WHITE PAPER

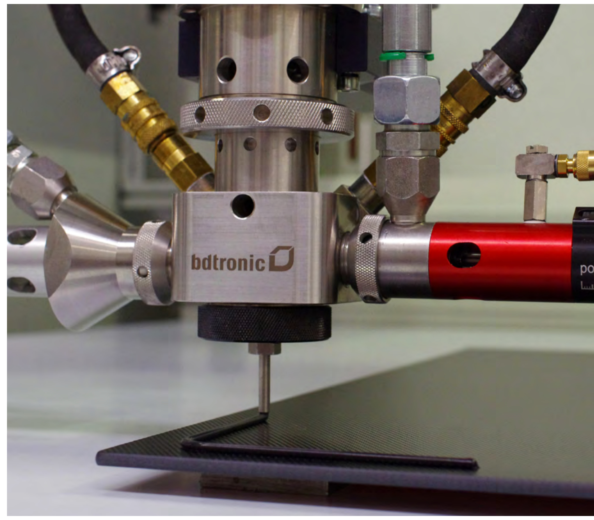
2-Part RTV silicone adhesive for fast, in-line manufacturing across multiple industries

Marcos Fernandez-Castaño Romera, Burak Akin Aksoy, Sven Roth

Dow technical support and development
Mobility and Transportation Electronics, EMEA
burak.aksoy@dow.com

Mark Bradford

Dow regional marketing manager
Consumer Electronics and Lighting, EMEA
mpbradford@dow.com



Abstract

What if you could tailor working times in your manufacturing process, provide robust adhesion to your materials, and help to meet your company sustainability goals — just by utilizing an innovation in room temperature vulcanizing (RTV) adhesives? And what if this **room-temperature cure** adhesive offered **tunable reactivity, better and faster primerless adhesion** to plastics, metals, glass and many more materials?

We think you should take a look.

DOWSIL™ EA-3838 Fast Adhesive is an RTV adhesive with full fixture time within 20* minutes, eliminates the need for ovens and primers in the assembly line, **reduces cycle times** from days to hours — or minutes, and bonds to a wide range of materials for fast in-line manufacturing.

DOWSIL™ EA-3838 Fast Adhesive was developed in 2020 targeting an optimized balance between fast cure rates, early adhesion development, and robust adhesion to metals, plastics, and ceramics. In this paper, DOWSIL™ EA-3838 Fast Adhesive is benchmarked against two comparable competitive materials across these three categories. The results presented herein show that DOWSIL™ EA-3838 Fast Adhesive can reduce fixture times by a factor of four relative to the best-performing benchmark, reducing fixture times from two hours to 30 minutes. Moreover, it exhibits stronger final lap shear strength across all tested substrates, making it the ideal candidate for customers seeking to speed up their assembly process, while imparting robust and durable adhesion to multiple materials.

Introduction

2-Part (2K) RTV silicone adhesives have drawn increased attention across several industries due to the need for less energy-intensive and high throughput manufacturing processes. This type of adhesive can bond to a plethora of substrates in a matter of minutes-to-hours without the need for flammable primers or energy-consuming ovens, removing the need for large areas to store curing parts, unlike their 1K RTV counterparts. They are the ideal choice of adhesive/sealant for customers seeking to maximize the number of bonded parts per hour. The key difference between 2K and 1K RTV enabling cycle time reductions from several days to a few hours lies in their different cure mechanisms: 1K adhesives rely on sluggish water diffusion from the environment for curing, 2K materials incorporate water in the formulation, leading to homogeneous cross-linking across the adhesive joint (see Figure 1). On the downside, 2K adhesives require mixing equipment for base and catalyst, introducing added complexity versus 1Ks, which can be directly applied onto the substrate.

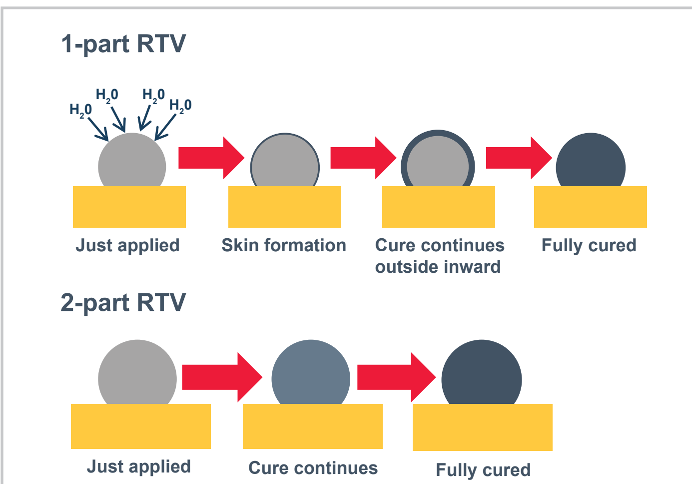


Figure 1. Cure mechanism of condensation 1-part versus 2-part RTV adhesives

*Time needed to achieve cohesive failure in a 2:1 and 4:1 mix ratio for most tested substrates

The cross-linking and adhesion reactions progress at different rates, whereby adhesion is slower than cross-linking. Such kinetic mismatch stems from the fact that the APs responsible for chemical anchoring to the surface need to travel first to the adhesive-substrate interface to effect bonding, whereas cross-linking can occur at any point and time. This distinction between cross-linking and adhesion reactions is important because balancing these two processes will determine both the speed and final strength of adhesion. For instance, if the network forms too quickly, it can do so at the expense of hindering AP migration, thus reducing the number of bonds generated at the interface, and weaking adhesion collectively. Other factors influencing adhesion are linked to the mobility of the APs, their solubility in the target substrate(s), as well as the ability to engender multiple bonds per AP molecule.

DOWSIL™ EA-3838 Fast Adhesive with its proprietary AP technology, was designed with the goal to accelerate adhesion development, maximize adhesion strength and durability to as many materials as possible, and allow for tunable base-to-catalyst mixing ratios, tailoring open times to the needs of the manufacturing process. In this report, we benchmark DOWSIL™ EA-3838 Fast Adhesive against two competitive 2K RTV alkoxy-silicone adhesives with emphasis on open times, early adhesion development, and final lap shear strength to various industry-relevant substrates.

Cure speed and early adhesion development

When selecting a 2K RTV adhesive for a continuous manufacturing process, it is important to consider both tack-free and fixture times (TFT and FT, respectively). TFT encompasses the time available after mixing base and catalyst, dispensing the adhesive bead, and bonding the substrates together. Ideally, TFT should be wide enough to prevent curing of the adhesive inside the mixer (longer ST), and fix in-line errors that may arise prior or after bonding the parts. By contrast, FTs — defined as the time elapsed after bonding the parts and safely removing the fixtures (i.e., the point after which the adhesive joint can withstand the weight of the parts on its own) — should be as short as possible to avoid accumulation of stock for curing parts. Since FT depends on the nature and weight of the bonded parts, it is often simpler to refer to the time needed for the adhesive to attain 100% CF modes.

Table 1 and Figure 2 below shows ST, TFT, and lap shear strength data of DOWSIL™ EA-3838 Fast Adhesive at two different mixing ratios versus benchmark 10 and 15 (BM10 and BM15 for short). BM10 is characterized by a short TFT of ca. 5 mins followed by 2 hours to reach 100% CF, whereas BM15 provides extended TFTs (10 mins). Accordingly, this comes at the expense of longer times to reach 100% CF (8 hrs). On the other hand, DOWSIL™ EA-3838 Fast Adhesive in a 2:1 ratio features the same TFT as BM10 (5 mins), but 100% CF is attained much faster inside 30 mins. Changing the mixing ratio to 4:1, yields extended TFTs of 15 minutes, but 100% CF is reached within just 1 hour, reducing FTs by two-fold relative to the best performing competitive product (BM10).

Table 1. Snap time, tack-free time, and fixture time of DOWSIL™ EA-3838 Fast Adhesive at two different ratios, versus BM10 and BM15.

Sample	ST (min:sec)	TFT (min:sec)	*100% CF
DOWSIL™ EA-3838 Fast Adhesive 2:1 by volume	2:50	5:20	30 min
DOWSIL™ EA-3838 Fast Adhesive 4:1 by weight	4:45	15:00	1 hour
BM10 2:1 by volume	5:20	9:00	2 hours
BM15 2:1 by volume	2:35	4:50	8 hours

**Time needed to reach 100% cohesive failure for a glass-stainless steel lap shear joint.*

These results further demonstrate the far superior early adhesion development capabilities of DOWSIL™ EA-3838 Fast Adhesive, and its unique ability to extend TFT through different mixing ratios. This provides operators with as much as 15 minutes to implement in-line changes, while keeping fixture times under one hour, thereby increasing productivity outputs by up to four times relative to the best-performing competition benchmark.

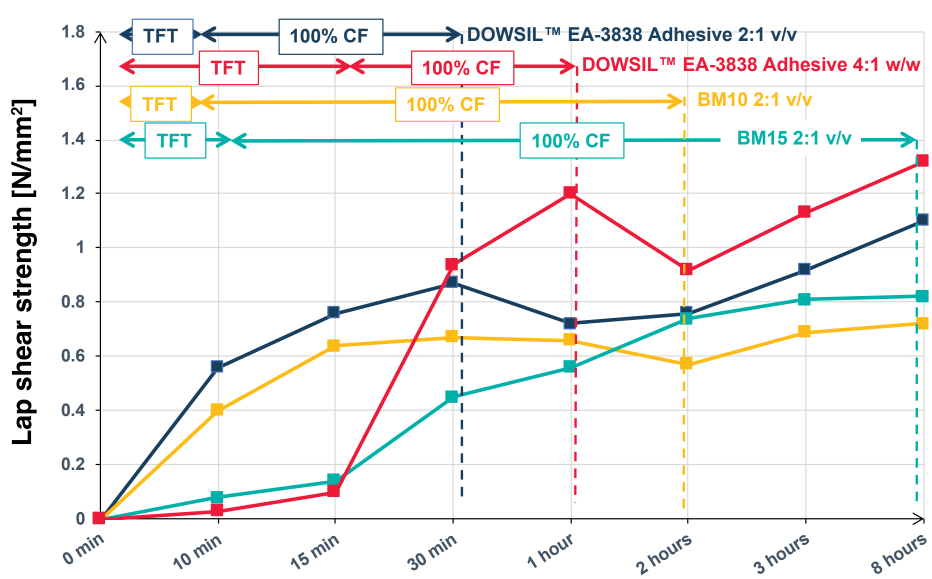


Figure 2. Time-dependent, early lap shear adhesion development after assembly of a stainless steel joint bonded on glass




Final adhesion to various plastics and metals

Final adhesion of all 2-part RTVs was studied by measuring lap shear strength on various industry-relevant plastics and metals one week after bonding the parts, and plotted jointly in the spider chart of Figure 3. The results from this graph show far superior adhesion performance of DOWSIL™ EA-3838 Fast Adhesive across all tested substrates compared to BM10 and BM15. Specifically, it achieves lap shear strength values greater than 1 MPa, and consistent 100% CF on all substrates including classically *difficult-to-bond* plastics such as ABS, PBT or PC. By contrast, BM10 and 15 were found to develop comparatively weaker bonding strengths on all substrates, but particularly so for plastics, potentially requiring surface activation steps (e.g., plasma treatment or priming), and increasing the complexity and overall capital investment costs of the manufacturing process.

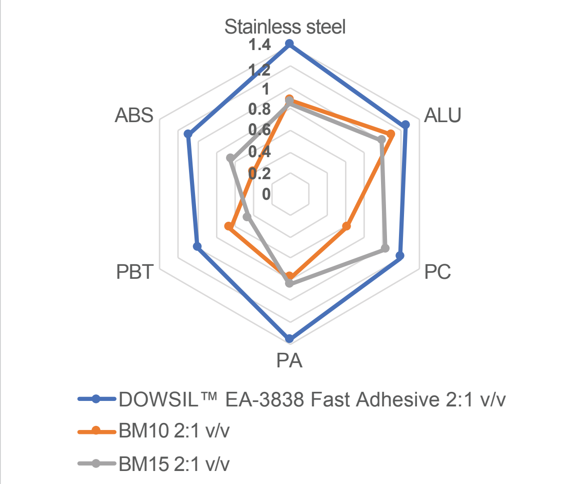
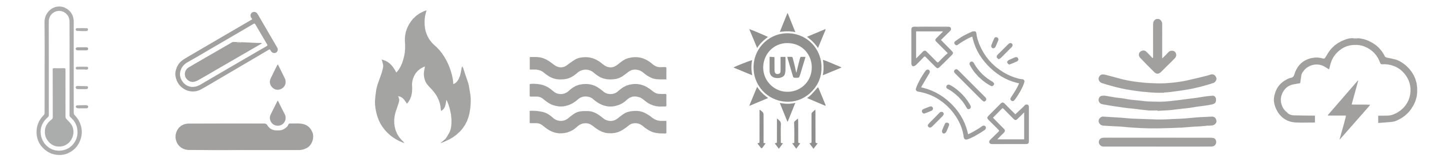


Figure 3. Lap shear strength [N/mm^2] after one week for different substrates, alongside different applications/ markets requiring fast and robust adhesion to metals, plastics, ceramics, and composites (including renewables, EV charging stations, display bonding, power electronics, appliances, and many more)

Key benefits of DOWSIL™ EA-3838 Fast Adhesive



Stable from -50ºC to 180ºC | **Non-corrosive, neutral, alkoxy cure** | **Fire resistant, UL94 certified** | **Provides vibration dampening** | **Resistant against UV degradation** | **Flexible over broad temperature range** | **Accommodates large CTE mismatches** | **Insulation against dust, salt, water**

Conclusions

Working times, early adhesion development, and final adhesion to different materials of three different 2-part RTV silicone adhesives were herein evaluated. The results presented show:

1. DOWSIL™ EA-3838 Fast Adhesive in 2:1 v/v ratio achieves 100% CF inside 30 minutes for a stainless-steel joint bonded on glass, representing a 4- and 16-fold reduction in fixture times relative BM10 and 15, respectively.
2. Changing mixing ratios from 2:1 to 4:1 in DOWSIL™ EA-3838 Fast Adhesive increases TFT from 5 to 15 minutes for extended open times, while maintaining open times under one hour, outperforming BM10 and 15 by 2- and 6-fold, respectively.
3. DOWSIL™ EA-3838 Fast Adhesive features stronger final adhesion on all evaluated substrates, including challenging plastics and metals.

In closing, DOWSIL™ EA-3838 Fast Adhesive manages to bridge the gap between fast cure rates, early adhesion development, and robust final adhesion, far outperforming competitive materials. This adhesive is the ideal choice for customers seeking to reduce cycle times, remove ovens and primers from their assembly lines, and develop strong and durable adhesion to a wide range of materials. Lastly, the tunable mixing ratios can be leveraged to extend working times, thereby allowing more time to implement changes in a way that is unlike any of its competitors.

Terms and Definitions

- **Silicone:** Silicones are a class of polymeric materials whose backbone is composed of (-Si-O-Si-) siloxane bonds. The binding energy of the Si-O bond is 433 KJ/mol making it significantly higher than that of carbon-carbon bonds (355 KJ/mol). Thus, compared to most common organic polymers, silicones exhibit superior thermal stability, UV and chemical resistance, flexibility over a broad temperature range, flame retardancy, etc.
- **RTV silicone:** Room Temperature Vulcanization silicones are a class of silicones that cure at room temperature without the need for ovens or any other external energy input. They are available as one- and two-component (base & catalyst) mixtures. RTV silicones can incorporate a platinum (addition cure) or tin catalyst (condensation cure). The latter need water either from the atmosphere or present in the formulation for curing, releasing a condensation product (most commonly methanol or ethanol).
- **Adhesion promoter (AP):** APs are small, highly mobile molecules that are added to the formulation to develop adhesion to surfaces. They do so by migrating to the substrate-adhesive interphase, where they react generating strong chemical bonds between the two materials.
- **Snap time (ST):** Length of time it takes for an RTV material to show the first sign of rubberiness after the material is completely formulated and exposed to normal curing conditions. ST is useful to estimate the time window available after mixing catalyst and base and dispensing the adhesive. Past the ST, the adhesive becomes too viscous to enable dispensing.
- **Tack-free time (TFT):** Also referred to as skin-over time, is defined as the time in minutes required for a curing material to form a non-tacky surface film. This method uses polyethylene film contact to determine the non-tacky characteristics and it is crucial to be able to calculate the process's open time (i.e., time window available after dispensing the adhesive and bonding the parts).
- **Cohesive/adhesive failure (CF/AF):** CF/AF is a qualitative way of assessing the strength of an adhesive joint by visually inspecting post-mortem samples. CF occurs when a fracture allows a layer of adhesive to remain on both surfaces indicating good adhesion. Conversely, if no adhesive is found on the surface of the substrate, this is typically associated with poor adhesion.
- **Lap shear strength:** The adhesion of primers, adhesives, and sealants is determined by measuring the amount of pull required to separate a lap shear laminate. The results are reported in force per unit area.

UL Certified

Image numbers: 68810023957, 66339223609, 66995207328, 68721946679, 55069554218

23BDE414

Form No. 11-4341-01 0224AMPM