Numerical study of polymer coating by UV photopolymerization.

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ABSTRACT:

Polymer-based coatings are used to protect a structure or device against mechanical attacks such as scratches, abrasion and erosion or against chemical attacks such as humidity, temperature, UV rays. This work concerns the development by photopolymerization UV of new coating materials based on a polymer as (Polyurethane Acrylate, oligomers) deposited on heat-sensitive materials such as thermoplastics (PC; PMMA,). Now, the polymers, which are already used in thermal powder coating. They generally show very high melting temperatures (around 200 °C). They will not be suitable for depositing on supports sensitive to high temperatures without risk of damaging them. In this work, we proposed a numerical study of the effect of different synthesis parameters (energy and applied UV rays, exposure time, temperature, external medium, etc.) on the conversion rate to a 3D mesh (crosslinking rate) and model optimization of coating parameters on heat-sensitive substrates.

KEYWORDS: polymers, coatings polymer, photopolymerization UV

1. INTRODUCTION

The photopolymerization refers to the transformation of a reactive liquid resin into a solid material under the action of UV irradiation. The component of the formulation that will allow this change of state is the photoinitiator. It will absorb the radiation and initiate the crosslinking by reacting with the functional groups of the oligomers and monomers. In order to achieve cross-linking, several compounds are needed in the formulation of UV products.

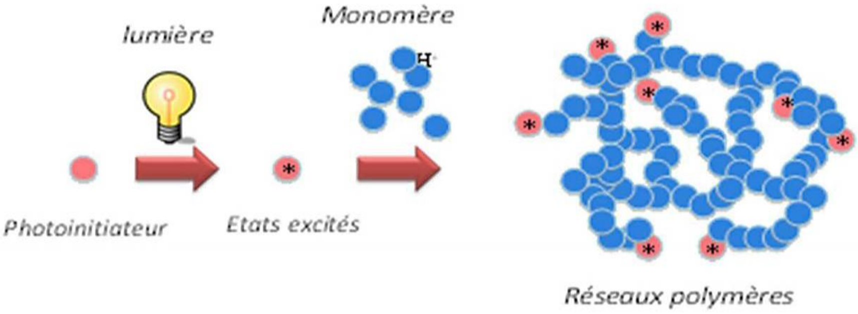

Figure 1: Schematic diagram of the light curing process.

2. MATERIAL AND METHODS:

2.1. Synthesis parameters:

Table 1: Comparative table of the two types of UV sources:

Parameters	Microwave lamps	LED
Power (W/cm)	120 à 240	4 à 12
Wavelength (nm)	200 à 400	365-445
Lifetime (h)	8000	15000

2.2. Basic equations:

The priming speed Va is expressed as follows:

$$V_a = n\,\phi\,I_a$$

With: $I_a = 2{,}3\ I_0\ \varepsilon\,\ell\,[A]$

ϕ : is the quantum efficiency of photolysis, in other words the efficiency of dissociation per photon absorbed.
n : the number of radicals formed from an initiator molecule,
I_a : the absorbed intensity.
Radiation that is neither absorbed nor reflected is transmitted to the lower layers according to the expression:

$$I_a = \frac{I_0\left(1 - 10^{-A\lambda}\right)}{d}$$

I_a is the absorbed energy, I_0 is the incident energy at wavelength λ, $A\lambda$ is the absorbance at wavelength λ and d is the film thickness.

2.3. Conversion rate (cross-linking):

The conversion rate can be determined according to the variations in intensity The Beer-Lambert law is written:

$$A = \varepsilon\,.\,\ell\,.\,c$$

Assuming that the Beer-Lambert law is valid in the range of concentrations used, the conversion rate is defined by the relationship:

$$\text{Conversion rate} = \frac{\text{reacted product quantity}}{\text{initial product quantity}} = \frac{C_0 - C}{C_0}$$

The concentration at time t in (mol. L -1) and C_0 the concentration at time t_0 in (mol. L -1). Then we have:

$$\text{Conversion rate} = \frac{A_0 - A}{A_0}$$

With : A is the absorbance of the irradiated product at time t and A_0 is the absorbance of the initial product before irradiation.

3. RESULTS AND DISCUSSIONS:

The results obtained by the numerical calculation model show the influence of the various parameters of UV photopolymerization on the rate of crosslinking:

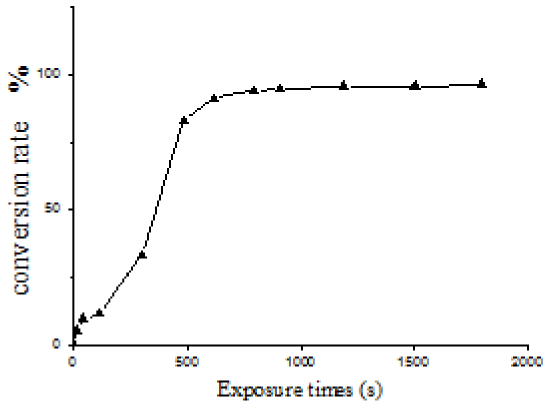

Figure 4: Conversion rate as a function of exposure time

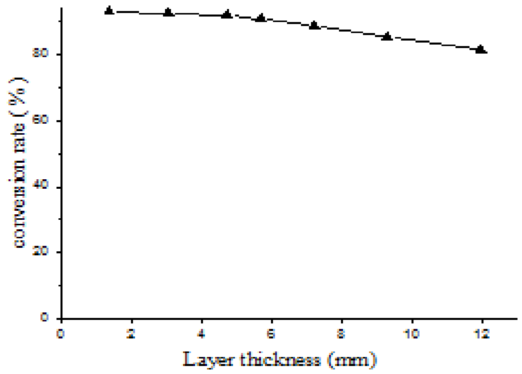

Figure 5: Conversion rate as a function of layer thickness.

The longer the exposure time, the greater the rate of crosslinking (figure 4), on the other hand, in contrast, the thickness of the deposit is reduced (figure 5).

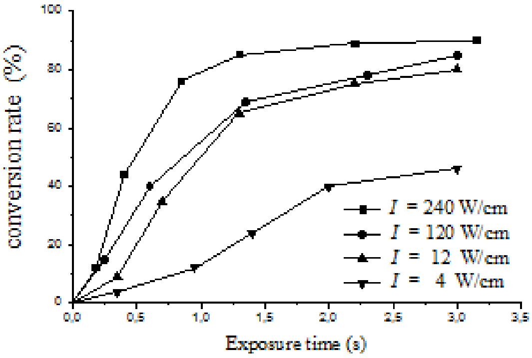

Figure 6: Conversion rate as a function of layer thickness with different UV light intensity.

The increase in the light intensity has the effect of increasing the rate of crosslinking, from the different intensity of UV is great and more conversion rate is increased despite the thickness of deposit is great (Figure 6).

4. CONCLUSION

We followed in this research, the main parameters of the coatings of the photopolymerization under UV radiation. The purpose of this work is to produce a numerical model for optimizing certain parameters of photopolymerization by UV radiation, and to study the influence of the rate of crosslinking on the thickness of deposit, speed of polymerization, transition temperature Tg of the material formed by radical polymerization and on the mechanical, thermal and chemical properties of the substrate studied.

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