LOCTITE®

INNOVATIVE HIGH PERFORMANCE 1-STEP CURE ACTIVE ALIGNMENT ADHESIVE FOR AUTOMOTIVE HIGH RESOLUTION CAMERA MODULE ASSEMBLY

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INTRODUCTION

Advanced driver assistance systems (ADAS) consist of multiple cameras, radar, ultrasonic, and light detection and ranging (Lidar) sensors, all sending data to a central processing unit that provides feedback to the driver and vehicle control systems. Warning signals alert the driver to potential hazards and provide critical information to vehicle control systems designed to automatically assist with braking and steering for collision avoidance. Advanced driver assistance systems have spurred the need for high-resolution camera designs. ADAS camera modules perform vital safety functions, providing a full 360-degree camera view around the vehicle to inform both driver and automated vehicle control systems of potential hazards in the driving environment, ensuring the safety of drivers, passengers, and pedestrians. ADAS cameras must provide high-resolution images and perform with superior reliability in harsh environments for the life span of the vehicle. Today's manufacturers of high-quality ADAS camera modules make use of the active alignment assembly process to achieve superior camera focus and produce high-resolution images. The active alignment process precisely positions the camera's optical components to the image sensor (**Figure 1**) while an adhesive is used to fix the components in place.

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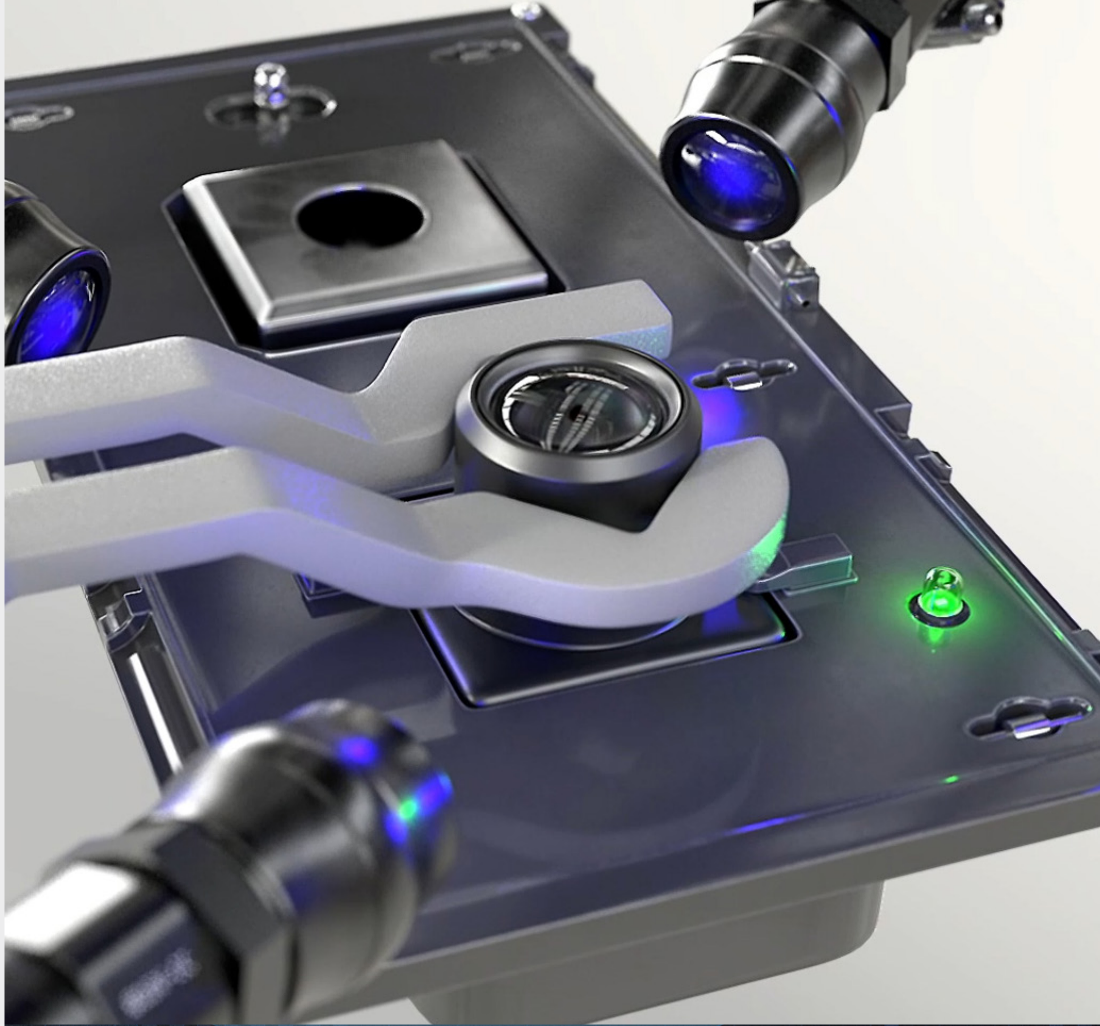

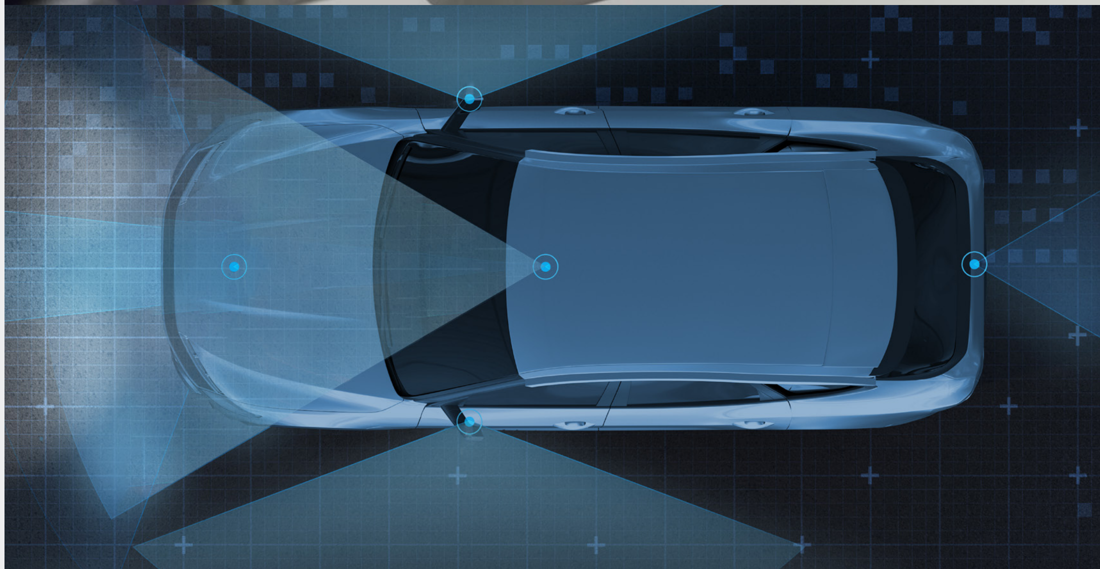

INTRODUCTION – CONTINUED

Compared to a threaded lens barrel, which can only be adjusted in the Z-direction, the active alignment workflow allows for six degrees of freedom in the alignment process, with an accuracy of 100 nanometers[i].

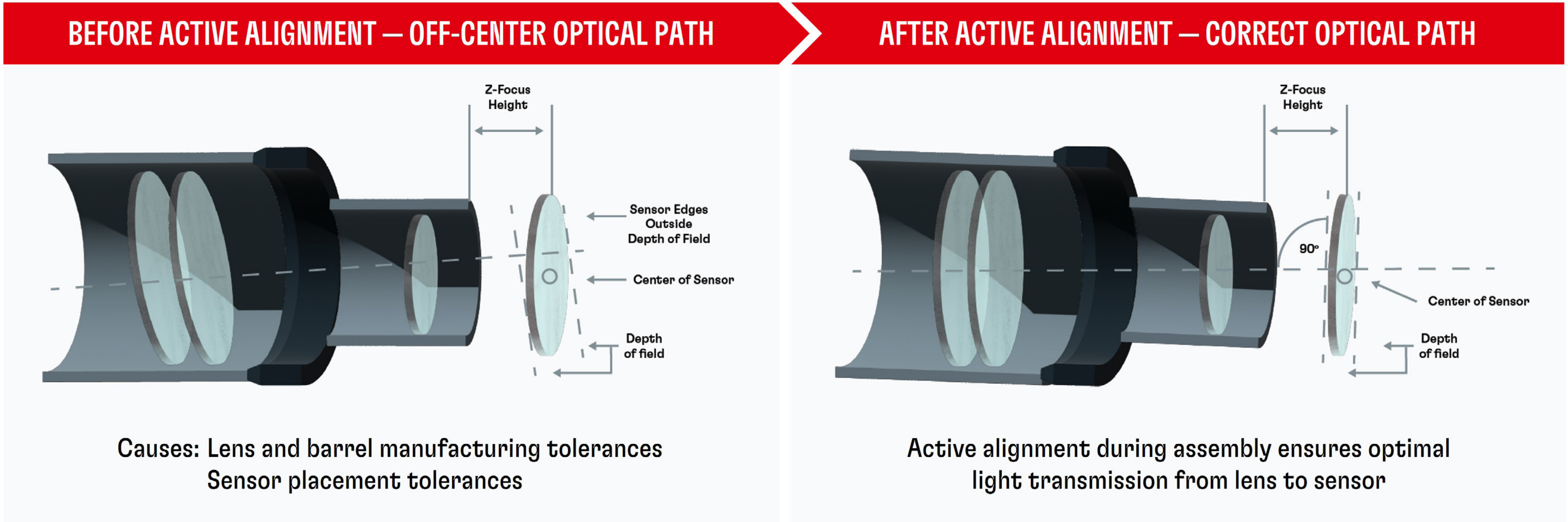

Figure 1. *Optical path adjustment during active alignment.*

ADAS cameras can only tolerate miniscule changes in the positions of their optical components, and the adhesive used plays a major role in meeting these precise positioning requirements. The adhesive must bond to a variety of substrates, cure quickly to high bond strength, and must exhibit low and consistent shrinkage during the curing process to ensure a truly reliable camera module that will perform dependably in harsh conditions for the life span of the vehicle. In addition, the increasing demand for ADAS cameras requires manufacturers to accelerate their assembly process and increase throughput while meeting demanding total cost targets. The standard assembly process requires an initial UV cure to lock the position of the camera. Then a second, energy intensive thermal post-curing step is needed to achieve the full performance of the adhesive. This subsequent cure not only exposes the camera module to thermal stresses but is also time consuming. Therefore, Henkel developed a revolutionary active alignment adhesive which can be cured within just a few seconds of UV LED irradiation. No post-cure is required, thereby reducing cycle time and thermal stress to the components.

CAMERA ASSEMBLY PROCESS

A traditional camera assembly process consists of five steps (**Figure 2**). The adhesive bead is first dispensed on the substrate, and the optical component is then placed and positioned. The actual active alignment takes place in the third step and when the position for the best focus is reached, the components are fixed with a short UV cure of a few seconds. These four steps take only a few seconds to complete. In the fifth, and most time-consuming step, the camera module is put into an oven for a duration of 30 to 100 minutes for the adhesive to undergo a post-cure and reach its final bond strength and final performance. Depending on the chemistry of the adhesive, the post-cure process could consist of exposure to moisture for several hours or up to several days. The entire curing process occurs in two subsequent steps. Therefore, existing camera module adhesives are referred to as dual-cure adhesives.

Figure 2. *Traditional camera module assembly process*

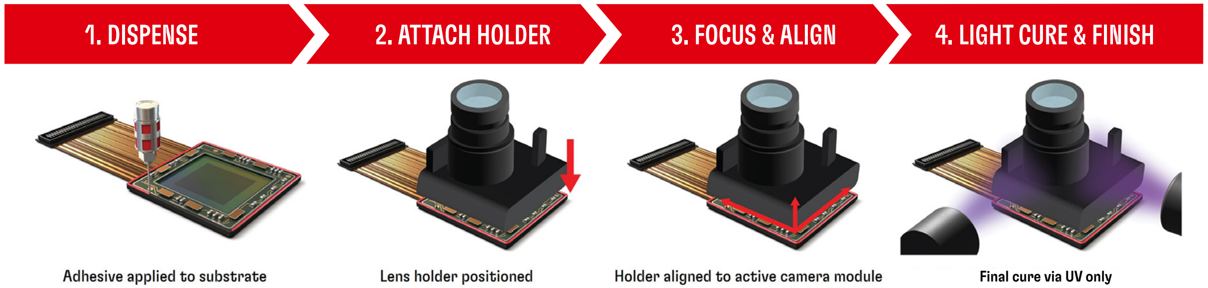

Figure 3. *Camera module assembly process with 1-step cure adhesive*

Henkel's new innovative active alignment adhesive is a single-cure adhesive that delivers high reliability under automotive operating conditions. It does not require the time-consuming and energy-consuming post-cure. Thus, the camera assembly process consists of only four steps (**Figure 3**), with the adhesive reaching its full performance and final bond strength from the fixing step, with just a few seconds of UV LED irradiation. The camera module is then ready for the next assembly step for its final application. The duration of the overall active alignment process is considerably reduced leading to a more sustainable process with time and energy savings, a reduced CO_2 footprint, and overall higher production efficiency.

ADHESIVE PERFORMANCE

The new LOCTITE® ABLESTIK NCA 01UV 1-step cure adhesive meets all requirements for high resolution cameras for automotive applications, showing high reliability and high dimensional stability, similarly to its dual-cure predecessors. It is also fully EU REACH-compliant as it is free of SVHC, or any toxic substances. To reach its full performance, LOCTITE® ABLESTIK NCA 01UV requires only a few seconds of UV LED irradiation at a wavelength of 365 nm set to reach an irradiance of 1,000 mW/cm^2 at the adhesive bead. Typical irradiation time is 3 seconds to reach a dosage of 3,000 mJ/cm^2.

ADHESIVE PERFORMANCE – CONTINUED

The key features of this revolutionary 1-step cure adhesive are summarized in the following table (**Table 1**).

Table 1. *Key features of innovative 1-step UV cure camera module adhesive LOCTITE® ABLESTIK NCA 01UV.*
**A lower viscosity version, "LOCTITE® ABLESTIK NCA 01UV LV" (viscosity of 13.8 Pa-s), is also available.*

Property	LOCTITE® ABLESTIK NCA 01UV
Cure type	UV LED
Chemistry	Epoxy cationic
Appearance	Opaque
SVHC-free	Yes
Non-toxic	Yes
REACH-compliant	Yes
Antimony-free	Yes
Outgassing test	Passed
Shelf life at -20°C	6 months
Viscosity at 23°C / $15s^{-1}$	27.8 Pa·s*
T_g by DMA (tan delta)	134°C
E' at 25°C by DMA	7.3 GPa
CTE 1 (average between 25°C to 125°C)	21 ppm/K
TGA onset	190°C
Cure depth	8 mm
Water absorption after 1000h immersion at RT	0.5%
Hardness shore D	94
Dimensional change	0.4%
Dimensional stability (bond line thickness change of 700 µm bond line)	
1,000 hr. 85°C / 85% rel. H	-0.2%
1,000 hr. heat storage 125°C	-0.5%
1,000 cycles heat shock -40°C to 125°C	-0.2%
Adhesion strength (die shear strength) on plama-treated aluminum to aluminum.	
Initial	10.3 MPa
1,000 hr. 85°C / 85% rel. H	17.7 MPa
1,000 hr. heat storage 125°C	7.3 MPa
1,000 cycles heat shock -40°C to 125°C	6.5 MPa

To ensure the camera maintains the correct focus, it is crucial that no further crosslinking and shrinkage can occur after UV exposure. To confirm the final properties were indeed reached after UV cure with no further crosslinking, the adhesive was also tested after an additional 30-minutes thermal exposure at 120°C, following a similar schedule to a dual-cure active alignment adhesive.

Dielectric Analysis (DEA) was used to evaluate the crosslinking during UV LED cure and to check if further crosslinking can occur during thermal exposure. This method measures ion viscosity, in Ω.cm, over time and over different cure steps. Typically, low ion viscosity is observed for uncured material where ions have high mobility, and the ion viscosity increases with crosslinking as mobility is greatly reduced. DEA can therefore be utilized to monitor the curing process of a material.

Figure 4 shows the evolution of ion viscosity over time, and over different cure steps for LOCTITE® ABLESTIK NCA 01UV. The test was performed as follows:

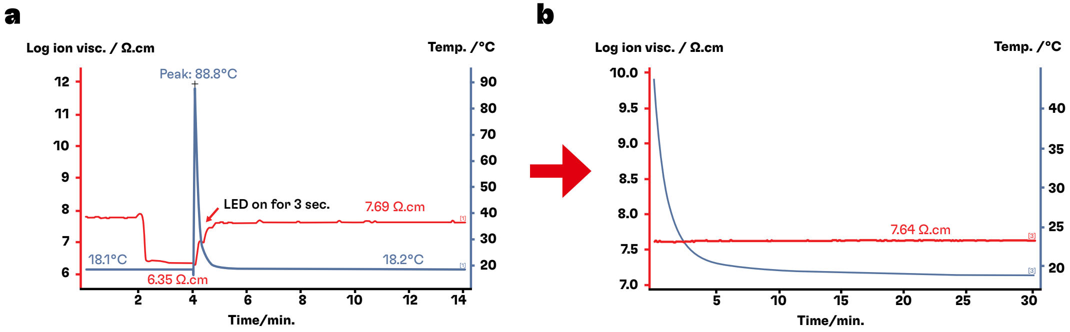

Figure 4. *Dielectric Analysis a) after UV (3 sec. - 365 nm - 1W/cm²) and b) during additional thermal ageing for 30 minutes at 120°C*

Uncured adhesive was applied on the sensor which was irradiated for 3 seconds once the signal was stable. The signal sharply increased from 6.35 Ω.cm to 7.62 Ω.cm. The sample was then subjected to a 30-minutes thermal exposure at 120°C, and the ion viscosity was measured again returning a value of 7.64 Ω.cm. As no significant increase in the ion viscosity was observed after the isothermal ageing, the test results indicate that no additional crosslinking occurred.

In parallel, the sample's temperature was monitored during the DEA measurement. The material self-heats during the UV LED exposure where its temperature sharply increases up to nearly 90°C during curing, facilitating obtaining a high glass transition temperature. The generated heat allows for completion of the crosslinking network and enables the adhesive to reach its full performance during the UV cure.

Dynamic Mechanical Analysis (DMA) was conducted to additionally confirm that isothermal ageing does not significantly increase the glass transition temperature or stiffness any further. **Figure 5** shows the comparison of the thermograms after UV cure and after an additional 30-minutes isothermal ageing at 120°C. As seen on the graphs, the 1-step UV cure adhesive reaches a very high T_g after only 3 seconds of UV LED irradiation. Moreover, no significant difference is observed in storage modulus, representing the stiffness of the cured material, at 25°C (respectively at 10.9 and 10.8 GPa) as well as in the glass transition temperature from the peak of tan δ (respectively 134 and 138°C). The peak shape of tan δ is unimodal and does not notably change after thermal exposure, indicating a homogeneously cured polymeric network comprised of a single glass transition.

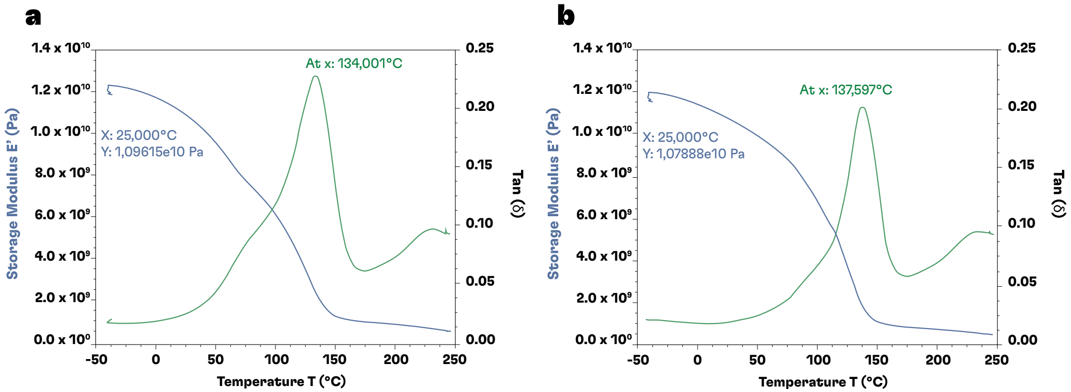

Figure 5. *DMA thermograms a) after UV and b) after additional thermal ageing for 30 minutes at 120°C*

Depending on the design and the application, shadowed areas can prevent the adhesive from being directly exposed to the UV LED light and therefore proper curing. Especially for camera modules, the presence of uncured material can be an issue if it contains volatiles that can contaminate sensitive parts and degrade the quality of the image. It is therefore of paramount importance that a 1-step cure camera adhesive has the potential to achieve high cure depths. With LOCTITE® ABLESTIK NCA 01UV, outstandingly high cure depths can be obtained which reduces the risk of having uncured adhesive present.

When compared with other active alignment adhesives of different chemical formulations available in the market, LOCTITE® ABLESTIK NCA 01UV shows a remarkably higher cure depth up to 8 times higher than traditional dual cure systems. The revolutionary 1-step cure adhesive reaches a cure depth as high as 7.2 mm already after 1 second of UV LED irradiation, and 8 mm after 3 seconds.

However, if any uncured adhesive is present, it is further crucial that the adhesive still hardens over time and does not release volatiles which could condense on sensitive opto-electronic components. In this regard, an outgassing test was performed (analogous to NASA outgassing test methods) on adhesive material, which was left to harden at room temperature without exposure to any light. During the test, the sample was exposed to high vacuum and high temperature for 24 hours, and volatile and condensable materials were collected on a cold aluminum plate positioned above the sample. The sample was then kept for 24 hours at 22°C and 55% relative humidity as this conditioning can cause mass gain from reabsorbed water, called Recovered Mass Loss. To pass the outgassing test, the Recovered Mass Loss must be below 1.00% and the Collected Volatile Condensable Material must be below 0.10%. For the sample cured in the dark over time and without any UV exposure, 0.00% of Volatile Condensable Material was collected, and the Recovered Mass Loss was only 0.42%. The results are presented in **Table 2.** Therefore, even if some adhesive does not immediately cure after UV LED exposure, despite the high cure depth, it will naturally harden over time and no volatiles will outgas, leading to no contamination on the final part. These features make the innovative 1-step UV LED cure adhesive fully compatible with the requirements of high-resolution cameras for automotive ADAS applications.

ADHESIVE PERFORMANCE – CONTINUED

Table 2. *Outgassing test results - * WVR = TML - RML*

	LOCTITE® ABLESTIK NCA 01UV	Acceptance Limit
TML [%] (Total Mass Loss)	0.50	
RML [%] (Recovered Mass Loss)	0.42	<1.00
CVCM [%] (Collected Volatile Condensable Material)	0.00	<0.10
WVR [%]* (Water Vapor Regained)	0.08	

COMMERCIAL BENEFITS AND LIFE CYCLE ANALYSIS

The key advantage of the LOCTITE® ABLESTIK NCA 01UV active alignment adhesive lies in its single step UV LED curability and thus in the elimination of the secondary oven curing step. Considerable savings of capital expenditures, operating and maintenance costs, manufacturing space, and energy can be achieved with a positive impact on the CO_2 footprint.

Assuming an average capital expenditure of 80,000 Euros for a heat cure oven, with an annual maintenance cost of 5,000 Euros, LOCTITE® ABLESTIK NCA 01UV would result in an annual cost savings of 21,000 Euros per year over 5 years for one oven (depreciation + maintenance cost). The freed-up space can also be used for additional investments in further camera production lines in order to increase the throughput and thus the overall production efficiency.

Furthermore, LOCTITE® ABLESTIK NCA 01UV enables optimization of the process time of the overall camera modules assembly line. Since 99% of the camera assembly cycle time can be attributed to oven curing, a significant process cycle improvement can be achieved by eliminating the heat cure process step.

Beyond equipment cost, energy consumption, assembly time, and process efficiency improvements, LOCTITE® ABLESTIK NCA 01UV enables manufacturers to have a positive impact on sustainability by eliminating oven curing. The annual energy consumption of a medium range oven that is post-curing adhesive for 70 minutes at 80°C for a year,[1] is equivalent to nearly 2.5 tons of CO_2[ii]. To sequester this amount of carbon, about 42 tree seedlings would need to grow for 10 years[iii]. This number differs depending on the oven and process used in production. However, the long-term cumulative impact of eliminating the oven cure step for a typical production site with multiple ovens will lead to a significant positive contribution to sustainability.

SUMMARY

LOCTITE® ABLESTIK NCA 01UV is a revolutionary 1-step cure automotive grade adhesive that has been formulated to maintain the beneficial characteristics of its recent dual-cure predecessors. It is antimony-free, SVHC-free, EU REACH-compliant, possesses a high glass transition temperature, low CTE, with high reliability and high dimensional stability, making it a preferred candidate for high resolution automotive ADAS cameras.

By reaching its full crosslinked network and final performance after just a few seconds of UV LED irradiation, this innovative 1-step UV LED cure camera module assembly adhesive not only eliminates thermal stress build-up in the assembly due to the traditional thermal post-cure, but also enables our customers to reduce process costs and time, reduce manufacturing footprint and increase assembly line throughput. Moreover, LOCTITE® ABLESTIK NCA 01UV offers a considerably more sustainable production process by significantly reducing the energy required for manufacturing, as well as the overall CO_2 footprint.

[1] Assuming a production rate of 240 cameras per hour, 84 kg of adhesive per year, and an oven of 11.2 meters long with a nominal power of 17 kWh using 1.6 kW to keep 80°C, and a consumption of 63 kWh per kg of adhesive, leading to a yearly consumption of about 5,300 kWh.

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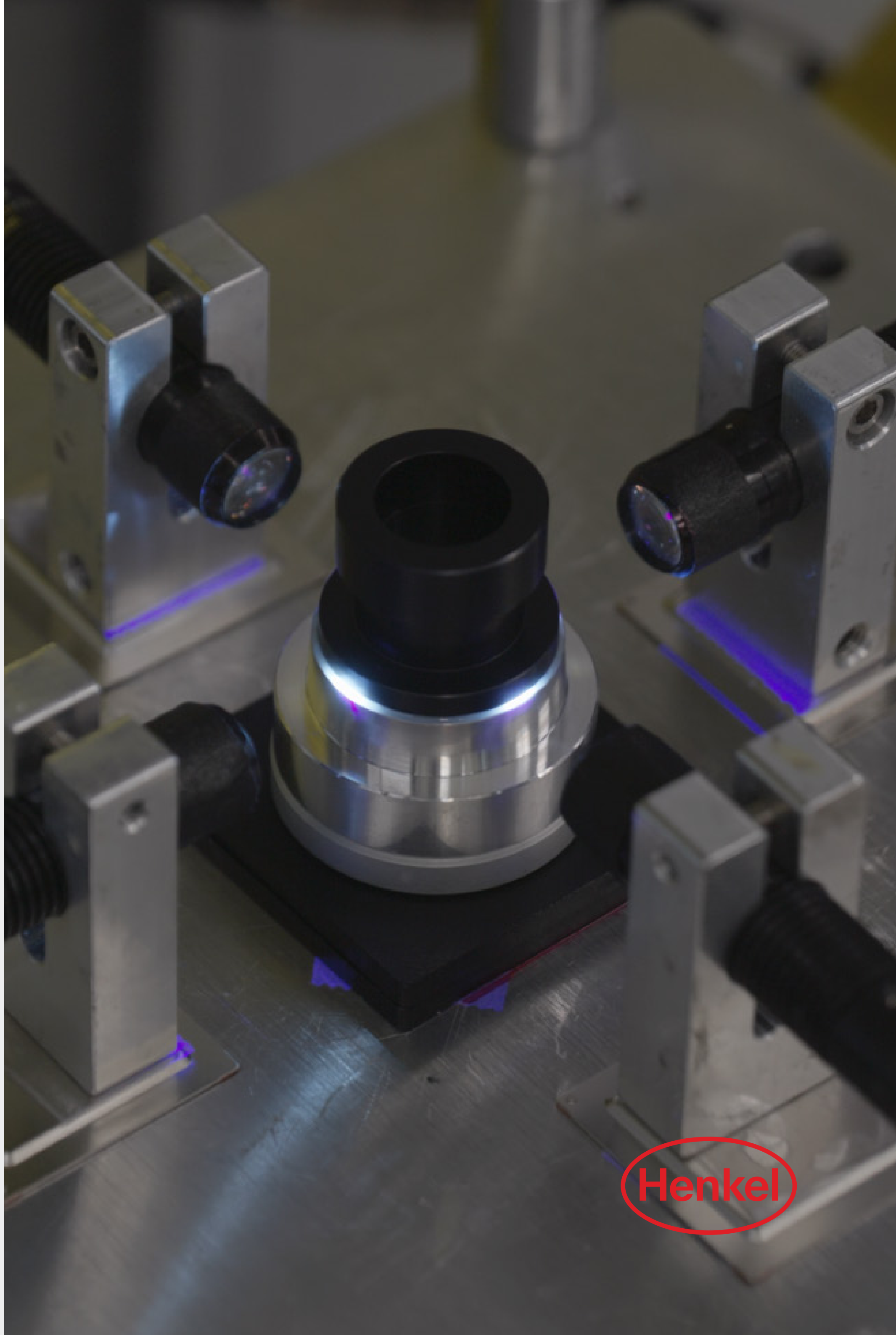

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