Opening up the low-toxicity future of crosslinking.

A breakthrough polymeric aziridine is making waves in the coatings industry.

NeoAdd® PAX

WHITEPAPER

covestro

Half the labeling, all the performance

In line with its strong purpose-led outlook, Covestro is committed to delivering sustainable solutions that are good for people and planet. Now, it has developed a game-changing polymeric aziridine crosslinker that eliminates the long-term health hazards of traditional aziridines, but with better functional performance than carbodiimides – opening up new horizons for paints and coatings.

With our world facing a series of interconnected environmental challenges, companies from across the chemicals industry are seeking to improve the impact of their product portfolios. In the paint and coatings industry in particular, crosslinkers are being singled out for their toxicity profiles – a result of the high reactivity that enables them to deliver strong functional performance. Traditionally, carbodiimides have been used as a low-toxicity alternative to aziridine crosslinkers. But any paint or ink manufacturer will know that carbodiimides too often fail to deliver on functional performance properties such as reactivity and chemical resistance. The paint and coatings industry has long searched for a new crosslinking solution – one that can deliver both low toxicity and high performance.

More sustainable solutions

Covestro works to develop more innovative solutions that meet the needs of the paint and coatings market. With a strong track record for delivering more sustainable solutions that compete with or outperform their conventional alternatives.

Driven by this approach and by industry need, we recently developed a world-first low-toxicity polymeric aziridine crosslinker family for waterborne coating systems: **NeoAdd® PAX**. Developed by a dedicated team of experts who drew on our global scientific capabilities, the unique patented technology of **NeoAdd® PAX**. delivers the best of both worlds. As a polymeric aziridine, it enables paint manufacturers, ink formulators, and converters to retain all the high-reactivity performance benefits of traditional aziridine crosslinkers, but thanks to its higher molecular weight and customized chemical structure, it exhibits much lower toxicity levels.

Non-genotoxic crosslinking

This lower toxicity allows converters, ink formulators, and paint manufacturers from a wide range of industries to work with materials that provide good performance at lower risk to operators. Indeed, **NeoAdd® PAX** requires only two safety labels, one of which applies to the solvent it is dissolved in, rather than the polymeric aziridine itself. This puts it on a similar labeling level to most carbodiimides – opening new high-performance application possibilities for formulators around the world, especially in the highly regulated food packaging industry.

Of course, the lower toxicity levels of **NeoAdd® PAX** also make it better for the environment than traditional aziridines. Genotoxicity in these crosslinkers has long threatened not only human health, but also the wider environment. Our new crosslinker is non-mutagenic and non-genotoxic – passing both the AMES and ToxTracker™ tests for these respective properties – which eliminates such concerns. As well as keeping chemical handlers safer, this means it requires less protective equipment and eliminates toxic waste, causing less environmental damage.

No-compromise functional performance

Unlike with carbodiimide crosslinkers – the traditional alternative to aziridines – the lower toxicity of **NeoAdd® PAX** doesn't compromise its functional performance. As a polymeric aziridine, our new crosslinker offers all the established performance benefits of aziridine chemistry. In particular, it delivers key functional performance advantages compared to most carbodiimide-based waterborne coating systems – most importantly, higher reactivity and higher chemical resistance at lower dosing levels.

These aren't the only functional performance benefits of **NeoAdd® PAX**. It also enables excellent water, scuff, and abrasion resistance. What's more, it delivers good adhesion on a wide range of substrates, especially treated plastic packaging films – even outperforming traditional aziridines in some cases. It can also function as an adhesion promotor when added to other coatings, making it suitable for substrates including industrial wood, metal, fabric, and leather.

A big bonus for processability

Beyond its functional performance, **NeoAdd® PAX** also offers several benefits for processability and application. For instance, unlike carbodiimides, which are typically cured at 176° F (80° C), **NeoAdd® PAX** can be cured at room temperature. This eliminates the need for stoving ovens, enabling formulators to improve processing efficiency and save money, time, and energy. And of course, eliminating stoving also reduces energy consumption and carbon emissions – another way **NeoAdd® PAX** enables greater sustainability.

This new crosslinker also offers significant advantages for flexible and reliable application. In particular, because of its special chemical properties and high levels of stability in water, its pot life can be several days long – compared with the typical 12 hours for traditional aziridines – depending on the characteristics of the coating system used. In this way, **NeoAdd® PAX** can improve product reliability and allow manufacturers to reduce product waste, enabling greater efficiency during application.

Putting NeoAdd® PAX to the test

But how well does **NeoAdd® PAX** perform in practice? Recently, we tested its performance in several areas against benchmark traditional aziridine crosslinker CX-100 and carbodiimide crosslinker CX-300. First, we tested crosslinking efficiency. Using dynamic mechanical thermal analysis (DMTA), we measured the elastic modulus of a fully cured model acrylic binder as temperatures increased, with each of the three different crosslinkers. Above glass transition temperature, elastic modulus can be used to measure crosslinking efficiency.

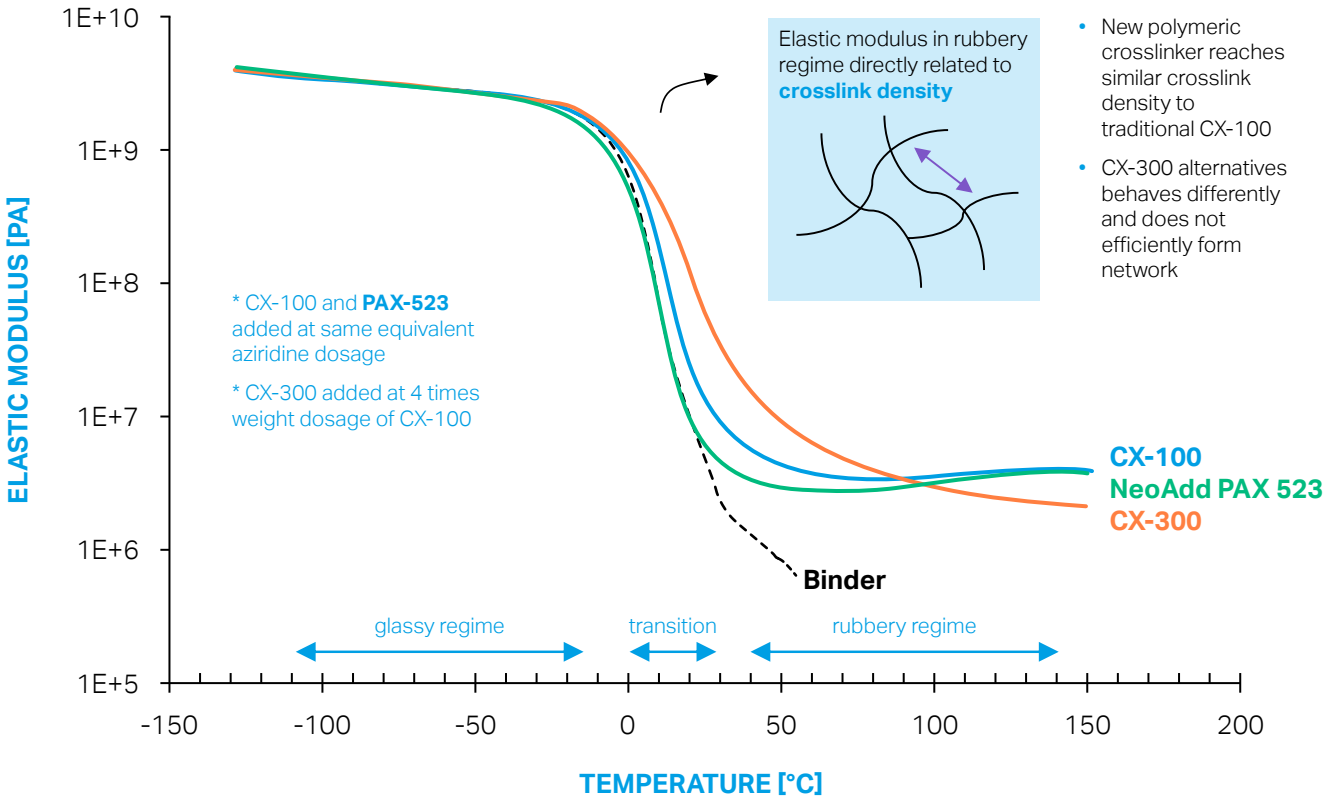
As shown in the graph below, **NeoAdd® PAX-523** reached a similar plateau elastic modulus to CX-100, demonstrating comparable crosslinking efficiency. The carbodiimide CX-300 crosslinker did not reach a well-defined plateau modulus at all, suggesting that its crosslinking mechanism is different and that it does not form an effective crosslinked network.

Secondly, we tested the reaction kinetics of **NeoAdd® PAX-523** compared with CX-100, at both 50° C and room temperature. As the graphs show, at 50° C, **NeoAdd® PAX-523** demonstrated faster reaction kinetics than CX-100. Similar results were obtained at room temperature: the reaction kinetics of both crosslinkers were logically slower than at 50° C, but **NeoAdd® PAX-523** still displayed faster reaction kinetics than CX-100, and both crosslinkers reached similar final crosslinking efficiencies compared with the test at 50° C. These results also suggest that **NeoAdd® PAX-523** transfers its properties to the acrylic binder more quickly than CX-100, which could enable potential shorter processing times for formulators.

We also tested **NeoAdd® PAX-523** for chemical resistance in flooring applications compared with CX-100 and CX-300, using the realistic required proportions of each crosslinker and scoring chemical resistance from 1 to 5. As shown in the table, **NeoAdd® PAX** achieved a perfect score for almost every substance – comparable performance to CX-100 and far better than CX-300.

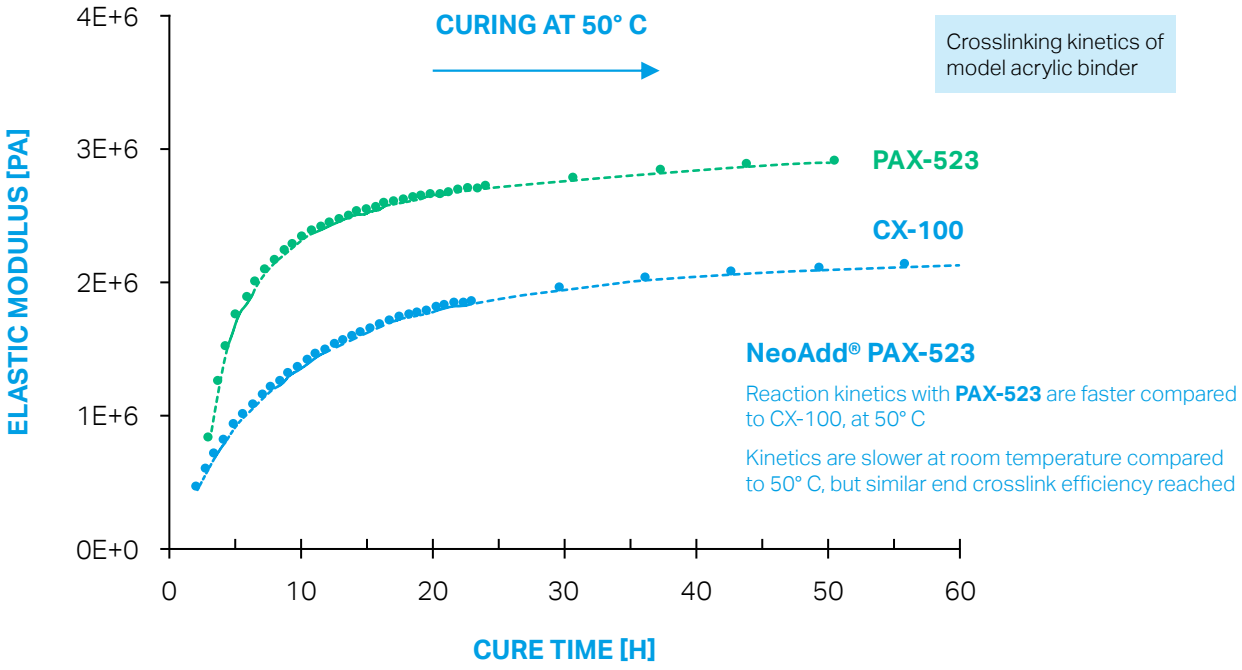
We then tested **NeoAdd® PAX**'s mechanical resistance properties compared with CX-100 and CX-300, again using realistic proportions of each crosslinker. As the table shows, **NeoAdd® PAX**'s König hardness after seven days was the same as CX-100's and outperformed CX-300's. Its total score for black heel mark resistance (BHMR) far outperformed CX-300's, and all three crosslinkers scored the same for nail scratch resistance.

Crosslinking efficiency



- New polymeric crosslinker reaches similar crosslink density to traditional CX-100
- CX-300 alternatives behaves differently and does not efficiently form network

Reaction kinetics of **NeoAdd® PAX** at 50° C

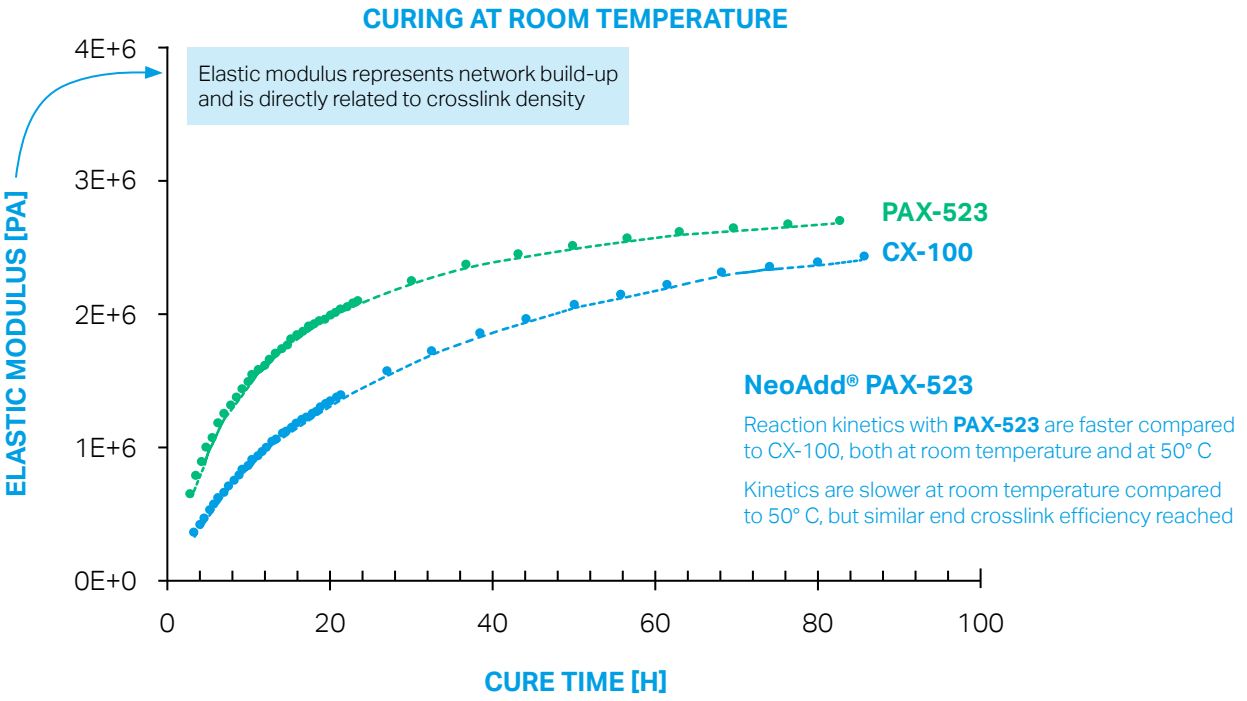


NeoAdd® PAX-523

Reaction kinetics with **PAX-523** are faster compared to CX-100, at 50° C

Kinetics are slower at room temperature compared to 50° C, but similar end crosslink efficiency reached

Reaction kinetics of **NeoAdd® PAX** at room temperature



With these strong results backing up its benefits for safety, sustainability, and performance, **NeoAdd® PAX** is set to open up a world of new possibilities for waterborne coatings. But for Covestro, this is only the beginning. Indeed, we strive to continue developing crosslinking solutions that meet the evolving needs of our customers and end-users, together with partners from across the value chain.

Specifically, over the coming months we plan to add new products to the **NeoAdd®** family that deliver even higher functional performance standards.

Formula based on % crosslinker (w/w) Crosslinker		**R-2180** 0 **blank**	**R-2180** 2 **CX-100**	**R-2180** 6 **CX-300**	**R-2180** 6 **PAX-523**
Dry properties: Chemical resistances (oak)					
Water: 16h	recovery	5	5	5	5
Ethanol, 48%: 1h	recovery	2	5	4	5
Coffee: 16h	recovery	3	4	1	3
Tea: 16h	recovery	5	5	4	5
Andy detergent: 16h	recovery	5	5	5	5
Dreft detergent: 16h	recovery	5	5	5	5
Ammonia, 10%: 2m	recovery	4	5	5	5
Ammonia, 10%: 10m	recovery	3	5	3	5
Ammonia, 10%: 1h	recovery	2	5	3	5
Acetic acid, 10%: 1h	recovery	5	5	5	5
	Total	**39**	**49**	**40**	**48**

Formula based on % crosslinker (w/w) Crosslinker		XK-12 0 blank	XK-12 2 CX-100	XK-12 6 XK-300	XK-12 6 NGX
Dry properties: König hardness					
1 Day RT (s)		88	69	85	88
7 Days RT (s)		120	112	123	112
Dry properties: BHMR					
Test chart: 1 day RT	black marking	1	2	1	2
Test chart: 7 days RT	black marking	0	3	0	3
Test chart: 1 day RT	damage	1	4	1	2
Test chart: 7 days RT	damage	0	4	0	3
oak: 7 days RT	black marking	1	4	1	3
oak: 7 days RT	damage	1	5	1	5
Dry properties: Mechanical		4	22	4	18
Nail scratch resistance		1	2	2	2

Finally, we tested **NeoAdd® PAX** for hardness and staining resistance in industrial wood furniture applications compared with CX-100 and CX-300, using realistic proportions of each crosslinker and scoring staining resistance from 1 to 5. As shown in the table below, **NeoAdd® PAX** outperformed CX-300 for hardness. Its staining resistance score was perfect for all substances – matching CX-100's and outperforming CX-300's.

Overall, these tests show **NeoAdd® PAX** delivering comparable performance to a traditional aziridine and outperforming a carbodiimide crosslinker for crosslinking efficiency and resistance properties, as well as outperforming a traditional aziridine for reaction kinetics.

Formula based on XK-117 Crosslinker amount 16h 50° C and 3-week drying RT	XK-117 0 blank	XK-117 2% CX-100	XK-117 4% CX-300	XK-117 4% PAX-523
Hardness	71	98	78	83
Staining resistances				
R2 Water: 24h	1	5	3	5
CR2 Ethanol, 48%: 1h	1	5	1	5
R2 Coffee: 1h	4	5	5	5
1B Coffee: 16h	3	5	5	5
1B Red wine: 6h	1	5	5	5
Total	**10**	**25**	**19**	**25**

A brighter future ahead

With these strong results backing up its benefits for safety, sustainability, and performance, **NeoAdd® PAX** is set to open up a world of new possibilities for waterborne coatings. But for Covestro, this is only the beginning. Indeed, we strive to continue developing crosslinking solutions that meet the evolving needs of our customers and end-users, together with partners from across the value chain.

Specifically, over the coming months we plan to add new products to the **NeoAdd®** family that deliver even higher functional performance standards. And ultimately, we hope that these crosslinkers will become the industry standard. As such, **NeoAdd® PAX** should help enable a brighter future, where sustainability, safety, and long-lasting functional performance are all possible.

Edition: August 2021 · Printed in Germany

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