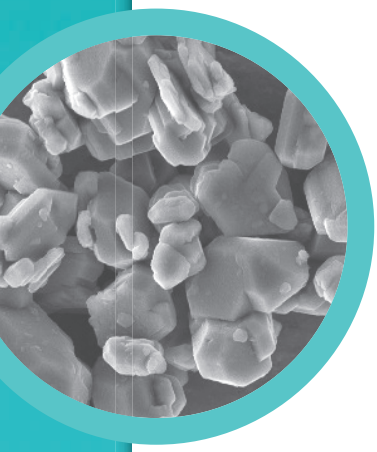
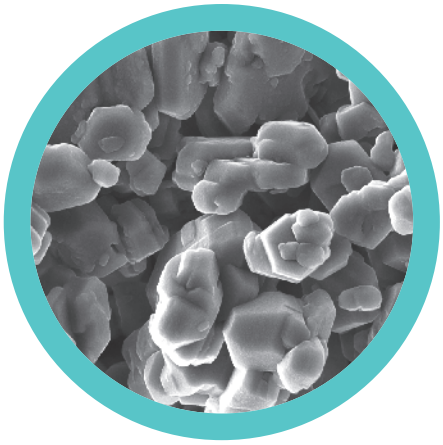
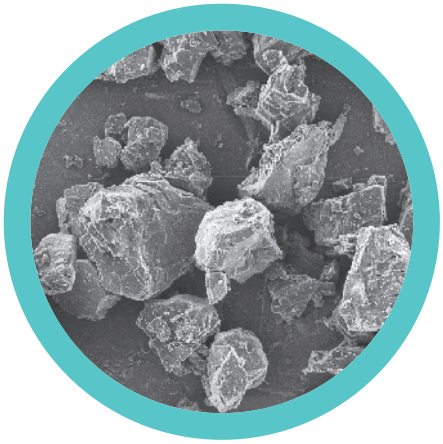
Nabaltec







Products & Applications

APYRAL®
Aluminum Hydroxide (ATH)

APYRAL®
made by Naprotec LLC –
Chattanooga, TN

Who is Naprotec LLC?

Naprotec LLC is a manufacturing entity located in Chattanooga, TN and is structured within the Nabaltec USA Corporation. Nabaltec USA operations also includes Nashtec LLC in Corpus Christi, TX. Nabaltec USA is 100 % owned by Nabaltec AG headquartered in Schwandorf, Germany.
Nabaltec AG is a global leader in the development and manufacture of highly specialized products based on aluminum hydroxide (also referred to as ATH, hydrated alumina or aluminum trihydrate) and aluminum oxide. The company's product range includes halogen free flame retardant fillers / extenders as well as specialty oxides for use in technical ceramics and the refractory industry.
Naprotec LLC was established in June 2018 in Chattanooga, TN which features an active rail siding (for bulk deliveries and shipments) and close proximity to the Tennessee River (for incoming shipments of raw material).

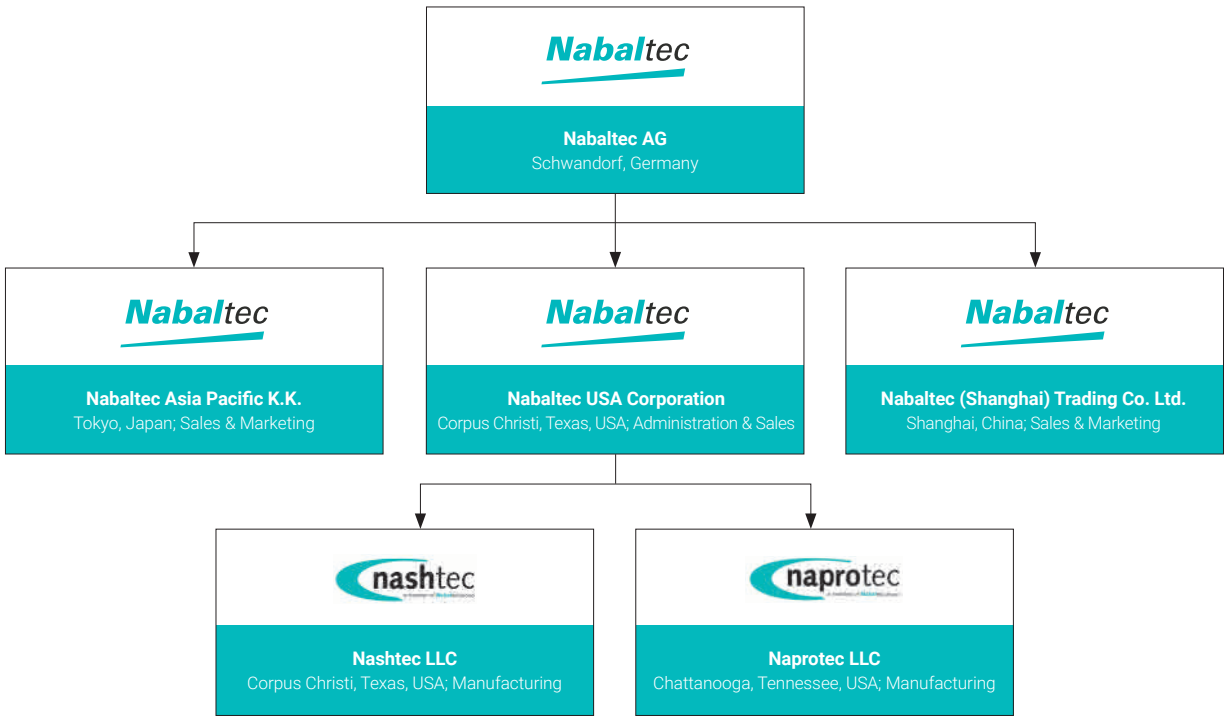
The large capacity Naprotec plant produces a wide variety of ground grades of ATH, surface treated ATH as well as viscosity optimized ATH based products.

Nabaltec Group

Nabaltec AG, Schwandorf, Germany
Ground, viscosity optimized, fine precipitated ATH, Specialty Alumina

nashtec LLC, Corpus Christi, TX
Fine precipitated ATH, Apyral 40CD

naprotec LLC, Chattanooga, TN
Ground, viscosity optimized, surface treated ATH and North American Distribution Center

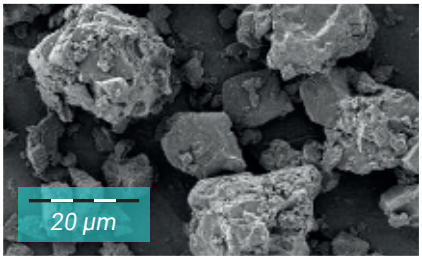


Naprotec APYRAL® product range

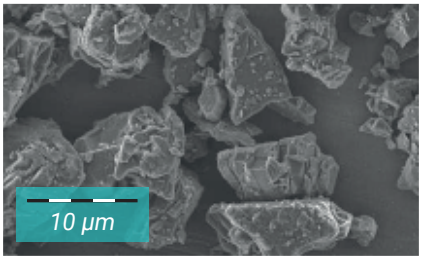
		Standard Grades APYRAL®						Viscosity Optimized APYRAL®				
ANALYSIS	**UNIT**	**410**	**413**	**414**	**418**	**420**	**440**	**411 XLV**	**425 XLV**	**460 XLV**	**475 XLV**	**499 XLV**
$Al(OH)_3$	%	99.6	99.6	99.6	99.6	99.6	99.6	99.6	99.6	99.6	99.6	99.6
Na_2O (water soluble)	%	0.05	0.04	0.03	0.04	0.04	0.05	0.04	0.03	0.03	0.03	0.03
Moisture (105 °C)	%	0.02	0.05	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.2
D50 (CILAS*)	µm	28	18	15	11	9	3.9	2.7	3	11	8	10
D50 (Microtrac)**	µm	38	25	21	15	12	5.3	3.5	6	16	16	28
Sieve residue (>45 µm / on 325 mesh)	%	36	11	6	0.3	0.1	0.01	0.03	0.03	15	30	44
Spec. surface area (BET)	m^2/g	0.9	1.2	1.1	1.6	1.8	2.8	2.9	2.2	1.6	1.5	1.4
Oil absorption***	ml/100g	18	19	19	20	21	24	17	15	13	12	11
Bulk density loose **Bulk density packed**	g/cm^3	0.93 1.1	0.9 1.0	0.83 1.0	0.70 0.83	0.65 0.75	0.58 0.7	0.55 0.65	0.6 0.7	0.7 0.85	0.7 0.85	0.73 0.9
Tappi brightness (457 nm)	no unit	80	83	83	85	85	88	90	89	86	86	87

** Median particle diameter by laser granulometry (CILAS 1064)*
*** Median particle diameter by laser granulometry (Microtrac 3500)*
**** Oleic acid*

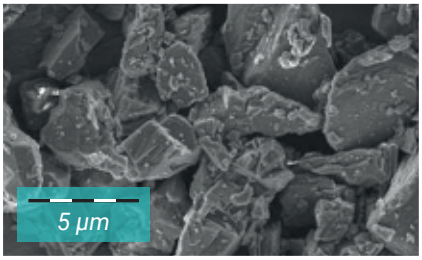
With its state-of-the-art production processes, Nabaltec AG offers ATH grades, where different characteristics concerning fineness, particle size, particle size distribution and morphology are optimized for various processes in a wide range of applications. The table above shows the most important typical values of the **APYRAL®** grades manufactured at Naprotec LLC, TN, enabling the formulator to choose the right products for the desired application.



SEM image of **APYRAL® 413**



SEM image of **APYRAL® 420**



SEM image of **APYRAL® 440**

Suggested Naprotec products for common applications

	Standard Grades APYRAL®						Viscosity Optimized APYRAL®				
Application \ APYRAL®	410	413	414	418	420	440	411 XLV	425 XLV	460 XLV	475 XLV	499 XLV
Abrasives						•					
Adhesives	•		•	•	•				•	•	•
Bitumen Roofing					•						
Carpet Backing	•										
Cast Acrylic Sheeting			•					•			
Caulks & Sealants				•	•			•	•	•	
Ceramics			•		•						
Coatings / Inks / Paint				•	•	•	•	•	•		
Cured In Place Pipe (CIPP)					•		•	•			
FRP Applications											
- Contact Molding (hand lay up / spray up)		•	•	•	•			•	•	•	•
- Continuous Panels			•	•	•		•	•	•		
- Electrical Laminates			•		•	•	•	•	•		
- Filament Winding			•		•	•	•	•	•		
- Pultrusion		•	•	•	•		•	•	•		
- Resin Transfer Molding (RTM) / Infusion				•	•	•	•	•	•		
- SMC / BMC / TMC		•	•	•	•	•	•	•	•	•	•
Gel Coats						•	•	•			
Injection Molding					•	•	•	•			
Mine Belts				•	•			•			
Phenolic Molding			•		•			•		•	
Polyurethane Foam					•	•	•	•			
Potting & Encapsulating	•	•	•	•	•	•	•	•	•	•	•
Powder Coatings					•	•	•	•			
Preform		•	•	•	•			•	•	•	
Roof Coating (acrylic trowel on)				•	•	•	•	•	•		
Rubber					•		•	•			
Silicone Elastomers		•			•	•	•	•	•		
Tooling	•	•		•	•			•		•	•
Wall Coverings (PVC)						•	•	•			

The table gives a general indication which **APYRAL®** grade should be used in a specific application. Some **APYRAL®** types can be used in more than one application. In contrast some **APYRAL®** types are especially tailored for special applications. To achieve the most optimal performance of the flame retarded compound system for each customer, the correct choice of **APYRAL®** for each application is important.

Physical properties of ATH & thermal decomposition reaction

ATH is safe and as a result no special precautions need to be taken during the processing or use of this product. Due to its inherent safety and relatively low cost ATH remains the largest volume flame retardant used in the world today. Today's emphasis on reducing or eliminating smoke generating halogenated flame retardants (bromine and chlorine) and antimony synergists has certainly helped to promote the demand for quality ATH products. ATH is essentially a functional filler and / or extender of thermoplastics and other material formulations including but not limited to thermoset and thermoplastic compounds.

It is less expensive on a volume basis than the plastics it is compounded into so the cost/volume-ratio of the compound is reduced.

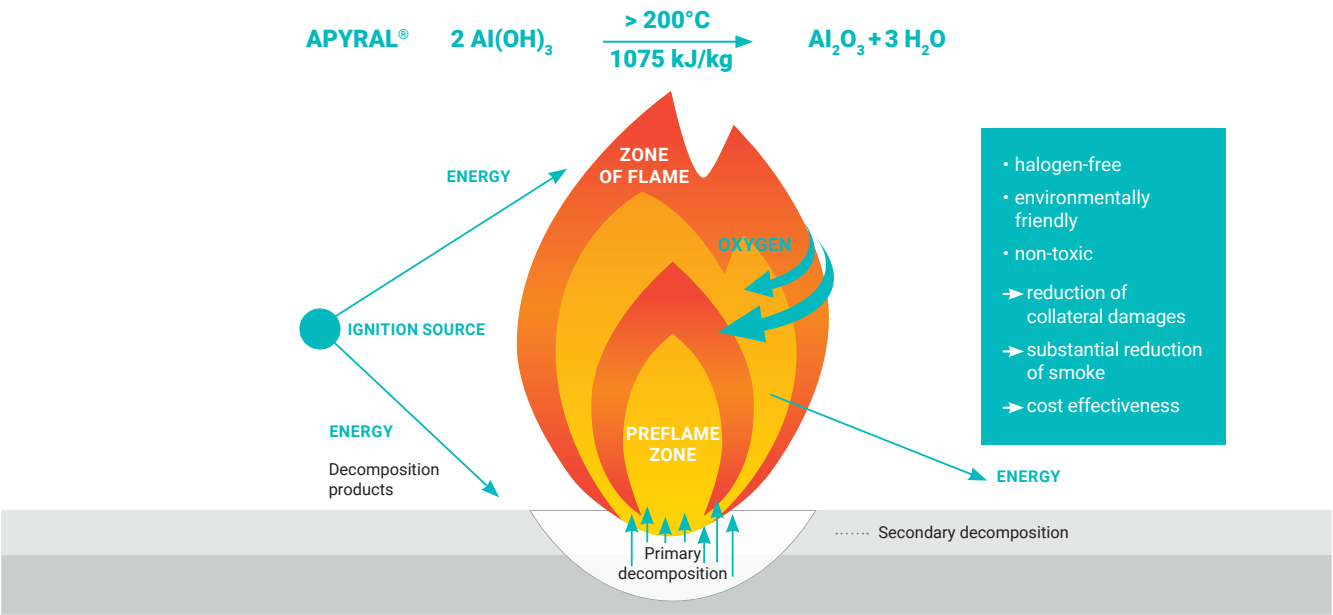
How does ATH work?

ATH or aluminum hydroxide has the chemical formula $Al(OH)_3$. When exposed to high heat ATH decomposes endothermically at approx. 392 °F (200 °C) giving off approx. 35 % of its weight in chemically combined water.

These water molecules help to reduce flame spread and smoke generation by taking away heat from the flame source, diluting volatile and potentially toxic decomposition products and forming a protective metal oxide layer on the surface of the flaming polymer.

Aluminum hydroxide is non-toxic, halogen free, chemically inert and has low abrasiveness. Additional benefits include arc track resistance, thermal conductivity, acid resistance and smoke suppression.

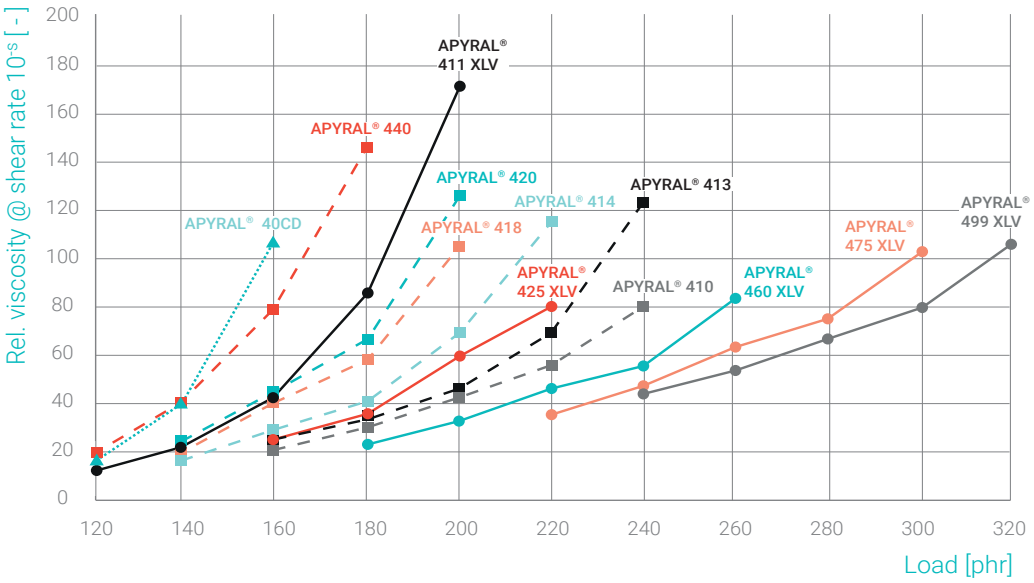
APYRAL®	$Al(OH)_3$
Chemical	Aluminum hydroxide
Mineral	Gibbsite (Hydragillite)
Common name	Aluminum trihydrate (ATH)
Loss on ignition	34.6 %
Density	2.4 g/cm³
Mohs hardness	3
pH	8 – 9
Refractive index	1.58
Decomposition temperature	200 °C / 392 °F
Heat of decomposition	1075 kJ/kg
Particle morphology	Hexagonal platelet
Physical form	White powder



Scheme of the processes involved during burning of an **APYRAL®** *filled polymer and the thermal decomposition reaction of ATH.*


TOYOTA

Rheological Properties of APYRAL®



Comparison of the increase in viscosity of a UP resin filled with various ***APYRAL®*** *types at 23 °C (rel. viscosity = ratio of the viscosities of resin with fillers to resin without fillers; UP resin: Palapreg P17-02, AOC. Initial viscosity approx. 1800 mPa*s, shear rate 10 1/s; no use of any additives).*

One of the most important physical parameters in using mineral flame retardants is the influence of the filler on the viscosity of the resin formulation. Generally, by the addition of fillers a significant increase of the viscosity occurs.

Basically viscosity is a function of the particle size. Usually finer grades exhibit a clearly higher viscosity than coarser grades. Very fine grades of **APYRAL®** lead to a strong viscosity increase at relatively low filler loadings, e.g. precipitated **APYRAL® 40CD** (manufactured by Nabaltec AG and Nashtec LLC). Standard types with particle sizes between 4 µm (**APYRAL® 440**) to 25 µm (**APYRAL® 410**) lead to medium viscosity levels and enable a wide range of applications.

But the viscosity is not solely dependent on the mean particle size, in fact it is a function of the particle size distribution, the specific BET surface area, and the morphology of the particles.

These effects are utilized in the range of viscosity optimized **APYRAL® XLV** grades. These products represent relatively broad particle size distributions with optimized packing densities and outstanding low viscosities in relation to their particle sizes. This enables the user to obtain formulations with extremely low viscosity and / or very high filling levels.

Since the width of the particle size distribution plays a very important role, these values are given on the technical data sheets of **APYRAL®**. Next to the parameters of the average grain size (D50) as well the D90 is given. This describes the coarse fraction in the particle size distribution. The significance of all these powder data for the viscosity is represented in the illustration above.

It is also important to mention that the viscosity is not a one-dimensional parameter, but next to the temperature it depends also on the shear rate.

Shear rate by different processes

Process	Shear rate [1/s]
Sedimentation	< 0.0001 – 0.01
Leveling	0.01 – 0.1
Sagging	0.01 – 1
Grouting / pouring	1 – 10
Coating by dipping	1 – 100
Tube flow, pumping, filling	1 – 1,000
Mixing, stirring	10 – 10,000
Coloring, painting, brushing	100 – 10,000
Spraying	1,000 – 10,000

A further important aspect is the sedimentation of the fillers, which is a complex function of the particle size, the particle size distribution, the filling level and the viscosity of the resin mixture. The sedimentation generally increases with increasing particle size, but decreases with increasing filler loading and viscosity.

APYRAL® HC Grades – for high Thermal Conductivity

ANALYSIS	UNIT	APYRAL® HC 500	APYRAL® HC 600	APYRAL® HC 700	APYRAL® HC 800
$Al(OH)_3$	%	99.5	99.5	99.5	99.5
Na_2O (water soluble)	%	0.02	0.02	0.02	0.02
Moisture*	%	0.1	0.1	0.15	0.15
D_{10}**	µm	1	1	1.5	1
D_{50}**	µm	30	18	20	5
D_{90}**	µm	110	66	55	23
Spec. surface area (BET)	m^2/g	1.3	1.5	1.8	2.5
Oil absorption***	ml/100g	11	12	13	16
MOHS hardness	-	3	3	3	3

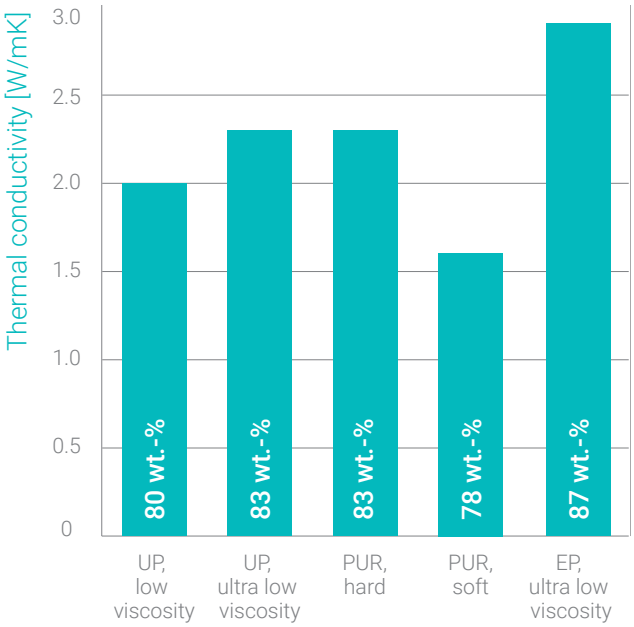
** 105 °C* *** Laser-Granulometer Microtrac S3500* **** Oleic acid*

APYRAL® HC grades have been designed for thermal conductivity (TC) applications. They combine the lowest viscosity and highest filler loadings possible with high thermal conductivity at low density and practically no abrasion to tools.

The outstanding viscosity performance of **APYRAL® HC 500** allow extremely filler loadings up to 87 wt.-%. With its low Density of 2.42 g/ml this results in volume based filler loads up to 77 vol.-%! Depending on the resin in use, TC levels up to 3 W/mK have been achieved. Even higher levels can be obtained when combining **APYRAL® HC** with other thermal conductive fillers like, boron nitride (BN), zinc oxide (ZnO), magnesia (MgO), and spherical alumina (Al_2O_3).

APYRAL® HC:
Recommended for thermal conductive

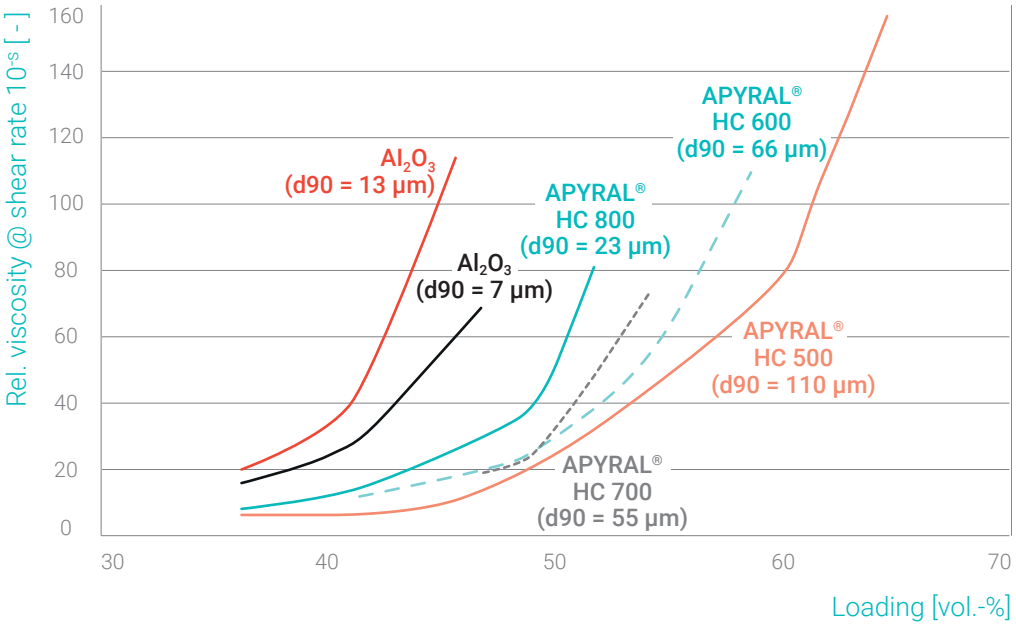
- Gap fillers
- Adhesives / PSA
- Thermal Interface Materials (TIM)
- Tapes
- Thin films



Thermal conductivity of selected resins due to high filling levels of **APYRAL® HC500**.

APYRAL® HC 500 & **600** are designed for highest loadings and TC levels, while **APYRAL® HC 700** & **800** have finer particle size for thinner applications, e.g. thin thermal management materials (TIM).

APYRAL® HC grades are globally available, not only by Naprotec LLC, USA but also from Nabaltec AG, Germany. This ensures global supply and double sourcing if necessary.



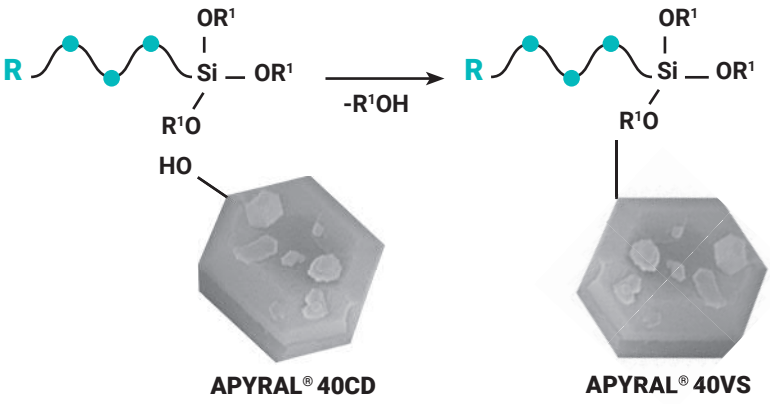
Viscosity in Polyol (Caradol ET 34-08, Shell; 22 °C, shear 10^{-s})

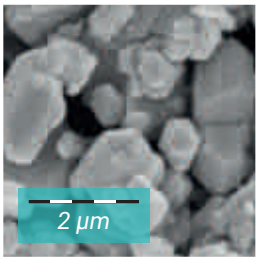
max. possible load [vol.-%]

max. possible load [wt.-%]

Resulting TC levels @ maximum possible filler loads in cured unsaturated polyester resin (UP; Palatal P80, AOC).

APYRAL® 40VS - and other surface treated ATH grades

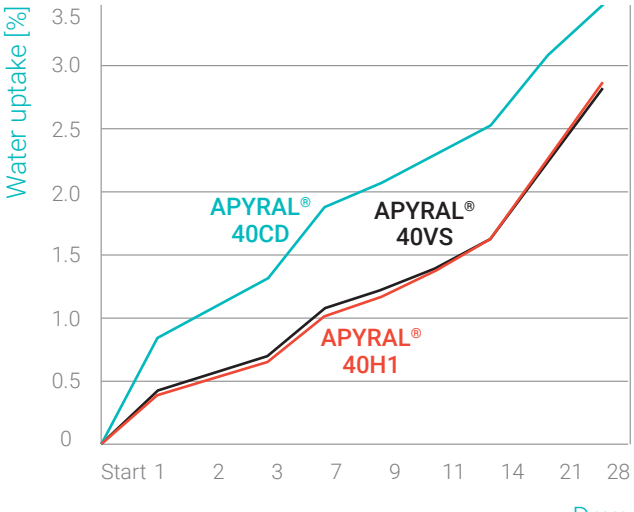




SEM image of
APYRAL® 40VS

R =
– NH_2 *(amino-)*
– *CHOCH (epoxy-)*
– $CH = CH_2$ *(vinyl-)*

... and others (functional or non-functional)



Water uptake of an LLDPE/EVA formulation with 60 wt.-% APYRAL® (90 °C / 28 days).

The use of coupling or bonding agents to enhance certain chemical and physical properties in various applications and polymer systems is common. Coupling agents enable an increased degree of interaction / bond between the inorganic **APYRAL®** filler and polymer. By use of various surface treatments certain chemical and physical characteristics can be tailored for what is needed in the end-use application.

As an example with certain surface functionalized **APYRAL®** grades, water uptake of the end use product can be significantly reduced. The percent loading or treatment levels can be adapted to improve the resultant physical and chemical properties.

One of the first surface treated products is **APYRAL® 40VS**, which is an **APYRAL® 40CD** modified with a vinyl functionality on the surface. Recently, our **APYRAL® 40H1** was added to our product portfolio, which is an **APYRAL® 40CD** with a non-reactive and non-polar surface treatment. Other surface modified grades, with or without functionality, are currently being developed. More surface treatments are available on request, not only on our **APYRAL® 40CD** but on all of our **APYRAL®** grades.

ANALYSIS	UNIT	APYRAL® 40CD	APYRAL® 40VS	APYRAL® 40H1
$Al(OH)_3$	%	99.5	98.5	98.5
Na_2O (water soluble)	%	0.011	0.008	0.005
Moisture / Volatiles	%	0.2	0.1	0.1
D_{10}	µm	0.5	0.5	0.5
D_{50}	µm	1.2	1.2	1.2
D_{90}	µm	2.2	2.2	2.2
Sieve residue (>45 µm / >345 mesh)	%	0.02	0.02	0.02
Spec. surface area (BET)	m^2/g	4.0	4.0	4.0
Specific conductivity	µS/cm	36	24	13
Bulk density	kg/m^3	400	500	600
Whiteness*	%	98	98	98

** Datacolor 400 Spectrophotometer*

Main advantages of APYRAL® 40VS and APYRAL® 40H1

- Improved handling and conveying
- Increased polymer compatibility
- Better hydrophobicity
- Reduced absorption of various additives
- Enhanced mechanical properties of the polymer compound

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