UV Light Curing Adhesive for Optical Assembly Application

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Abstract: UV light-curable adhesives cure in seconds upon exposure to long wave ultraviolet light and/or visible light, heat, or with an activator. Light-curable adhesives optimize the speed of automated assembly, enable 100% in-line inspection, and increase product throughput. Industrial adhesives are available for glass assembly, plastic sealing, metal bonding, and as well as for joining dissimilar substrates.

Keywords: UV curing, UV photo-polymerization.

1. INTRODUCTION

Traditionally, adhesive and resin composite systems have contained camphoroquinone (CQ), a visible-light-sensitive diketone photoinitiator responsible for initiating free-radical polymerization. CQ absorbs energy in the visible-light region of 400 to 500 nanometers with a peak at 468 nanometers. Photon's associated with this frequency range will be absorbed by camphoroquinone, raising it from the ground state to an excited, but short-lived, activated triplet state. When the excited triplet bumps into an amine co-initiator, an aminoalkyl free radical forms that is capable of initiating polymerization.

In a few products, new photo-initiators have been introduced by manufacturers to reduce the intensity of the yellow color of the composite resin restorative material typically produced with the addition of camphoroquinone or to prevent the inactivation of the amine co-initiator by acidic monomers contained in some enamel and plastic adhesives. These new photo-initiators absorb light energy in lower regions of the visible-light spectrum. Examples would be phenyl-propanedione (PPD) and Lucirin TPO.

Light energy may be provided by four types of curing lights: quartz-tungsten-halogen (QTH), light-emitting diode (LED), plasma-arc (PAC) or argon laser.

UV light provides rapid, full curing power. It's useable energy focuses the most effective wave light in a shorter time, thereby yielding a faster cure. It is usable for all curing composites, and reportedly results in restorations exhibiting strength and shrinkage equal to traditional methods.

The lamp is a high-power, UV that provides a uniform approach to high speed curing and glued applications. There are so successful that not only do the composites cure quickly with UV light, they all polymerize in just 20 seconds using any conventional curing light.

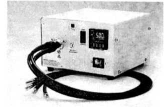

Fig. 1 The curing light unit

UV light cures composite material in 1-3 seconds and comes transparent in 40 minutes using its UV light based technology. With its unique range of features, it has revolutionized the optical industry.

Curing takes seconds and can be used with most types of composites.

The curing is faster and harder: the composite stays more flexible and shows little shrinkage. The curing light unit (fig. 1) features consistent high power output (600 mw/cm^2), one-hand operation 10-90 second timer cycles, and 11mm auto-clavable light guide with 4 mounting options. The curing light unit has an improved fan and vent design for better cooling and lower noise levels. The curing light unit offers superior performance and design at an affordable cost.

The photo-polymerisation problem is governed by reaction-diffusion equations for the initiator concentration I and the rate of conversion C. The Navier-Stokes equation under the Boussinesq approximation models the free convection.

$$\frac{\delta I}{\delta t}+u\frac{\delta I}{\delta x}+v\frac{\delta I}{\delta y}=-\propto 1000JI \quad (1)$$

$$\frac{\delta C}{\delta t}+u\frac{\delta C}{\delta x}+v\frac{\delta C}{\delta y}=kT\sqrt{\propto 1000JI}(1-C) \quad (2)$$

$$\frac{\delta T}{\delta t}+u\frac{\delta T}{\delta x}+v\frac{\delta T}{\delta y}-k\Delta T=qkT\sqrt{\propto 1000JI}(1-C) \quad (3)$$

$$\frac{\delta \Psi}{\delta t}+u\frac{\delta \Psi}{\delta x}+v\frac{\delta \Psi}{\delta y}-v\Delta\Psi=k_0 g\frac{\delta T}{\delta x} \quad (4)$$

The stream function-vortices formulation has the following boundary conditions:

$$\varpi=0;\Psi=0;\frac{\delta T}{\delta n}=0 \quad (5)$$

(free surface boundary condition);

or $$u=0;v=0;\frac{\delta T}{\delta n}=0 \quad (6)$$

(no slip boundary condition).

2. PARAMETERS

Glue parameters are related to future destination of optical product. Adhesive type is *LENS BOND TYPE J 91* for some applications and *NORLAND OPTIONAL ADHESIVE+MONOMERIC STYRENE 40Z* the other type. Lens Bond optical cements are synthetic polymer adhesives manufactured under the strictest quality control. They are filtered to remove all particles larger than 1 micron in size, and filled under clean room conditions. These cements will meet and exceed military environmental specifications. LENS BOND Optical Cements are easy to use. This cement remains slightly elastic after curing being a general purpose, one component, water white, 100% solids ultraviolet curing optical cement. The width of glue film g_z is given in the following range: $g_z=0{,}002\div 0{,}1\ mm$. The other parameters are:

$$I_0=\frac{0{,}003mol}{L};C_0=0;T_0=294K \quad (7)$$

$$g=980cms^{-2};\vartheta_{(viscosity)}=10^{-2}cm^2s^{-1} \quad (8)$$

$$k_{(thermal\ diffusivity)}=1{,}3\ 10^{-3}cm^2\ s^{-1} \quad (9)$$

$$\alpha_{(molar\ absoption\ coefficient)}=63mol^{-1}\ L\ cm^{-1} \quad (10)$$

$$k_{0(thermal\ expansion\ coefficient)}=6{,}2\ 10^{-4}K^{-1} \quad (11)$$

$$q_{(adiabatic\ heat\ release)}=148 \quad (12)$$

Two types of parameters have to be considered during the curing process: lamp and adhesive materials parameters. Any of them can influence dramatically the quality of the final product. That's why those parameters are highlights and keep under control to avoid any predictable damage or bad influence on optical final product parameters.

$$k(T)=A_p exp\left(\frac{-E_p}{R\ G\ T}\right)\sqrt{\frac{1{,}6}{2A_t exp\left(-\frac{E_t}{R\ G\ T}\right)}} \quad (13)$$

Where:

$$A_{p(pre-exp\ factorfor\ propagation\ step)}=2{,}2624\ 10^{07}$$

$$A_{t(pre-exp\ factorfor\ termination\ step)}=1{,}336\ 10^{11}$$

$$E_{p(energy\ of\ act\ for\ propagation\ step)}=2{,}079\ 10^{04}$$

$$E_{t(energy\ of\ act\ for\ termination\ step)}=2{,}814\ 10^{04}$$

$$RG_{gas\ constant}=8{,}314$$

Parameters considered and controlled by usual means are the following:

- Adhesive parameters (consider a bulk or drop with maximum dimensions);
- Radiation (light) source parameters.

The process is accompanied by heat release, an important amount of heat being around the surface cured. The ambient temperature is limited by a fan and goes up to 25% higher

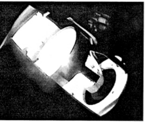

Fig. 2 Inside view of power generator

than the temperature of the whole ambient. Heat production is governed by the following parameters:

$J=J_0 e^{(\varepsilon(-x))}$;

Intensity $I=0{,}5Wcm^{-2}$;

Wavelength $\lambda=365\cdot 10^{-9}m$;

Planck's constant $h=6{,}62\cdot 10^{-34}$;

keep the unit focused on material much longer than if the light was uniformly spread and focused on adhesive material.

3. THE EVOLUTION OF CONVERSION

As it is shown in the figure 7, the evolution of conversion is a matter of time.

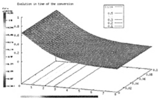

Fig. 7 Evolution of conversion

As long as you keep the light on the adhesive material surface as deeper the polymerisation is done. So, the curator has to experience the relation between the time and depth for each material and to design such a graph or to adapt one graph which is closer to the real behaviour, figure 8, and to compare the polymerization effectiveness of different posterior composites, to compare the polymerization effectiveness of different increments in two composites.

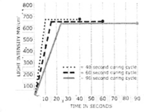

Fig. 8 Time to achieve polymerisation

For each composites manufacturers claim effective polymerization in increments greater than 2mm. The specimens have to be polymerized with used curing light (600mW/cm^2) for the time recommended by the manufacturers. The results give a correction factor, which is applicable to all depth. To indirectly assess the effectiveness of composite polymerization, micro-hardness is to be determined immediately after polymerization on the bottom and top surfaces of the composite slabs. A hardness ratio can be calculated using the following formula: HR=VHN of bottom surface/VHN of top surface. Ideally, HR should be 1, when the VHN of the bottom is similar to the top. It has been suggested that an effective polymerization is achieved when HR~0.8.

On the other hand the potential for interstitial temperature rise may vary among different types of light sources and different position of the same source towards pieces. An experiment in prototype present interstitial temperature behaviour of optical light-curing sources tested with and without curing composite in the preparation site. Temperature-controlled air flowed through the interstitial place at a fixed rate.

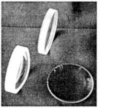

Fig. 9 Optical pieces (lens) before and after curing glue

In Fig. 9 is seen in counters glued optical components, but not seen on glued area edge.

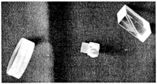

Fig. 10 Other types of glued optical pieces

In fig. 10 note the bonding between the final product parts, as this detail do not bother.

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