ERJ - TOP 10 - ELASTOMERS FOR SUSTAINABILITY

1. Personal Details

Name of person completing form: Marjolein Groeneweg, Marketing Director, Synthos

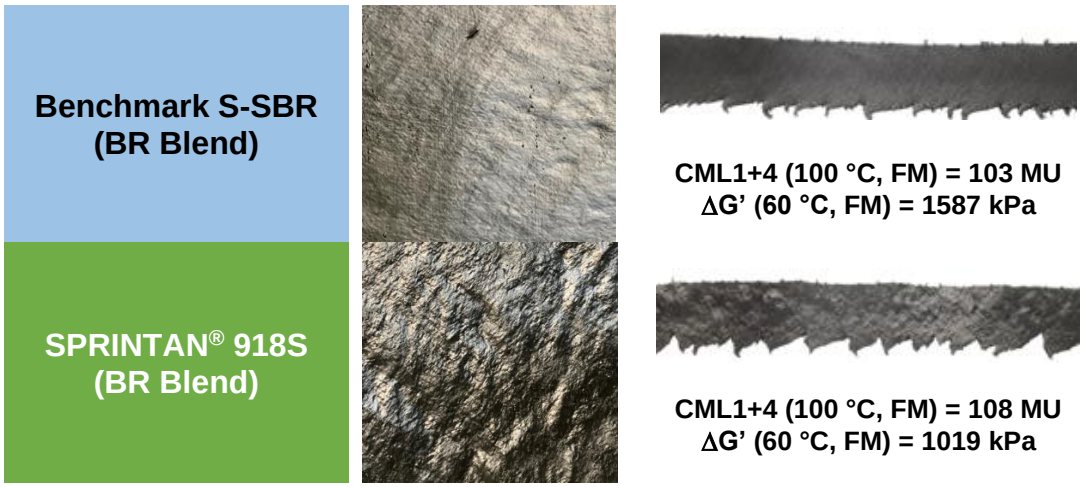
2. Title of product or project

Extending the EV tire magic triangle with multi-functionalized SPRINTAN® 918S S-SBR for improved wet and dry braking performance, increased abrasion resistance and lower rolling resistance.

3. Main materials technologies involved.

- Unique, proprietary, functionalization technology specifically developed for high-molecular weight oil-extended S-SBR, combining outstanding elasticity at low frequency (correlated to rolling resistance) with exceptional wet grip performance and wear resistance, while providing processing characteristics comparable to a non-functionalized S-SBR.
- The unique microstructure (level of styrene and vinyl groups) has been optimized with the aim of achieving excellent wet braking performance at a comparatively low glass transition temperature, which in turn optimizes wear performance.

Processing of Silica-filled Rubber Formulation



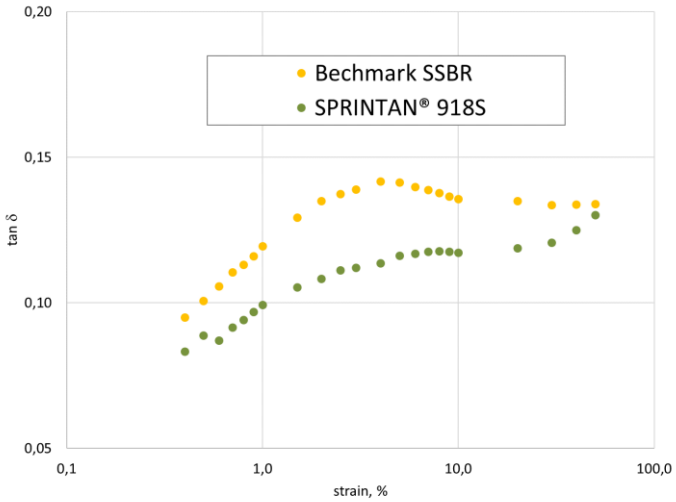
Sheets from production mixer material

Garvey profiles and properties

SPRINTAN® 918S provides processing comparable to benchmark.

Mechanical Performance of Cured Rubber Formulation

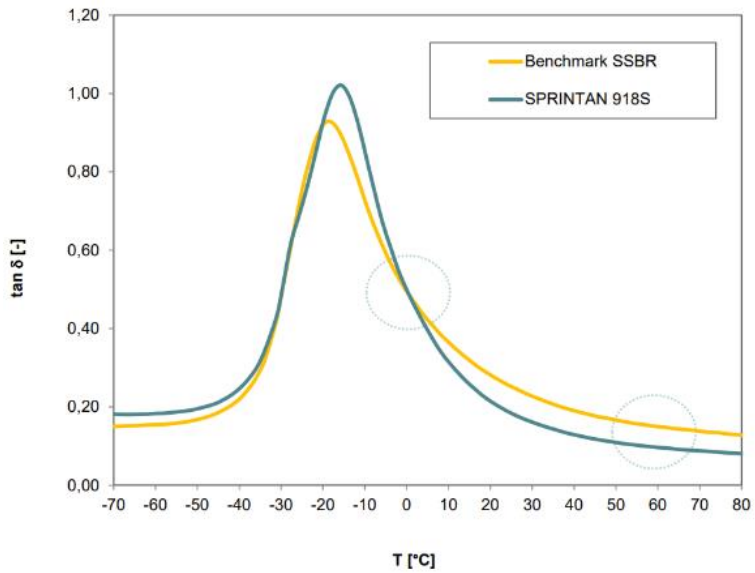
	Benchmark S-SBR	SPRINTAN® 918S
Tensile Strength [MPa]	22.8	22.1
Elongation at break [%]	504	430
Modulus 100 [MPa]	2.6	2.7
Modulus 300 [MPa]	12.0	14.2
Shore A (RT)	67.5	65.8
Rebound (60 °C) [%]	54.5	58.2
Heat build-up [°C]	128.9	113.0
DIN abrasion [mm³]	117	107

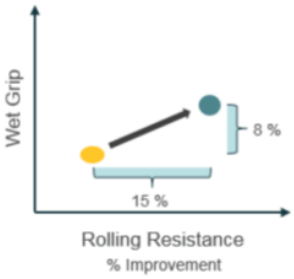


RPA Rolling Resistance test (60 °C) (t_{95}/160 °C)

SPRINTAN® 918S provides excellent mechanical property profile.

Dynamic Lab Predictors for Tire Performance

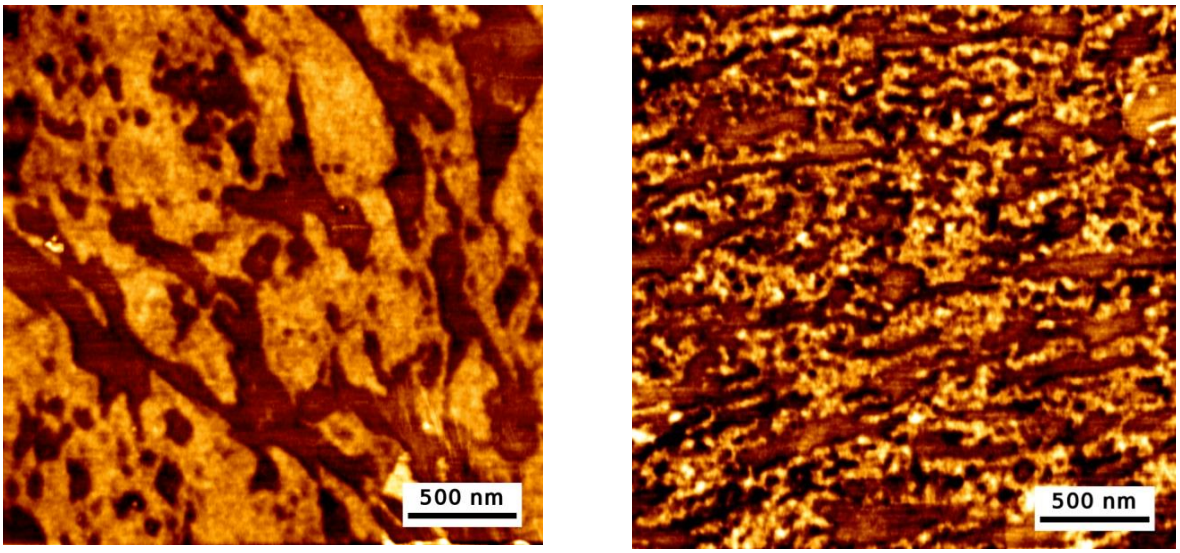




SPRINTAN® 918S offers a 15% improvement in rolling resistance with an 8% improvement in wet grip for high surface silica-based rubber formulations.

Morphology of Cured Silica filled Rubber Composites

Benchmark S-SBR **SPRINTAN® 918S**



SPRINTAN® 918S refines the blend morphology.

Electric vehicles, with their high curb weight and ample torque, are putting tires under severe levels of stress and strain. At the same time, the lowest possible rolling resistance of the tires is a must to extend the EV 's range as much as possible. And for this combination of seemingly contradictory properties, SPRINTAN® 918S meets all requirements and its unique performance balance makes it the ideal choice for all summer-, winter- and all-season (U)UHP tire treads and especially for EV tires.

4. Main goal or objective of the development project

Prior to the development of SPRINTAN® 918S, high grip S-SBR typically had high glass transition temperatures and their use was essentially limited to UHP or (U)UHP summer treads. Because these polymers were traditionally optimized for wet grip, they did not contribute significantly to improving the rolling resistance of tire treads. However, today's requirements are becoming more stringent towards CO_2 emission reduction and require products that enable more efficient e-mobility.

SPRINTAN® 918S was developed precisely with these requirements in mind - and offers excellent grip performance and improved wear resistance.

5. Technical challenges addressed by the project team

The main challenges in the development of medium-T_G functionalized S-SBR SPRINTAN® 918S lay in achieving the required high wet grip performance at a comparatively low polymer glass transition temperature. Careful fine-tuning of the micro- and macrostructure, in combination with the functionalization technology was carried out to ensure that low-temperature performance as well as wear resistance could still benefit from high main chain flexibility. To maximize the fuel efficiency potential, strong polymer-filler interaction through reactive functional elements was

designed into SPRINTAN® 918S, while still maintaining adequate processing of the compounds during mixing and extrusion in tire production.

Efficient silica-active functionalization of S-SBR often has the disadvantage of difficult processing characteristics, including high compound viscosity, poor green strength, or deteriorated extrusion behavior. However, the new S-SBR offers a functional S-SBR design that essentially retains the processing properties of a comparable non-functionalized S-SBR grade. Accordingly, SPRINTAN® 918S can be used in state-of-the-art compounding and extrusion processes without compromising tire production rates.

6. What is the commercial status of the technology or product?

Due to current demand, Synthos is now producing SPRINTAN® 918S on a regular basis. While already with commercially attractive volumes, a further boost in SPRINTAN® 918S demand is anticipated soon, as other tire manufacturers use this new S-SBR grade in tire developments for a wide range of tire applications. One tire manufacturer reports a 7 % improvement in wet braking performance, a 2 % improvement in dry braking performance and a 3 % improvement in abrasion resistance, without any deterioration in fuel efficiency. Our customers' experience shows that these results should be considered as an extension of the magic triangle.

Finally, SPRINTAN® 918S is now also available as bio/circular-attributed S-SBR under ISCC Plus certification. SPRINTAN® 918S ISCC certified has the same product properties as its conventional variant, meets the same specifications, and can therefore be considered interchangeable and the same.

All Synthos synthetic rubber products are available as ISCC Plus certified material since July 2022.

7. Please describe the contribution of the technology or product to sustainability

The use of SPRINTAN® 918S in tire tread allows a reduction of the tire rolling resistance, which reduces the amount of energy required to travel a given distance. This consequently reduces fuel consumption or extends the range of electrical vehicles.

90 % of energy consumption over the life cycle of a tire is attributed to the tire use-phase, in the form of the fuel or electric energy consumption of the vehicle. Therefore, developing new polymers and compounding concepts to improve rolling resistance of the tire and therewith fuel efficiency of the car, addresses the core element how the environmental impact of tires can be reduced.

Based on lab indicator data confirmed by tire customers, SPRINTAN® 918S (compared to non-functionalized high grip S-SBR) improves fuel efficiency of the whole car by approx. 1.5 %. Considering in Europe alone, 18 million vehicles are sold, the benefit of this increased fuel efficiency would translate in approx. 540.000 tons less fuel consumed or a reduction of CO_2 emissions by 1.3 million tons.*[1] When it comes to electric mobility, SPRINTAN® 918S, as a grip component in the tire tread, is an important step towards extended range in high-torque electric vehicles. To further support the move from internal combustion engines towards more sustainable forms of propulsion, Synthos is actively collaborating with key customers to continuously improve tire performance for this growing segment.

8. Scope for further enhancements to the technology or product

Synthos is already actively developing the next generation of multi-functionalized S-SBR with further enhanced interaction between the polymer and surrounding filler particles. The next generation S-SBR will enable continuous improvements in rolling resistance and greater wear performance, and therefore will positively impact environmental footprint.

9. Any further comments to further highlight the contribution of this development project to environmental sustainability?

Looking at the contribution tires can bring to sustainable, individual mobility, it is not enough to focus only on rolling resistance and wet grip potential but also on tire wear. Indeed, tire weight can be lowered further, reducing rolling resistance and in turn reducing particulate emissions during the tire use phase.

SPRINTAN® 918S, with its unique composition and proprietary, effective functionalization technology addresses all these key requirements, and is thus supporting the global decarbonization initiatives of the transportation sector, so vital in the fight against accelerating global warming and for the preservation of primary raw materials.

In line with Synthos strong commitment to moving in the green direction, SPRINTAN® 918S is now also available as bio/circular-attributed SSBR under ISCC Plus certification.

*
https://www.iea.org/reports/tracking-transport-2019/fuel-economy-of-cars-and-vans
https://www.spritmonitor.de/de/berechnung_co2_ausstoss.html

[1]Based on 2020 European average fuel economy of new cars of 7.5l/100 km, combined with an average annual travel distance of 40,000 km.

Appendix

Requirements of EV Passenger Car Tires

Due to the higher weight of EV's, their HP tires, must offer:

→ Long driving range → reduced rolling resistance

→ Long service timeline → good abrasion resistance

→ Physical stability → excellent mechanical properties

→ Uncompromised safety → high wet grip performance

Highly functionalized S-SBR is typically part of the solution, but....

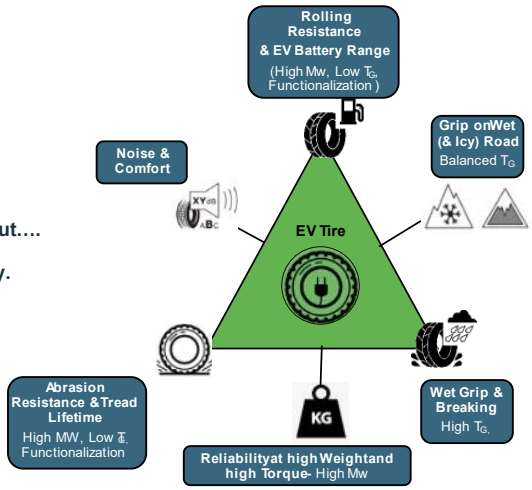
the higher the functionalization, the lower the processability.

Customer feedback highlights that selected S-SBR must not

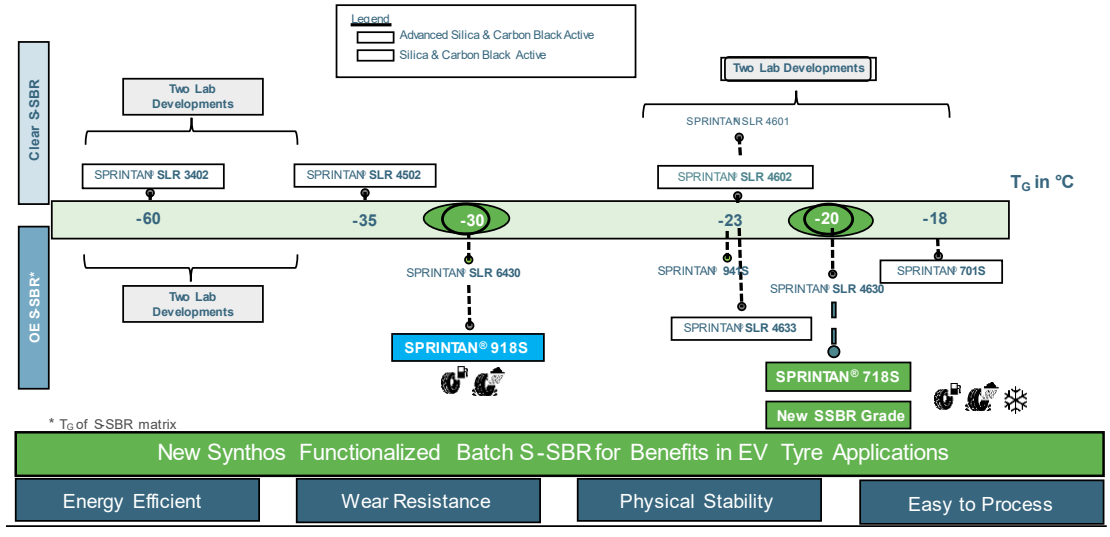
→ Slow down high throughput mixing or extrusion processes

→ Deteriorate rubber compound green strength or shape

→ Increase complexity of the mixing or extrusion process



Batch S-SBR Portfolio and Upcoming Developments



SPRINTAN® 918S

Polymer Characteristics a nd Insight into Standard Silica Formulation with BR as Blend Component

	Benchmark S-SBR	SPRINTAN® 918S
Styrene [wt %]	40	**40**
Vinyl [wt%]	24	**26**
T_G [°C]	-34	**-33**
Mooney ML1+4 [MU]	67	**76**
TDAE [phr]	37.5	**25**
Functionalization	No	**For Silica and Carbon Black**

Filler: Standard Silica

Mixer: 1.6l HF
Mixing: 3-step process
Strategy : Comparison to same softener level

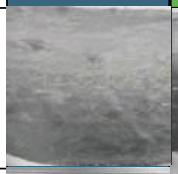
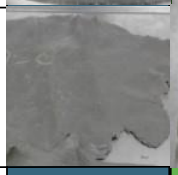
Component	SPRINTAN® 918S	Benchmark S-SBR
	[phr]	[phr]
SSBR	**100**	**110**
High-Cis NiBR	20	←
Silica BET160m²/g	80	←
SilaneTESPD	6.9	←
6 PPD	2.0	←
Wax	1.5	←
Zinc oxide	2.5	←
Stearic acid	1.0	←
TDAE	**10**	**0**
Sulfur	1.4	←
TBBS	1.7	←
DPG	2.0	←
Sum	229	229

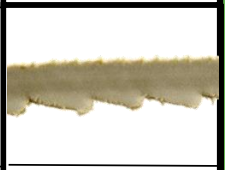
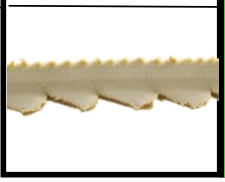
- Comparable microstructure with a non -functionalized grade, giving excellent Performance at good Processability
- Reduced oil concentration improves flexibility for Compounders to add Oils / Processing Aids

SPRINTAN® 918S – Benefits

Standard Silica Formulation with BR as Blend Component

Processing

	Benchmark S-SBR	SPRINTAN® 918S
First mixing stage		
Final mixing stage		
ML [MU]	68	**76**
CML [MU]	94	**82**

	Benchmark S-SBR	SPRINTAN® 918S
Final Viscosity CML [MU]	94	82
n_{Screw} = 10 rpm		
n_{Screw} = 40 rpm		

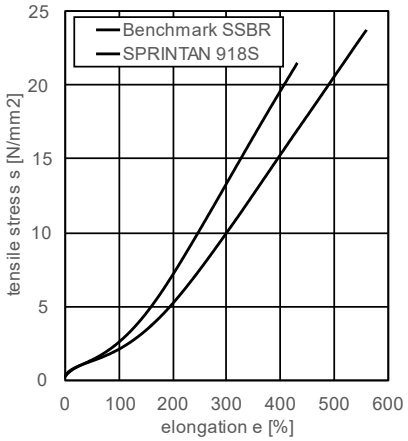
SPRINTAN® 918S provides balanced Compound Viscosity vs. Benchmark-SBR

SPRINTAN® 918S – Benefits

Standard Silica Formulation with BR as Blend Component

Mechanical Performance

	Benchmark S-SBR	SPRINTAN® 918S
Tensile Strength [MPa]	23.6	**21.6**
Elongation @ Break [%]	559	**432**
Modulus 100 [MPa]	2.1	**2.6**
Modulus 300 [MPa]	9.9	**13.3**
Shore A hardness @ RT	63.3	**61.9**
Rebound resilience @ 0 °C [%]	11.7	**10.3**
Rebound resilience @ 60 °C [%]	56.5	**59.7**

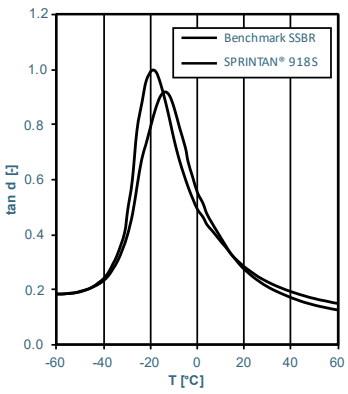


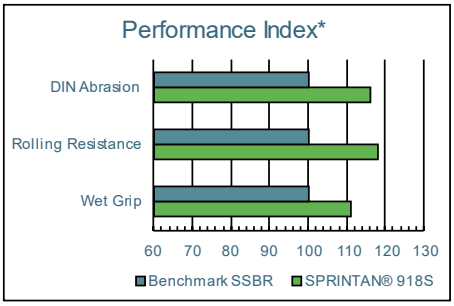
SPRINTAN® 918S provides excellent Mechanical Properties

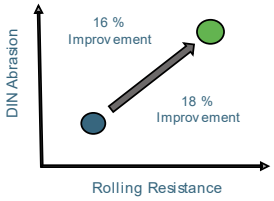
SPRINTAN® 918S – Benefits

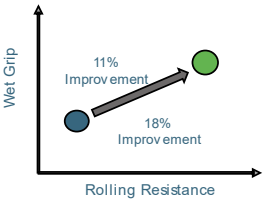
Standard Silica Formulation with BR as Blend Component

Dynamic Performance









15% Improved DIN Abrasion Resistance

20% Improved Rolling Resistance Indicator at Enhanced Wet Grip Level Indicator

*values >100 indicate improved performance