1K UV-A Hard Coats for Polycarbonate Head Light Refinishing

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1. Abstract

The automotive industry over the last several decades has pushed the technology for automotive forward head lighting from glass to polycarbonate plastics (PC). Although there are obvious advantages to polycarbonate, such as weight reduction and improved safety, there are also issues with deterioration over time of the ultra violet (UV) cured protective hard coatings used to protect the polycarbonate plastic from impact abrasion, moisture and sunlight.

Today there are an estimated 248 million registered vehicles and 496 million PC UV hard coated head lights in service in the United States. Americans continue to hang onto their cars, minivans and crossovers -- many of them first purchased when President Clinton was in office -- helping to push the average age of the nation's light-vehicle population to a record high of 11.4 in August of 2013. At the same time, the nation's aging car and light-truck population is creating pent-up demand that is spurring U.S. new-vehicle sales to new record highs with projections that the total number of cars and light trucks in operation in the U.S. will grow to 260 million by 2018. With this large number of older vehicles in service and the significant growth in volume of the number of vehicles older than 12 years surging over the past five years by more than 20 percent, just a small percentage of deteriorated PC head lights is a large potential refinish market.

Attempts to resolve the issue of deteriorated PC UV hard coats has seen the introduction of everything from tooth paste to OEM style UV-A refinishing hard coats. This paper will review this new and developing UV cure coatings market, and also present a solution based on the use of a 1K UV A cure head light refinishing system.

2. Introduction

Over the last several years, several after-market suppliers to the automotive industry have developed a refinishing technique to replace deteriorated UV hard coats on PC auto head lights. These UV hard coats have deteriorated due to sunlight, moisture, carwashes, dirt and many other environmental conditions. As with any new large market it will generate the proliferation of new ideas and products. The important aspect of this new market will be products that just don't offer a 'band-aid' to the issues, but offers true performance to the vehicle owner.

3. Current products in the market to solve the deteriorated UV hard coat issue

Attempts to resolve the issue of deteriorated PC UV hard coats has seen the introduction of everything from tooth paste to OEM style UV-A refinishing hard coats. The basic issue is depicted in Photo 1.

Photo 1. Deteriorated PC head light where the light performance audit shows only 3,000 Candela on low beam and 7,000 Candela on high beam (Candela definition; unit of luminous intensity)

The PC head light on this vehicle in service has deteriorated to a level where driving with such low performing head lights is dangerous to the vehicle owner. The candela survey done on these head lights showed that the light output on low beam was 3,000 Candela and 7,000 Candela on high beam. The test was performed on untouched head lamps using a Hoppy Vision 100 Light Reader.

Several products have been introduced to the market to try and resolve this issue. Several types [1] use a sanding operation and polishing to rejuvenate the deteriorated head lamp. Another promotes the removal of the deteriorated hard coat and then a sealant that will protect the PC for 2 years [2]. In all about 20 types of techniques were found offering a solution to solving the problem of deteriorated UV hard coats. About half of the techniques we surveyed used a sanding and polishing technique while the other half used some type of sealant or protectant after removal of the UV hard coat.

The professional technique for refinishing shows the use of a solvent based acrylic or a traditional 2K polyurethane that is traditionally used to do auto refinishing. One of the products surveyed found a 2K PUR [3] that has such performance. The development of a UV cure PC refinishing system was first introduced at a conference in February 2005 [4]. This paper introduced the concept of an OEM style UV-A refinish hard coat. Prior to that, a patent [5] filed on March 18, 2004 as well as another patent filed on June 20th, 2005 reviews the removal of the deteriorated hard coat and application of a sealer or coating [6].

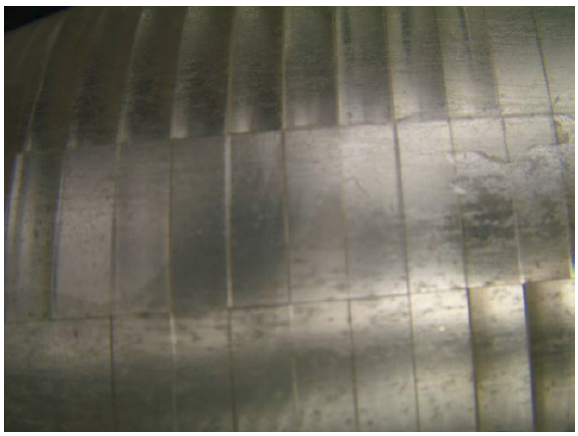

Photo 2. This photo shows an even worse performance of the UV hard coat. This particular PC head light saw the rigors of multiple car washes that have completely removed the UV cure hard coat.

The repair of the PC whether it is polishing or coating elevates the performance of the head light output. Replacement costs for the head light assembly are extremely high. The ability to refinish the head light is a distinct advantage for the vehicle owner.

4. OEM Style UV-A Refinish Hard coats for refinishing deteriorated PC head lights

When searching for a technology to replace the deteriorated OEM hard coat through refinishing techniques it is important to use a similar technology. Researchers went to the traditional formulations as described in a recent paper [7]. In this paper, it was shown that the traditional polyisocyanurate chemistry in the OEM environment would perform and has performed to meet the stringent OEM performance requirements. As can be seen in Table 1, the formulation is designed to be used on PC substrates that are already protected by UV-absorbers and HALS-amines. In addition the UV hard coat is also protected by UV-absorbers and HALS-amines. Weathering studies have shown that aliphatic urethane acrylate 'Echo' (Table 2) performs extremely well in accelerated weathering. Product Echo has gone greater than 5000 hours in the accelerated weathering studies such as Xenon arch using ISO 11341 testing parameters. So, for the PC refinisher, it is evident that by using this base oligomer (Echo) the expectations are that the system will perform better than any other type or style of product in the PC auto headlight refinishing market place.

Formulation	Function	% by weight
UV-curing oilgomer	resin	80
Monomer	react. thinner	80
BAPO	UV-initiator	4.9
Additive	leveling agent	1.6
Additive	UV-absorber	3.8
Additive	HALS-amine	1.7
Curing	1,800 mJ/cm² (Hg spectrum)	
DFT	ca. 25 µm	
Substrate	PC (UV-absorber/HALS-amine)	

Table 1. Formulation is the type and style of a formulation that has a proven record in the OEM automotive headlight environment.

Taking a page out of the performance aspect of these OEM PC UV hard coat, formulations were developed to mimic the style and performance of the OEM hard coat. Essentially the old UV hard coat is removed by wet sanding at different grit levels until virgin PC is obtained. Once this is completed the OEM style product is spray applied, flashed and UV cured with a UVA style light source.

Weathering data			
Urethane Acrylate	**ISO11341 Xenon Test**	**CAM 180**	**UV - B**
ECHO	> 5000 h	5000 h	2500 h
Fox Trot 1	3750 h	3250 h	2500 h
Alpha 1	>4000 h	>4000 h	2500 h
Bravo 1	5000 h	5000 h	2500 h
Delta 1	3000 h	3000 h	2500 h
Test parameters: Chalking, adhesion, cracks, blisters			

Table 2. This table shows the relationship of high performance UV oligomers used in the OEM UV Hard Coat market

The resulting unit will show an increase as described previously from a 3,000 Candela for low beam to a 7,000 Candela (a difference of 4,000 Candela) after the OEM style refinish UV A hard coat that was applied. In addition; the high beam which was surveyed to be at a 7,000 Candela, jumped to 17,000 Candela after refinishing (a difference of 10,000 Candela). With this kind of vast improvement, it is no wonder that this is an up and coming market for the automotive refinisher.

Photo 3. PC Headlights that have been refinished with an OEM style UV-A hard coat

5. New advanced oligomer technology for the PC Head lamp refinishing market

As was shown in the earlier discussion, the traditional polyisocyanurate based oligomer (Echo) performs well in accelerated weathering studies. One draw-back to this style of chemistry is the acrylate monomer used in this formulation. This particular monomer in a closed OEM contained environment has been used quite successfully. However, in a refinish environment, the spray atomization of the monomer would be of concern. Researcher's realized this and needed to try and develop a new style of chemistry termed an allophanate. [7] The uniqueness of this allophanate chemistry is the ability to 'taylor' make the molecule so that the hydrogen bonding is placed in the so-called sweet spot of the chemistry. This means that in the traditional polyisocyanurate, oligomers

have a significant level of hydrogen bonding. Thus the resultant viscosity of the oligomer is too high and needs to be cut in acrylate monomer to obtain a use viscosity.

With the development of the allophanate oligomers this reduced hydrogen bonding helped dramatically reduce the use viscosity.

Urethane Acrylate	Alpha 1	Bravo 1	Echo	Delta 1
Form supplied	*100 %*	*100 %*	*80% (20%monomer)*	*100 %*
Type	*aliphatic*	*aliphatic*	*aliphatic*	*aliphatic*
Viscosity (23 °C, mPas)	*ca. 60,000*	*ca. 35,000*	*ca. 34,000*	*ca. 8,000*
Hazen colour value	*< 100*	*< 100*	*< 100*	*< 100*
Molecular weight, g/mol (GPC)	*ca. 1,100*	*800*	*1,400*	*1,250*
Functionality cal.	*ca. 4*	*ca. 3*	*ca.3*	*ca.3*
Double bond density , Val/kg	*ca. 3.8*	*ca. 4.1*	*ca. 1.6*	*ca. 2.8*
UV reactivity (3 %, Dar. 1173, 1 lamp 80 W/cm)	*ca. 25 m/min ca. 140 mJ/cm²*	*ca. 10 m/min ca. 450 mJ/cm²*	*ca. 20.0 m/min ca. 155 mJ/cm²*	*ca. 7,5 m/min ca. 450 mJ/cm²*
Pendelum hardness	*ca. 140*	*ca. 170*	*ca. 180*	*ca. 60*
Tg in °C	*ca. 65*	*ca. 80*	*ca. 75*	*ca. 30*
Elongation at break in %	*ca. 4*	*ca. 3*	*ca. 2*	*ca. 17*
Tensile strength in N/ mm²	*ca. 65*	*ca. 40*	*ca. 20*	*ca. 22*
Special properties	*Balanced properties, high scratch resistance combined with high fct. oligomers.*	*Well balanced properties, good barrier against water and corrosive environment.*	*High reactivity and hardness, high resistance against mechanical and chemical attack.*	*Product is designed to adjust flexibility combined with the other allophanate urethane acrylates.*

Table3. Table 3 shows the relationship between a polyisocyanurate and the allophanate based oligomer technologies. Echo is a polyisocyanurate oligomer while the allophanate oligomer technology is Alpha 1, Bravo 1 and Delta 1.

This use viscosity is quite evident by comparing Echo (isocyanaurate oligomer) to the Bravo 1 (allophanate based oligomer) base viscosities as shown in Table 3. Where Echo has a viscosity of 34,000 mPa s the Bravo 1 comes in at 35,000 mPa s. To get Echo down to the same level of viscosity, the addition of 20% monomer is needed to meet the same viscosity as the allophanate oligomer.

So for the development of newer PC auto head light UV A coatings it would make more sense to use the Bravo 1 technology so that the use of any monomer is eliminated due to industrial hygiene concerns.

Photo 4. 36 months of service in the North Eastern part of the US shows limited degradation to the OEM Style Refinishing UVA Cured Hard Coat.

Longevity of the OEM Style UV-A cured refinish hard coat is another question that looms in the minds of the critics of this technique.

In Photo 4, the use of this Alpha 1 (allophanate) shows the lack of deterioration over 36 months of use in the North Eastern part of the US. Planned work to use Bravo 1 (allophanate) as described previously will allow better use viscosities. Bravo 1 has just cleared TSCA registration and will be evaluated for this market. This performance proves that the use of an OEM style UV-A refinish hard coat has performance attributes beyond other products in the market. It is also obvious from this photo that under this severe environment, as shown by the stone chips above the head light, that the integrity of the hard coat was not violated by this severe environment.

6. UVA cure light sources for use within the automotive PC headlight refinishing

Obviously when you jump into the realm of site applied UV curing systems you need to ensure that worker safety is important. In the auto and aerospace markets, the UV equipment suppliers responded with the development of a UV-A light source that was specifically designed with PC UV-A refinishing in mind.

As is shown in Photo 5, the UV-A light source is mounted on a very unique stand allowing the auto technician flexibility in performing the refinishing of the PC headlamp. An additional safety aspect of this lamp is the use of safety shutters that can be used when the lamp is warming up, so as not to expose the refinish technician to UV-A exposure.

Photo5. Development of UV A curing lamp by H & S AUTOSHOT. Model number UVL-0400-03

7. Conclusions

With over 496 million PC head lights in service and with the average age of US vehicles on the road today at 11.4 years, the need for a OEM Style UV-A refinish hard coat system has become very apparent.

Since the inception of the use of a UV Hard coat to protect PC headlamps the question about longevity has always been an open question. It is obvious that not all UV hard coats exhibit the same performance. The development of an OEM Style UV-A refinish hard coat hopes to resolve the important safety issues. The allophanate chemistry is the most sustainable as it does not require the use of additional monomers and offers an ultra-low VOC formulation.

References

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