

The role of environmental stress cracking (ESC) in the life expectancy of electronic devices

How ESC impacts device performance, longevity, and customer satisfaction

With the increased miniaturization and portability of medical devices and consumer electronics comes an increased need for a combination of impact strength and chemical resistance.

- In the medical environment, chemical threats include aggressive disinfection to prevent healthcare-associated infections (HAIs).
- In consumer electronics, challenges come from prolonged exposure to liquid chemical agents such as sweat, body oils, sunscreen, and cleaning products.

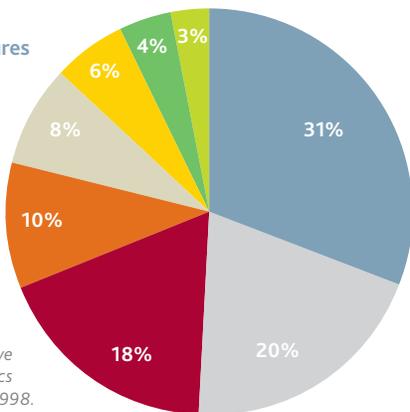
The combination of stress and chemical exposure can result in environmental stress cracking (ESC), which can lead to premature part failure related to:

- Loss of flexibility and impact strength
- Cracking and cracking
- Discoloration, hazing, and surface chalking
- Loss of desired finish

Table 1— What makes plastic parts fail?

Analysis of 5,000 part failures

- ESC—31%
- Dynamic fatigue—20%
- Static notch fracture—18%
- Creep/relaxation—10%
- Chemical attack—8%
- UV attack—6%
- Heat degradation—4%
- Wear/abrasion—3%



SOURCE: Polypropylene Definitive User's Guide and Databook. Plastics Design Library. New York, U.S.A. 1998.

Electronic device housings and other components made with polymers that have improved ESC resistance can extend product life and contribute to many aspects of perceived quality enhancements and elevated customer satisfaction. (See consumer review examples on page 2.)

See inside ...

- ➔ Predicting the ESCR (ESC resistance) of polymers
- ➔ How customer reviews talk about ESC
- ➔ Reducing ESC with disinfectant-ready polymers
- ➔ Comparing the fitness of polymers used in electronic devices

ESC—the major contributor to plastic parts failure

For years, ESC has been one of the most common causes of unexpected brittle failure of thermoplastic polymers. In a respected analysis of 5,000 plastic part failures, ESC was identified as the major contributing cause in 31% of the cases. If you add the 8% attributed to the closely related "Chemical attack," the total is nearly 40%.

ESC is often difficult to isolate because it varies drastically based on applications and use environments—and it manifests later in the product life cycle. It is often difficult to predict what kind of chemical exposure a product will experience. Portable and wearable devices tend to be at higher risk for stress cracking due to the environments they are exposed to and the levels of stress they experience in typical use. These applications are prime candidates for materials that demonstrate a high level of chemical resistance.

What is ESC?

- Environmental stress cracking occurs when a plastic resin is exposed to a specific chemical agent and stress—the combination results in crazing, cracking, and eventual part failure.
- Technically, it is not a chemical reaction—the agent does not cause direct chemical attack or molecular degradation. Instead, the liquid chemical penetrates the molecular structure, interfering with the binding of polymer chains and accelerating the process of macroscopic brittle-crack formation.^{1,2}
- ESC steps are similar to those responsible for creep failure and include fluid absorption, plasticization, craze initiation (crazing precedes cracking), crack growth, and finally, fracture.²

¹ Andersen B, *Investigations of Environmental Stress Cracking Resistance of LDPE/EVA Blends [dissertation]*. Halle (Saale), Germany: Martin-Luther-Universität; 2004, p. 11-17. Available at: <https://sundoc.bibliothek.uni-halle.de/diss-online/04/04H140/prom.pdf>. Accessed Sept. 18, 2018.

² Jansen J; *Environmental Stress Cracking—the plastic killer*. *Advanced Materials & Processes*, June 2004, p 50-53. Available at: <https://pdfs.semanticscholar.org/ebde/1e236ba4ddc-53bcc01e57a6dd28a4809a58f.pdf>. Accessed Sept. 18, 2018.

How customer reviews talk about ESC

In the consumer electronics market, online customer reviews provide a platform for consumers to freely share opinions of products such as headphones—and strongly influence the perceptions of a manufacturer's company and brand values.

Eastman recently applied proprietary CORA software to evaluate online reviews for 134 consumer electronics products across 18 product segments. In Amazon reviews related to headphones, consumers often presented ESC symptoms in terms of broken plastic. Here are the most common customer review topics in negative reviews (1 to 3 stars):

- Plastic breaking
- Sound quality
- Comfort
- Noise cancellation
- Earbud issues

No brand was immune from these reviews. Some of the most popular products on the market had a high percentage of negative reviews with mention of plastic breaking.

One big takeaway: Even the most advanced technological features can be undermined by materials that aren't matched to the application and the use environment.

Predicting the ESCR of polymers

While many factors are involved in ESC, three application factors can be predictive:

- The properties of the polymer
- The chemical(s) contacting the part
- The stress applied to the part

One simple **4-step** test is becoming a respected protocol in medical and other markets. It provides a good predictor of ESC—and can be inexpensively conducted without sophisticated testing equipment.

1. Select the appropriate jig that provides the appropriate strain level for the application factors.
2. Load flex bars molded from the candidate polymers onto the jig. Include nonexposed flex bars as a control for calculations in Step 4.
3. Apply chemicals (lipids, lotions, cleaners, adhesives, etc.) to the flex bars using presoaked pieces of cotton. Enclose the sample jig in a plastic bag and leave at room temperature for 24 hours. Look for crazing and cracking when the samples are removed.
4. Perform reverse side impact testing—applying the force on the reverse side of the crazing/cracking—and calculate the percent retention of properties (comparing exposed bars to nonexposed controls).

Reducing ESC with disinfectant-ready polymers

Clorox Healthcare® is a leader in testing the compatibility of its disinfectants with different surfaces.

Using the 4-step test, Clorox has also collaborated with Eastman to test compatibility with leading polymers used in medical devices and electronic housings.

Clorox now recommends the 4-step test as a practical and cost-effective in-house protocol that can help identify disinfectant-ready polymers.

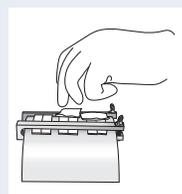
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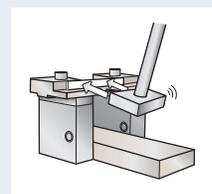
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3.



4.



Comparing the fitness of polymers used in electronic devices

Tables 2 and 3 compare the ability of popular polymers to withstand exposure to certain household agents and medical

disinfectants. By quantifying chemical resistance and impact strength, these results can help identify which polymers offer the greatest ESCR for a specific application.

Table 2—Chemical resistance of Eastman Tritan™ copolyester and Eastman Trēva™ engineering bioplastic after exposure to key chemicals of concern

	Chemical	% Retention in impact energy					
		Tritan TX1001	Tritan TX1501HF	Trēva GC6021	PC	PC/ABS	ABS
Human interface	Sebum (skin oil)	●	●	●	◐	◑	◑
	Artificial sweat	●	●	●	●	●	●
	Mayonnaise	●	◐	●	◐	◑	◑
Cleaners	70% IPA	●	●	●	●	◑	◑
	Formula 409® cleaner	●	●	●	◐	◑	◑
	Windex®	●	●	●	◐	◑	◑
	Acetone	◐	◐	◐	◑	◑	◑
	Purell® Hand Sanitizer	●	●	●	●	●	◑
Laundry	Tide® Original Powder	●	●	●	◐	◑	◑
Outdoor	Banana Boat® SPF 100	◑	◑	●	●	◑	◑
	40% DEET	◑	◑	◐	◑	◑	◑

Based on reverse-side impact test method after 24 hours strain exposure

- 80% to 100% property retention
- ◐ 60% to 80%
- ◑ 30% to 60%
- ◒ 0% to 30%

Table 3—4-step test results—retention of impact energy

Materials	Control (joules)	Disinfectants						
		Diversey Virex® TB (ether, benzyl quat)	Clorox Healthcare® Bleach Germicidal Wipes (germicidal hypochlorite)	Clorox Healthcare® Multi-Surface (IPA quat)	Clorox Healthcare® Hydrogen Peroxide (H ₂ O ₂ cleaner)	PDI Sani-Cloth® AFIII (benzyl quat, DPG ether)	PDI Super Sani-Cloth® (IPA quat)	PDI Sani-Cloth® Plus (IPA benzyl quat)
% Retention in impact energy to break								
Eastman Tritan™ MX711 copolyester	4.3	75 ± 26	89 ± 1	92 ± 4	95 ± 5	109 ± 3	101 ± 3	114 ± 1
Eastman Tritan™ MX731 copolyester	4.3	65 ± 24	96 ± 5	98 ± 5	99 ± 5	104 ± 2	100 ± 2	116 ± 1
Eastman MXF221 copolyester	5.2	94 ± 2	95 ± 2	92 ± 3	98 ± 1	93 ± 4	83 ± 1	96 ± 3
PC/PBT	5.3	8 ± 3	98 ± 2	57 ± 45	94 ± 2	9 ± 2	91 ± 8	16 ± 2
PC/polyester	5.5	6 ± 1	6 ± 2	91 ± 12	23 ± 1	5 ± 0	75 ± 28	8 ± 2
PC/ABS 1	6.8	15 ± 1	70 ± 21	84 ± 13	97 ± 2	20 ± 3	16 ± 1	71 ± 22
PC/ABS 2	6.6	Break on jig	102 ± 1	64 ± 21	69 ± 32	6 ± 1	42 ± 37	5 ± 0
PVC	4.5	19 ± 2	19 ± 0	45 ± 36	56 ± 32	46 ± 36	18 ± 2	100 ± 0

% Retention

- ≥ 80%
- ≥ 60%
- < 60%

For additional information on applications and testing,
contact Rick Noller, rnoller@eastman.com.

Test results show that Eastman Tritan™ copolyesters offer overall high chemical resistance and retain a high level of their original impact strength. In addition to providing improved ESCR, Tritan offers these benefits for headphone parts:

- Excellent tintability and retention of color and gloss
- Made without bisphenol A (BPA), other bisphenols, styrenics, halogens, or any of the 900+ materials of concern¹ on the California Proposition 65 (Prop 65) list
- Excellent compatibility with bonding and other secondary operations, including decorations, printing, painting, overmolding, labels, and decals
- Low processing temperatures to reduce the risk of warped parts label damage, or ink washout
- Well-suited to overmolding techniques that can add grippy "soft-touch" textures and other user-friendly sources of comfort and functionality
- Helps reduce waste, energy consumption, and greenhouse gas (GHG) emissions.

¹ E Watson, "Amended Prop 65 regulations likely to prompt a significant uptick in litigation, predict attorneys". Food Navigator-USA.com website, 31 August 2018. Find at: https://www.foodnavigator-usa.com/Article/2018/09/01/Amended-Prop-65-regulations-likely-to-prompt-a-significant-uptick-in-litigation-predict-attorneys?utm_source=newsletter_daily&utm_medium=email&utm_campaign=04-Sep2018&c=WB6VMRCy9nWqQ3bbTv1uA%3D%3D&p2. Accessed Sept. 18, 2018.

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