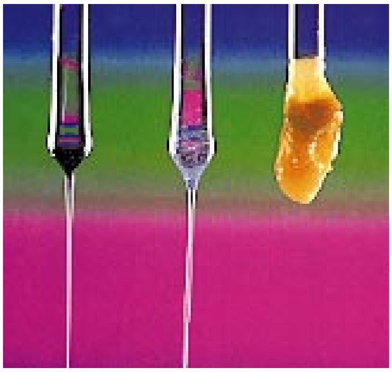
DuPont

Kevlar®
pulp

Kevlar® Brand Pulp in Adhesives, Sealants, Coatings and Fiber-Reinforced Plastics



KEVLAR® pulps offer viscosity control that is superior to that of other materials. This photograph compares these high performers to fumed silica at work in adhesives. From left to right: 100% epoxy; epoxy with 5.0% fumed silica and epoxy with 1.5% KEVLAR® pulp.

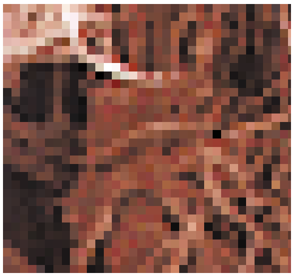


Figure 1. The fibrous nature of KEVLAR® makes it a natural thixotrope.
The main fibers of KEVLAR® pulp are surrounded by many smaller, attached fibrils, resulting in high surface area.

Better control over viscosity and costs

In adhesive, sealant, coating and fiber-reinforced plastic applications, KEVLAR® gives you the best of both worlds. You get better viscosity control and lower costs.

Better viscosity control and stability

KEVLAR® is a fibrous thixotrope. It thickens or builds viscosity through the random orientation and physical entanglement of fibers and tiny fibrils *(Figure 1)*. Under shear, these fibers align and the material thins. This built-in thixotropic mechanism provides superior viscosity control that is unaffected by processing or aging.

Lower costs

Because KEVLAR® is such a strong performer, you need significantly less to achieve thixotropic properties equivalent to those obtainable with other materials, such as fumed silica.

Superior thermal and chemical resistance

KEVLAR® is ideal for a full range of temperatures, from cryogenic to 350°C (662°F).

KEVLAR® is inert in most common chemicals, including organic solvents; however, it is not stable in hot concentrated acids and bases.

Plus a whole lot more…

KEVLAR® also provides outstanding mechanical reinforcement properties. And, it's safe for the environment.

On the following pages, you will see the superior thixotropic and reinforcing properties for KEVLAR® in sealants, adhesives, coatings and fiber-reinforced plastics.

Excellent thixotropy and reinforcement

In adhesive and sealants, KEVLAR® brand pulp provides:

- Excellent viscosity control and reinforcement
- Stable thixotropic properties over time
- Resistance to overprocessing

Superior viscosity control

To establish the performance of KEVLAR® brand pulp relative to that of fused silica, a series of tests were conducted using:[1–3]

- Pure epoxy
- Epoxy compounded with 0.4% (by weight) KEVLAR® pulp
- Epoxy compounded with 5.0% (by weight) fumed silica

At these levels, the viscosities of the thixotropic resin systems were equivalent at low shear, indicating equal sag resistance *(Figure 2)*. This was later confirmed when the samples were tested for slump resistance according to ASTM D-2202 *(Table 1)*.

Under high shear, the viscosity of the sample with KEVLAR® approached that of the pure epoxy and was actually lower than that of the fumed silica sample. This suggests that adhesives with KEVLAR® are easier to process (pump, meter or spray) than adhesives with fumed silica.

These tests prove that a small amount of KEVLAR® can replace a significantly larger amount of fumed silica, while delivering equivalent performance. Thus, KEVLAR® is a better, less expensive thixotrope than fumed silica *(Figures 3 and 4)*.

Enhanced viscosity stability

KEVLAR® pulp is highly resistant to processing, aging and changing temperature—factors that can adversely affect other thixotropes.

- **Resistance to processing.** Fibrous thixotropes, such as KEVLAR® pulp, build viscosity through their physical structure. Under shear, the fibers align and the material thins. Once the shear is removed, the fibers disorient and the material immediately returns to its original viscosity. KEVLAR® pulp is a tough and resilient fiber; unlike asbestos, it does not break down and is therefore unaffected by processing.

Figure 2. Viscosity vs. shear rate of KEVLAR® pulp and fumed silica in epoxy.

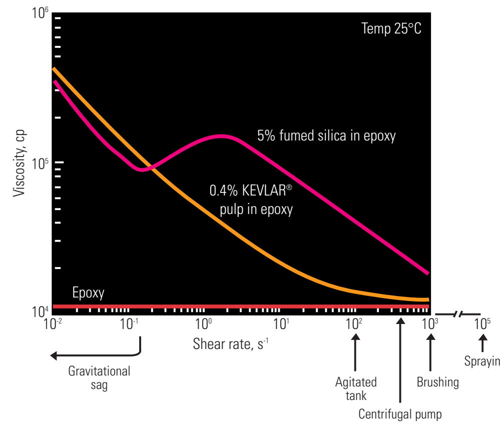


Table 1. Adhesive slump test* results.

Material	Time, sec
Pure epoxy	9
5% fumed silica	24
0.4% KEVLAR® pulp	27

*ASTM D-2202

Figure 3. Relative weight needed to achieve equivalent thixotropic performance with KEVLAR® and fumed silica.
As you can see, to achieve equivalent thixotropic performance, it requires significantly less KEVLAR® than fumed silica.

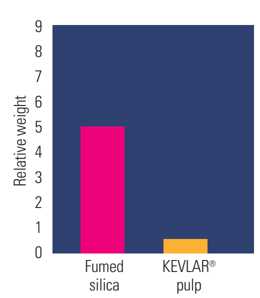
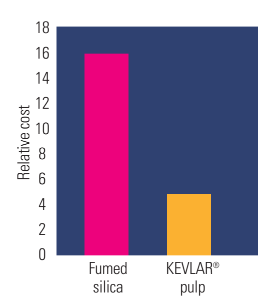


Figure 4. Relative cost to achieve equivalent thixotropic performance with KEVLAR® and fumed silica.
Fumed silica costs up to three times more than KEVLAR® to achieve the same thixotropic properties.



1. All viscosity vs. shear rate tests were run on a "HAAKE-Rotovisco" RV-12 cone and plate viscometer, unless otherwise specified.
2. All epoxies are "Epon" 828 (Shell), unless otherwise noted.
3. The viscosity of the epoxy with fumed silica changed substantially with time. Because of this, all samples were aged seven days prior to testing, unless otherwise indicated.

Figure 5. Effect of agitation on viscosity vs. shear rate for 0.4% KEVLAR® in epoxy.*

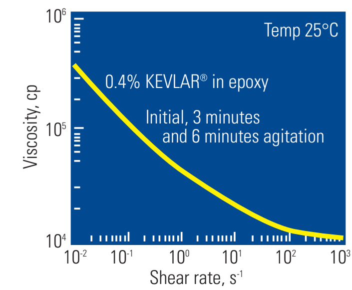


Figure 6. Effect of agitation on viscosity vs. shear rate for 5% fumed silica in epoxy.*

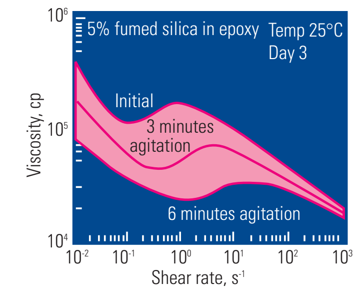


Figure 7. Effect of time on viscosity vs. shear rate for 0.4% KEVLAR® pulp in epoxy.

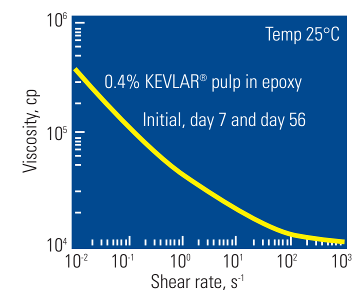


Figure 8. Effect of time on viscosity vs. shear rate for 5% fumed silica in epoxy.

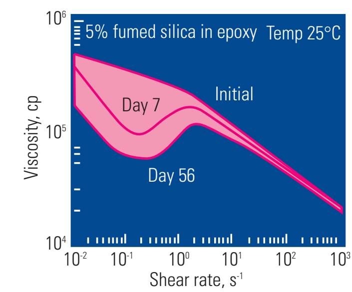
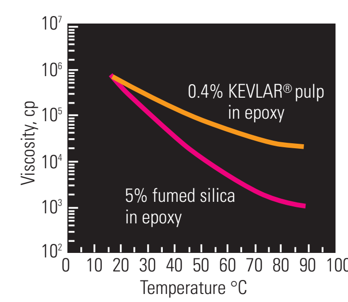


Figure 9. Effect of temperature on viscosity at low shear rate for 0.4% KEVLAR® pulp and 5% fumed silica in epoxy.**



*12,000 rpm in Waring® 700 Blender.
**Brookfield Viscometer at 0.3 rpm.

Particulate thixotropes, such as fumed silica, build viscosity by forming networks via hydrogen bonding. Under shear, these networks break down, causing the material to thin. If too much shear is applied (by mixing the resin too long, for example), the networks do not completely reform when the shear is removed and viscosity is decreased. The result is reduced performance, batch-to-batch variability or increased cost if more thixotrope is required.

Figures 5 and 6 show the effect of vigorous agitation on viscosity vs. shear rate for epoxy samples containing various thixotropes. The viscosity of the epoxy with KEVLAR® remained unchanged, while the viscosity of the fumed silica sample decreased significantly after agitation.

- **Resistance to aging.** KEVLAR® pulps maintain their viscosity-building properties indefinitely due to the physical nature of the fibers and the thixotropic mechanism *(Figure 7)*. The benefits of this superior resistance to aging are increased shelf life and consistent performance. In contrast, fumed silica loses its effectiveness as a thixotrope over time *(Figure 8)*.
- **Resistance to temperature changes.** Laboratory tests have been conducted to measure the effect of temperature on viscosity for epoxy resins with KEVLAR® pulp and fumed silica *(Figure 9)*. At higher temperatures, the epoxies with KEVLAR® pulp thinned less than the epoxy with fumed silica. Thus, adhesives with KEVLAR® are less likely to drip at higher temperatures.

Unmatched reinforcement

Because KEVLAR® is a high-performance, engineered short fiber, it reinforces the matrix in which it is compounded. *Table 2* demonstrates how low levels of KEVLAR® pulp significantly improve the tensile strength, modulus and tear strength of both a PVC plastisol adhesive and a silicone sealant.

Table 2. Plastisol and silicone reinforced with KEVLAR® pulp vs. unreinforced.

PVC plastisol adhesive	20°C (68°F)			75°C (167°F)		
% KEVLAR® pulp	Tensile strength	Modulus	Tear strength	Tensile strength	Modulus	Tear strength
0	1.0	1.0	1.0	1.0	1.0	1.0
2.5	2.6×	5.1×	4.6×	4.3×	6.5×	3.1×
5.0	2.5×	6.5×	4.0×	2.7×	6.3×	4.0×
Silicone sealant	20°C (68°F)			200°C (392°F)		
% KEVLAR® pulp	Tensile strength	Modulus	Tear strength	Tensile strength	Modulus	Tear strength
0	1.0	1.0	1.0	1.0	1.0	1.0
2.5	2.4×	8.7×	3.7×	2.8×	3.1×	5.0×
5.0	3.2×	14.0×	5.0×	3.1×	3.6×	8.2×

NOTE: The control was normalized to 1.0 and the test was calculated as a ratio to the control.

Higher film build and easy application

In coatings, KEVLAR® offers:

- Superior long-term performance
- Easy application
- Tougher, thicker coatings

KEVLAR® imparts both sag resistance *and* mechanical reinforcement, making it well suited for many coating systems, including:

- Highway and traffic line paints
- Block fillers
- Floor coatings
- Marine coatings
- Roof mastics and other asphaltic coatings
- Textured decorative coatings

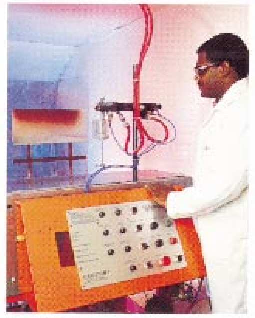
Higher film build

KEVLAR® results in a slightly raised texture, which is less visible with higher film builds. In laboratory tests, an epoxy amine coating without KEVLAR® dripped after five passes. By adding only 0.2% KEVLAR®, the coating did not drip until eight passes had been sprayed. With more passes per coat, the result is a thicker, tougher coating in less time.

Increased chip and scratch resistance

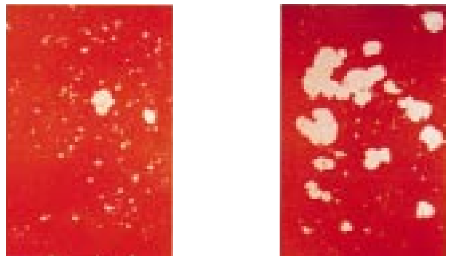
In a chip resistance test (ASTM D-3170-87), adding 0.15% KEVLAR® improved the rating of an epoxy amine industrial coating from 5D to 7D *(Figure 10)*. This dramatic improvement can greatly reduce the potential for chipping to bare metal.

In the standard pencil hardness test, adding 0.2% KEVLAR® to an epoxy amine coating increased the pencil hardness from "B" to "2H," an increase of four levels.



Coatings with KEVLAR® are easy to spray, yet they allow higher film builds and provide better reinforcing properties than other materials.

Figure 10. Comparative chip resistance test (ASTM D-3170-87) of an epoxy amine coating with KEVLAR® and with fumed silica.



Contains 0.15% KEVLAR® pulp — Contains 0.36% fumed silica

Easy application

Coatings with KEVLAR® thin at high shear for easy spraying because the fibers align in the direction of flow. Once the shear is removed, the fibers disorient and the coating immediately returns to its original, thicker viscosity. This results in less sagging, permitting a higher film build.

Increased reinforcement in polyurethane

Unlike particulates, KEVLAR® has a high aspect ratio (length to diameter), which lends reinforcement to the systems they modify. In laboratory tests, 0.71% KEVLAR® compounded into a castable polyurethane almost doubled its tear resistance and tripled its abrasion resistance *(Table 3)*.

Table 3. Polyurethane reinforcement with KEVLAR®

% Pulp	Tear strength*	Wear resistance**
0	1.0	1.0
0.71	1.8×	2.9×

*Trouser tear strength.
**NBS Abrasion Index.
NOTE: The control was normalized to 1.0 and the test sample was calculated as a ratio to the control.

Excellent sag resistance during layup or spray-up

In fiber-reinforced plastic (FRP) applications, KEVLAR® offers:

- Superior, consistent performance at lower cost
- Easy application and longer shelf life

KEVLAR® is well suited for all FRP resin systems, including polyesters, epoxies and urethanes. In addition, because KEVLAR® does not depend on hydrogen bonding for its thixotropic properties, it works as well in vinyl esters as it does in any other resin. In contrast, fumed silicas require a higher-grade, more expensive hydrophobic product to achieve the same results in vinyl esters *(Table 4)*.

KEVLAR® is well suited for FRP systems, such as bathtubs, shower stalls, truck caps, boats and other molded parts. It is also ideal for making thick putties to reinforce and repair molded parts. It may not be suitable for certain gel coats because fibrous thixotropes result in a slightly textured surface.

Lower costs

KEVLAR® provides the desirable thixotropic characteristics for FRP resins at a fraction of the cost of fumed silica.

With KEVLAR®, cost savings of 1 to 2 cents per pound have been demonstrated in a standard polyester laminating resin. Using only 0.2% KEVLAR® pulp gives the same viscosity in the low-shear, gravitational sag region as 1.5% fumed silica (*Figure 11*).

These results have been confirmed by a modified slump test in which the sample with KEVLAR® traveled more slowly down a vertical surface than the fumed silica sample *(Table 5)*.

Easy to use

Resins with KEVLAR® thin substantially under shear, simplifying application during manufacture *(Figure 11)*. Because the fibers align, the resins can be easily sprayed through a chopper gun, as well as troweled or brushed onto a mold.

Table 4. Modified slump test* in vinyl ester*

Material	Time, sec
Pure vinyl ester	3.3
2% hydrophobic fumed silica	10.3
2% standard hydrophilic fumed silica	5.8
0.2% KEVLAR® pulp	11.0

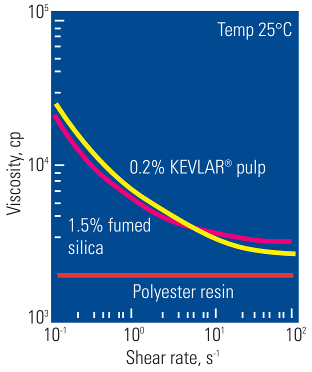
*Time for a 4-mm (5⁄32-in.) thick sample to traverse 152 mm (6 in.) on a vertical surface.
**"Derakane" 411-45 (DOW).

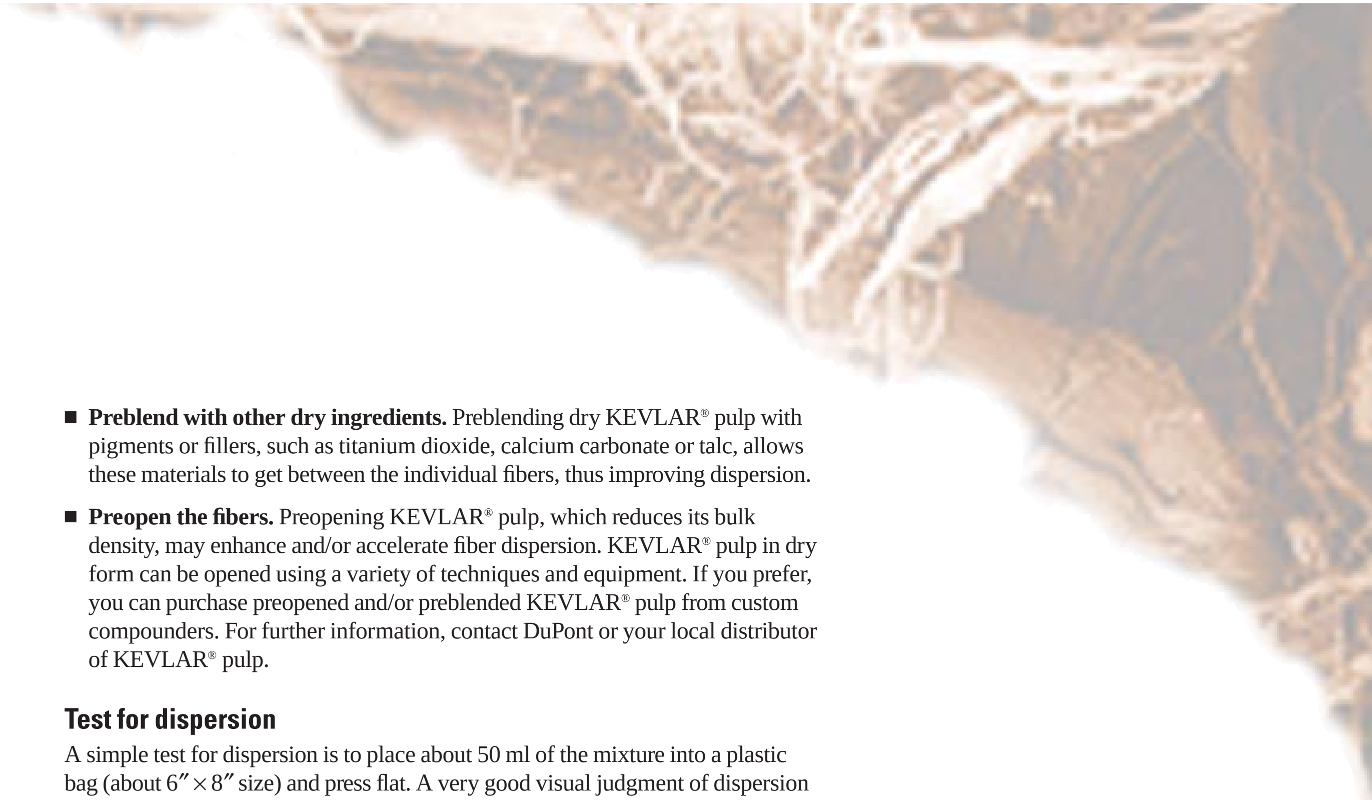
Table 5. Modified slump test* in polyester

Sample	Time, sec
1.5% fumed silica	37.3
00.2% KEVLAR® pulp	11.0

*Time for a 4-mm (5⁄32-in.) thick sample to traverse 152 mm (6 in.) on a vertical surface.

Figure 11. Comparison of viscosity vs. shear rate for 0.2% KEVLAR® and 1.5% fumed silica in a polyester resin.
Unless otherwise noted, polyester resin is "Polylite" 31-011 (Reichold).





Longer shelf life

The settling rate of KEVLAR® in polyester resins is slower than that of fumed silica. Even if settling does occur, the KEVLAR® can be easily redispersed; it will not form a hard mass in the container. This characteristic lengthens the shelf life of the resin and reduces inconsistency problems. In addition, resins with KEVLAR® will not lose viscosity due to aging or excess processing.

Mixing, safety and handling

Processing KEVLAR® pulp

KEVLAR® pulp is a tough, engineered fiber that is not brittle and cannot be broken down or reduced to dust by mixing. In fact, no amount of mixing or other shearing will affect the viscosity build of a system containing this fiber, since the thixotropic mechanism is a function of its physical structure.

High-speed mixing

Because KEVLAR® pulp is tough and highly fibrillated, it can be more difficult to disperse than other thixotropes. The key to good dispersion is to effectively separate the fibers from each other by pulling them apart, thus allowing each fiber to be wet out.

This separation is best accomplished using high-speed, high-shear mixing equipment, such as a Cowles mixer or Double-Planetary mixer (higher energy and/or speed is better). Mixers with a scraping blade are also very useful; slow-speed mixers, such as those with a sigma blade, are less effective. For laboratory use, a standard kitchen blender works well.

Optimum dispersion methods

Several other techniques can be used to optimize dispersion. These methods are described below in their order of effectiveness for the many materials tested by DuPont. Although each of these techniques may not be appropriate for all materials or processing conditions, using the proper method or combination of methods can greatly improve uniformity.

- **Make a concentrate.** Making a concentrated solution will efficiently separate the fibers. High-shear mixing is the most efficient way to make the concentrate, which can then be easily diluted in the resin using low-shear mixing. For example, to make a 0.5% solution of KEVLAR®, add 5% KEVLAR® and mix under high shear. This will produce a very thick, uniform mix that can be diluted easily to 0.5%.
- **Add KEVLAR® pulp at a viscous stage.** The more viscous the solution, the easier it is to obtain a uniform dispersion. Add the pulp when the mixture is already thick—either premix it with the resin or add it before the final solvents.
- **Preblend with other dry ingredients.** Preblending dry KEVLAR® pulp with pigments or fillers, such as titanium dioxide, calcium carbonate or talc, allows these materials to get between the individual fibers, thus improving dispersion.
- **Preopen the fibers.** Preopening KEVLAR® pulp, which reduces its bulk density, may enhance and/or accelerate fiber dispersion. KEVLAR® pulp in dry form can be opened using a variety of techniques and equipment. If you prefer, you can purchase preopened and/or preblended KEVLAR® pulp from custom compounders. For further information, contact DuPont or your local distributor of KEVLAR® pulp.

Test for dispersion

A simple test for dispersion is to place about 50 ml of the mixture into a plastic bag (about 6″ × 8″ size) and press flat. A very good visual judgment of dispersion can then be made.

Separation

Because of density differences and/or air entrainment, separation of KEVLAR® and other solids can occur in low-viscosity media after some time. Redispersion is easily achieved with only minimal mixing. Minimizing air entrainment will help stabilize dispersions.

Filter screens

In some applications, screens are used to filter out impurities. Fine filters cannot be used with KEVLAR® pulp, as it will form a mat on the screen.

For more information about KEVLAR® or to receive a list of distributors, please call 1-800-4-KEVLAR® (453-8527).

DuPont
Advanced Fibers Systems
Customer Inquiry Center
5401 Jefferson Davis Highway
Richmond, VA 23234
Tel.: (800) 453-8527
(800) 383-4400
Fax: (800) 787-7086
(800) 383-3963

DuPont
Engineering Fibres
P.O. Box 50
CH-1218 Le Grand-Saconnex
Geneva, Switzerland
Tel.: ++41-22-717 51 11
Fax: ++41-22-717 60 21

DuPont Canada Inc.
Advanced Fibers Systems
P.O. Box 2200
Streetsville Postal Station
7070 Mississauga Road
Mississauga, Ontario L5M 2H3
Tel.: (905) 821-5193

H-XXXXX 2/99

DUPONT

Kevlar®

Only by DuPont