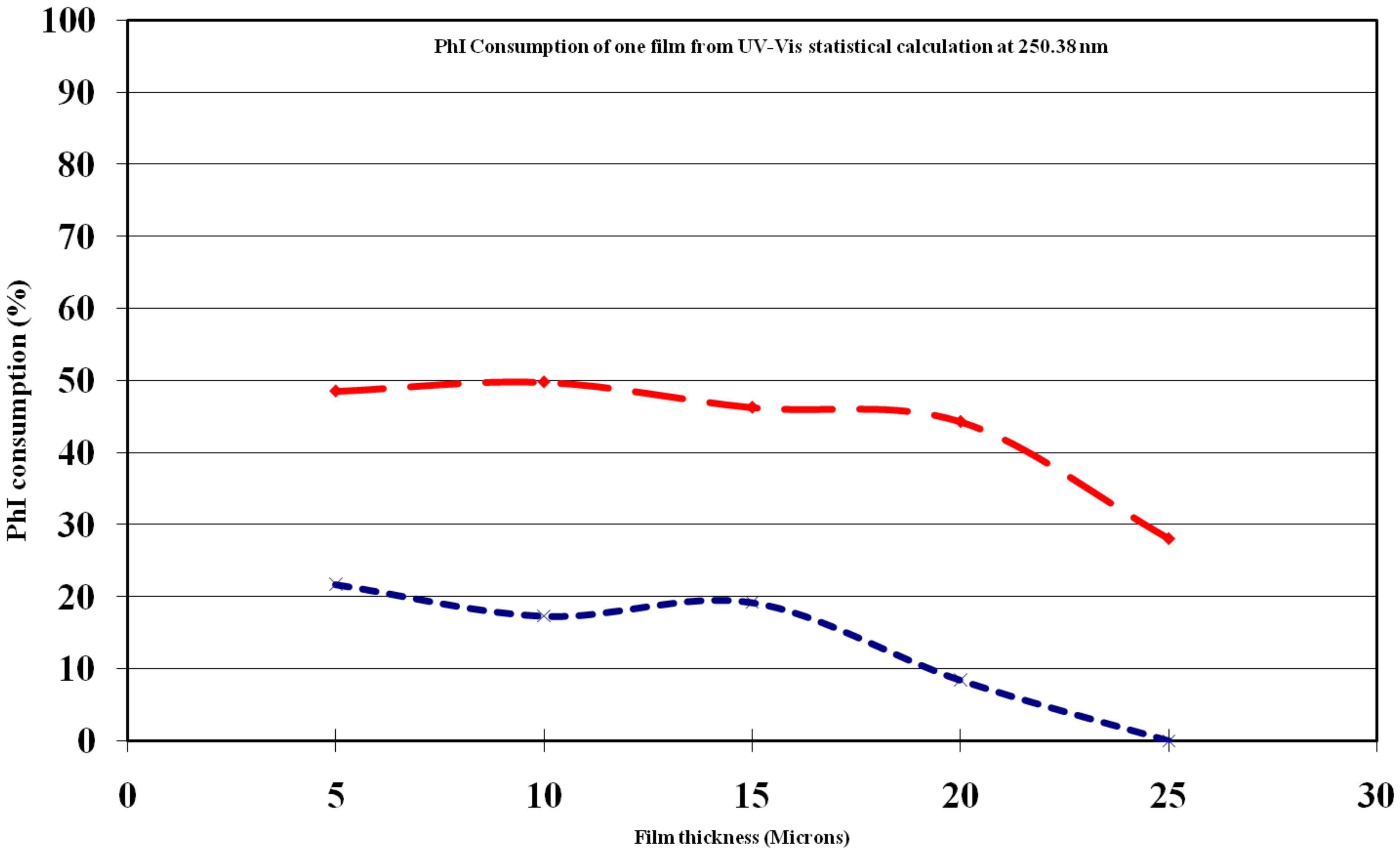


Fig. 9 Depth Profile of PhI Consumption as a function of depth and curing power at 50 fpm, EB8402/SR506 (7:3) BPh 0.5%, MDEA 0.5%, BYK 348 0.75% in air

PhI (Bph) Photo Decomposition with Equal UVA dose

	LH6H (100% power)	LH6H (35% power)
UVA	721 mJ/cm^2	183 mJ/ cm^2
Curing Speed	200 fpm	50fpm
Cons. of Bottom 5	7%	0%
Cons. of Top 5	30%	21%

Conclusions:

1. Photo Decomposition efficiency of PhI (Bph) in thin film is higher than that in thick film

2. For a 25 µm film, more inner filter effect is observed in bottom 5 µm than in top 5 µm

3. high I_0 (mW/cm^2) can reduce inner filter effect and increase phto-polymerization rate in bottom 5 µm

4. Through cure at depth part of cured film can be improved by using a high UV intensity Lamp

Related publications:

- Progress of Organic Coatings, 1967, 2008
- Polymer Paint Color Journal, April 2009
- Polymer Paint Color Journal, May 2009
- Polymer Science: Basic and Applications of Polymerization Reactions, Chapter 12, 2009, edited by Prof. J. P. Fouassier
- Proceedings of RadTech China 2011, Dong Guan