Application of NSA04 Nano Silica-Alumina Alloy in Tires:-Enhanced Wear Resistance, Improved Wet Grip, and Reduced Rolling Resistance, etc.

GreenThinking® NSA04: A nano silica-alumina alloy (nano silica-alumina, $Al_2SiO_5 \cdot nH_2O$) functional material specifically designed to enhance tire wet grip performance, wear resistance, and rolling resistance performance. With an average particle size of approximately 500 nanometers, the mechanism of action of the nano silica-alumina alloy primarily lies in its unique physical and chemical properties, including the formation of Al-O-Si bonds that puncture the water film between the tire and the road surface. This significantly improves tire grip on wet roads. Furthermore, it enables excellent interfacial bonding with the rubber matrix, enhancing rubber's abrasion resistance, reducing heat generation, and improving fatigue resistance. The nano silica-alumina alloy has broad applicability and is suitable for various tire types, including passenger car tires, commercial vehicle tires, and high-performance racing tires. In high-performance tires, its use can markedly improve overall performance, delivering superior grip on wet surfaces and enhanced wear resistance, while simultaneously lowering rolling resistance and improving fuel economy.

➢ Key Performance

1.Wet Grip Performance: Combined with the silane coupling agent Si75, the nano silica-alumina alloy effectively disrupts the water film between the tire and the road surface, increasing friction on wet roads. This performance enhancement stems primarily from the material's high specific surface area and excellent dispersibility, allowing it to form effective reinforcing phases within the rubber matrix and thereby improve wet grip.

2.Wear Resistance: The high specific surface area and fine particle characteristics of the nano silica-alumina alloy enable the formation of micro-reinforcing particles within the rubber matrix. These particles effectively distribute stress, enhancing the rubber's abrasion resistance. This is crucial for extending tire service life and reducing replacement frequency.

3.Reduced Rolling Resistance: The incorporation of the nano silica-alumina alloy modifies the rubber's molecular structure and interfacial bonding, leading to lower tire rolling resistance. This improvement contributes to enhanced vehicle fuel economy, reducing energy consumption and emissions.

➢ Applications:

The application scenarios of GreenThinking® NSA04 Nano Silica-Alumina Alloy in tires primarily include the following aspects:

1.Enhanced Wet Grip Performance:

The nano silica-alumina alloy, combined with a silane coupling agent, can puncture the water film between the tire and the road surface, thereby improving the tire's grip on wet roads. This characteristic is particularly crucial for driving safety in rainy conditions, effectively reducing the risk of skidding and hydroplaning.

2.Improved Wear Resistance:

Due to its high specific surface area and excellent dispersibility, the nano silica-alumina alloy forms micro-reinforcing particles within the rubber matrix, enhancing the rubber's abrasion resistance. This is especially important for tires subject to long driving hours and high wear, such as commercial vehicle tires and high-performance racing tires.

3.Reduced Rolling Resistance:

The incorporation of the nano silica-alumina alloy modifies the rubber's molecular structure and interfacial bonding, leading to lower tire rolling resistance. This performance improvement helps enhance vehicle fuel economy, reducing energy consumption and emissions.

4.Enhanced Mechanical Properties:

Adding the nano silica-alumina alloy improves the rubber's tear resistance and fatigue resistance, providing greater stability during high-speed driving and frequent braking. This is significant for extending tire service life and improving safety.

➢ Dosage Recommendations:

•**Addition Method:** NSA04 is typically added **during the primary mixing stage** and is usually used in conjunction with additives like silane coupling agents.

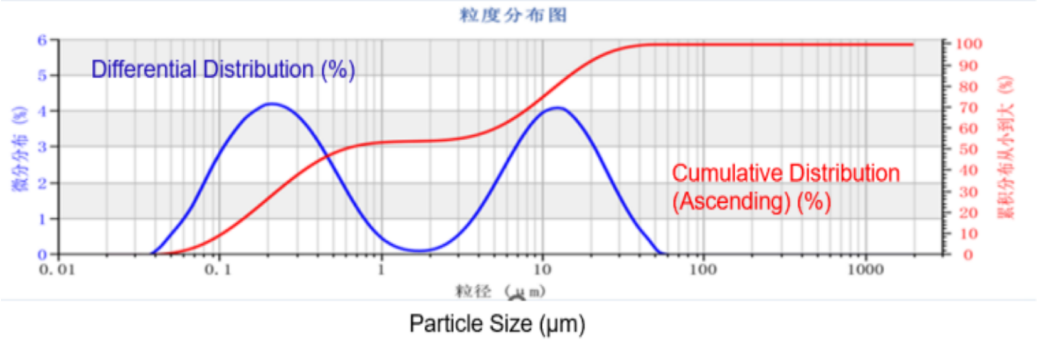
•**Recommended Dosage: 10-30 Phr (parts per hundred parts of rubber)**. The specific amount can be adjusted based on actual processing conditions and performance requirements.

NSA04 Nano Silica-Alumina Alloy: Physical Form and Particle Size Distribution (PSD)

Particle Size Test Report

Sample Name:	SOP Name:	Measurement Time:	Sample Code:
PF87	Nano Silica-Alumina Alloy	2025/5/20 14:50	0001
Tester:	Background Sampling Time:	Single Sampling Time:	Result Type:
Tiangong Laboratory	9 seconds	9 seconds	Volume (V)
Sample Material:	Refractive Index of Sample Material:	Absorption of Sample Material:	Dispersion Medium:
Nano Reinforcing Agent	1.5	0.01	Water
Refractive Index of Dispersion Medium:	Analysis Mode:	Extinction (%):	Analysis Range (um):
1.33	General Mode	6.69	0.02 ~ 2000
D10(um):	D25 (um):	D50 (um):	D75 (um):
0.104	0.188	0.583	10.108
D90 (um):	D97 (um):	D(3, 2) (um):	D(4, 3) (um):
18.137	27.769	0.288	6.114
Span:	Specific Surface Area by Volume (sq. m/c.c.):	Specific Surface Area by Weight (m²/kg):	Residue on Sieve (%):
30.94	20.834	20833.66	0.377
Dmin Setting Value:	Concentration(%Vol):	C. V (%):	
0.005	0.0043	138.24	

Particle Size Distribution Graph



Particle Size (μm)

NSA04 Nano Silica-Alumina Alloy: Experimental Control Formulation

Material Name	Formula 1	Formula 2	Formula 3
SSBR	70	70	70
BR	30	30	30
N234	5	5	5
Precipitated silica	80	80	80
Zinc oxide	2	2	2
Stearic acid	2	2	2
Si 75	6.8	6.8	6.8
6PPD	2	2	2
AKPP	4	4	4
Microcrystalline wax	1.3	1.3	1.3
TMQ	0.5	0.5	0.5
Environmentally friendly oil	1	1	1
Styrene resin	8.8	8.8	8.8
S	1.8	1.8	1.8
CBS	2	2	2
DPG	2	2	2
NSA04(Nano Silica-Alumina Alloy)		15	12.5
Total	219.2	234.2	231.7

NSA04 Nano Silica-Alumina Alloy: Cure Curve (Rheometer Curve)

160℃*60min	ML	MH	ts1	ts2	t10	t50	t90	门尼
Formulation 1: Blank	1.92	14.05	2.44	2.83	2.55	3.54	6.66	59.8
Formulation 2: 15phr	1.76	14.59	2.27	2.60	2.40	3.22	6.27	55.9
Formulation 3: 12.5phr	1.70	15.06	2.22	2.55	2.37	3.16	6.04	55.50

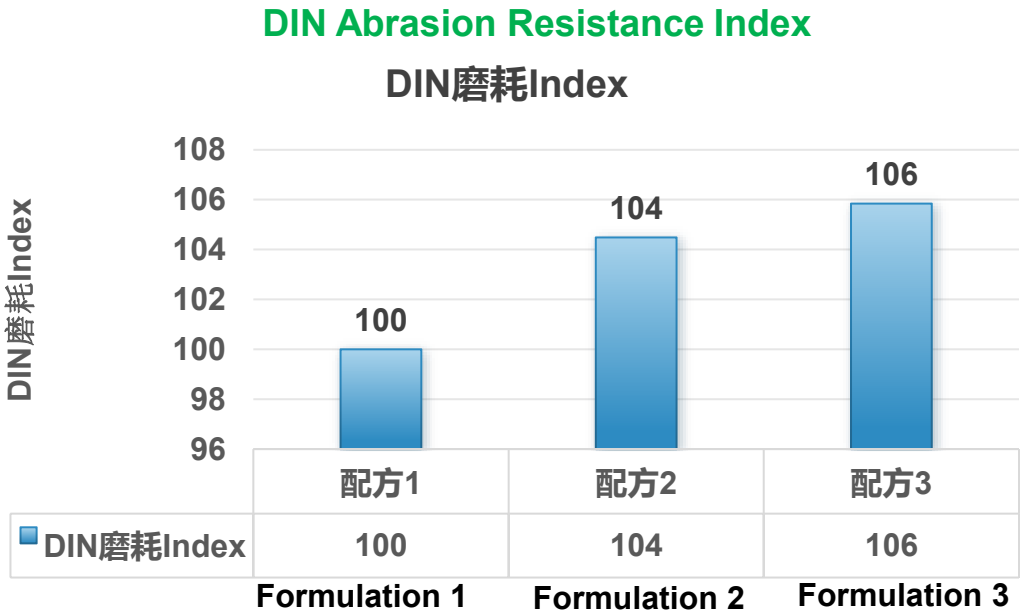
Conclusions:

- NSA04 (Nano Silica-Alumina Alloy) accelerates the cure rate, thus improving production efficiency.
- NSA04 (Nano Silica-Alumina Alloy) reduces Mooney viscosity, enhancing compound flowability.

NSA04 Nano Silica-Alumina Alloy：DIN Abrasion Resistance Test

➢ **NSA04： The wear resistance performance has improved by approximately 6%** ↑

DIN Abrasion Resistance	Loss-Vol (cm3)
Formulation 1: Blank	0.163
Formulation 2: 15phr	0.156
Formulation 3: 12.5phr	0.154



➢ **Conclusions:**

NSA04 (Nano Silica-Alumina Alloy) reduces abrasion loss, demonstrating approximately 6% improvement in abrasion resistance.

NSA04 Nano Silica-Alumina Alloy：Conventional Property Testing

160*30min	Hardness	Specific Gravity	Tensile Strength (Mpa)	Elongation at Break (%)	Tensile Stress at 50% Strain (MPa)	Modulus at 100% (M100) (MPa)	Modulus at 300% (M300) (MPa)
Formulation 1: Blank	64.2	1.208	24.8	420.6	2.1	3.5	15.5
Formulation 2: 15phr	64.8	1.202	27.9	433.4	2.4	3.9	17.4
Formulation 3: 12.5phr	64.7	1.205	25.3	436.0	2.5	4.2	17.8

➢ **Conclusions：**

NSA04 (Nano Silica-Alumina Alloy) enhances both tensile strength and elongation at break, contributing to improved modulus properties (e.g., M300).

NSA04 Nano Silica-Alumina Alloy : Conventional Property Testing

Aging	Tensile Strength (Mpa)	Elongation at Break (%)	Tensile stress at 50% strain (MPa)	Modulus at 100% (M100) (MPa)
Formulation 1: Blank	22.8	291.0	3.0	5.5
Formulation 2: 15phr	24.4	303.0	3.1	5.7
Formulation 3: 12.5phr	22.3	298.0	3.3	5.9

➢ **Conclusions:**

NSA04 (Nano Silica-Alumina Alloy) increases tear strength both before and after aging compared to the control formulation.

NSA04 Nano Silica-Alumina Alloy： Aging Resistance Test

Curing: 160°C × 30 min (ASTM D3182) **Aging**: 100°C × 48 h (ASTM D573)	Tear strength (kN/m) - Before aging	Tear strength (kN/m) - After aging
Formulation 1: Blank	18.1	9.1
Formulation 2: 15phr	18	9.8
Formulation 3: 12.5phr	21.9	10.3

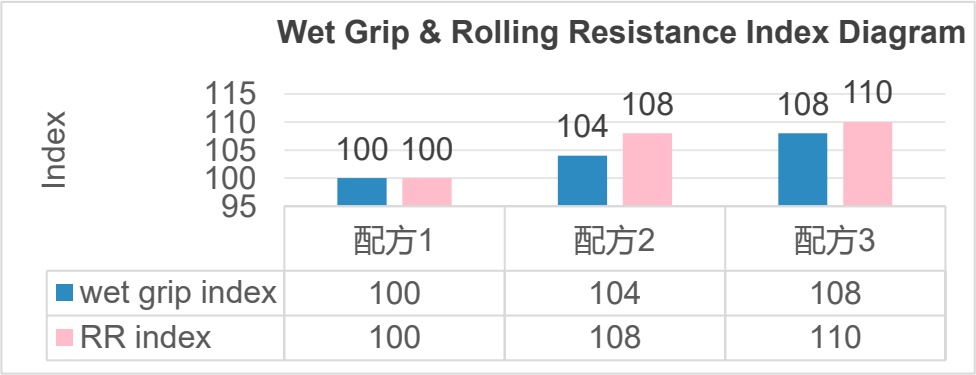
➢ **Conclusions**：

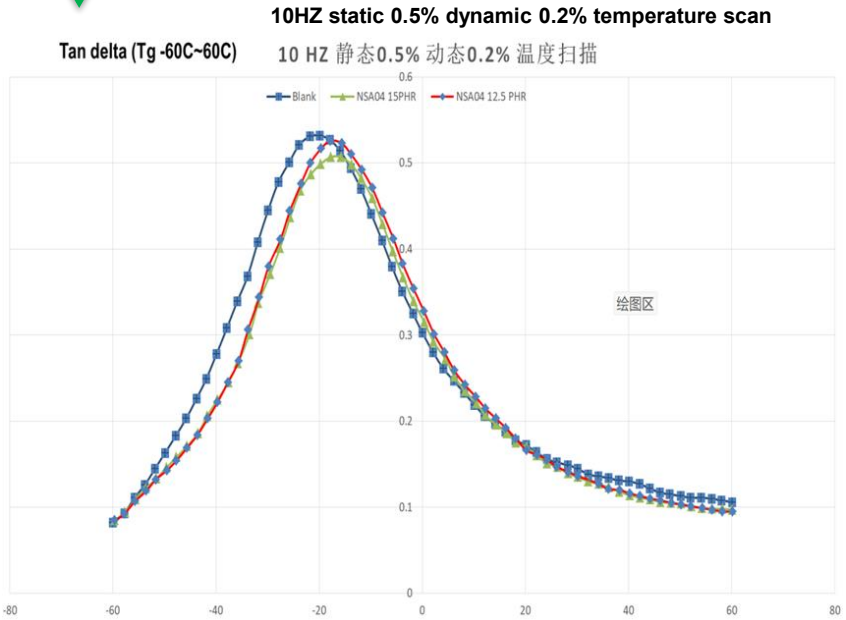
NSA04 (Nano Silica-Alumina Alloy) increases tear strength both before and after aging compared to the control formulation.

NSA04 Nano Silica-Alumina Alloy： DMA Test Data

➢ **NSA04：** **Optimal Dynamic Performance Enhancement — Peak Wet Grip Improvement (8.3%)↑with Maximum Rolling Resistance Reduction (10.4%).↓**

DMA data	tan 0℃	tan 20℃	tan 60℃
Formulation 1: Blank	0. 303	0. 172	0. 106
Formulation 2: 15phr	0. 315	0. 170	0. 097
Formulation 3: 12. 5phr	0. 328	0. 166	0. 095





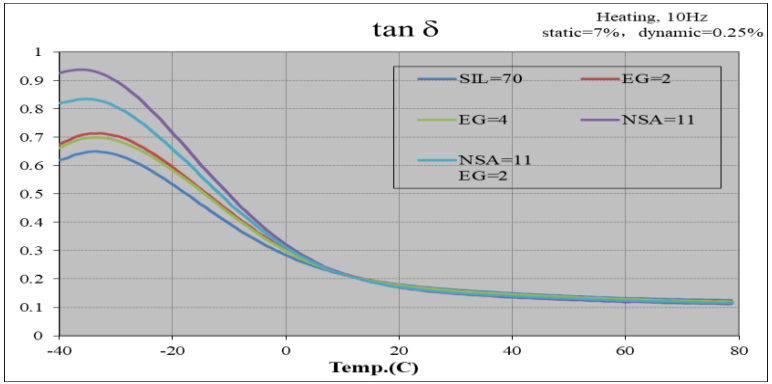
Conclusion: NSA04(nano-silicon-aluminum alloy) can effectively improve wet grip and reduce rolling resistance, forming hard particles of Al-O-Si bond compounds.

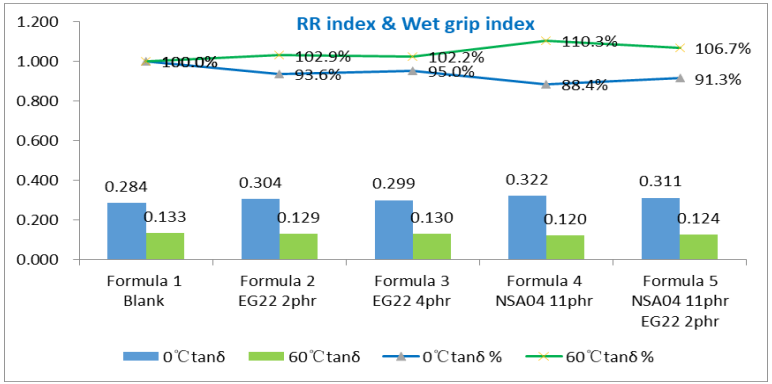
NSA04 Nano Silica-Alumina Alloy： DMA Test Data

	Formulation 1: Blank	Formulation 2: EG22 2phr	Formulation 3: EG22 4phr	Formulation 4: NSA04 11phr	Formulation 5: NSA04 11phr EG22 2phr
NR 20号标胶	25	25	25	25	25
NS612	75	75	75	75	75
N330	4	4	4	4	4
HD165MP	70	70	70	59	59
Si75	5.6	5.6	5.6	5.6	5.6
Oil	10	10	10	10	10
6PPD	2	2	2	2	2
TMQ	1	1	1	1	1
ZnO	2	2	2	2	2
Stearic acid	2	2	2	2	2
DPG	1	1	1	1	1
EG22		2	4		2
NSA04				11	11
Resin	15	15	15	15	15
CBS	2.3	2.3	2.3	2.3	2.3
S	1.4	1.4	1.4	1.4	1.4
Total	216.3	216.3	220.3	205.3	205.3

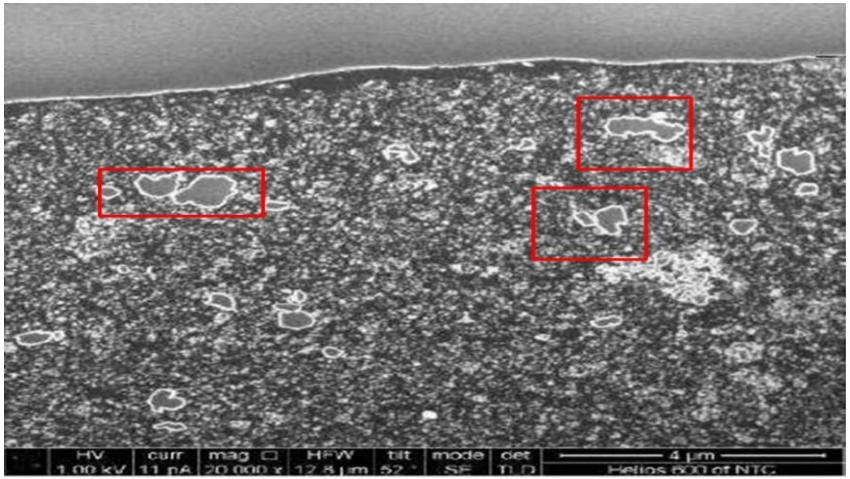
ML(1+4)100℃	74.18	68.35	63.1	65.26	62.31
Scorch Time（130℃）min	37.4	43.7	40.0	47.6	40.3
T10 (min)	6.1	10.8	10.8	10.3	10.3
T90 (min)	24.6	27.6	29.1	26.6	28.5
ML(dNm)	3.10	2.29	1.89	2.11	1.85
MH(dNm)	22.98	20.69	20.83	19.76	20.93
Shore A	63.4	61.4	62.7	58.44	60.5
M100% MPa	2.38	2.32	2.55	2.26	2.41
M200% MPa	4.91	4.83	5.33	4.83	5.09
M300% MPa	8.68	8.57	9.15	8.52	8.83
Tensile strength (MPa)	21.6	23.2	21.5	23.8	21.5
Elongation at break (%)	600	646	606	653	608
Resilience	49	50	46	55	51
Tg	-33.6	-32.9	-33.6	-35.9	-35.2
0℃tanδ	0.284	**0.304**	0.299	0.322	0.311
25℃tanδ	0.170	0.165	0.166	0.156	0.160
60℃tanδ	0.133	**0.129**	0.130	0.120	0.124

NSA04： Optimal Dynamic Performance Enhancement — Peak Wet Grip Improvement (10.3%) with Maximum Rolling Resistance Reduction (11.6%).





NSA04 Nano Silica-Alumina Alloy： XPC

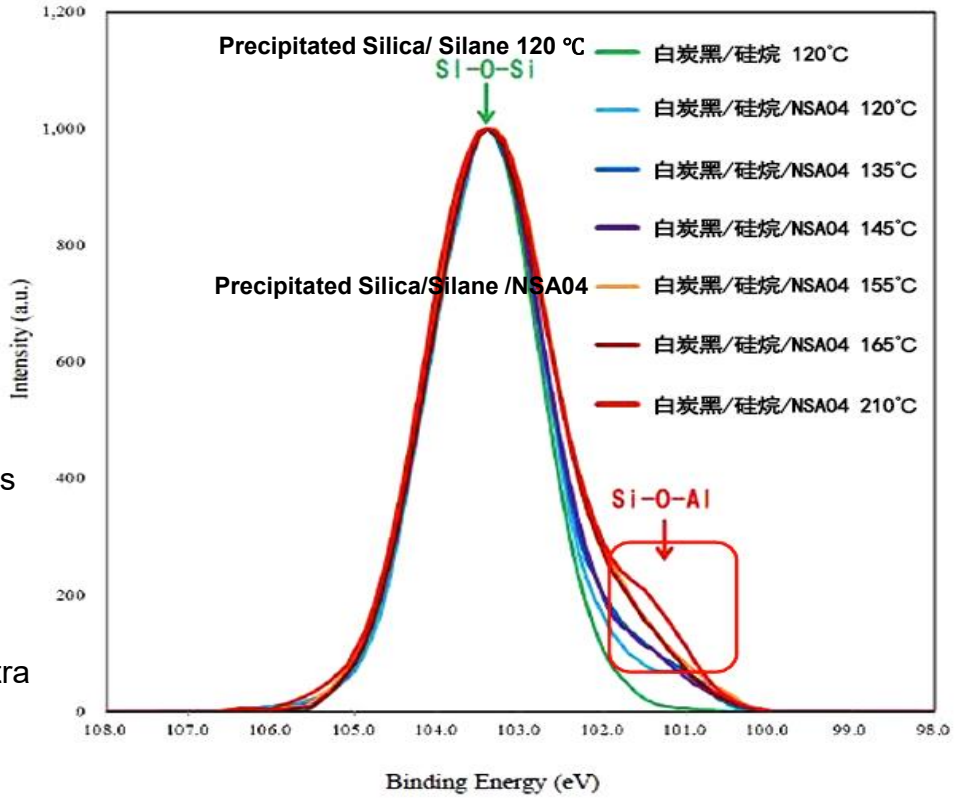


SEM cross-sectional image (20K) of the reaction between NSA04 and silica. The position of NSA04 is highlighted with white outlines in the image, indicating that during the material mixing stage, as the temperature increases, NSA04 undergoes changes. Its outline has transformed into alumina or aluminosilicate bonds.

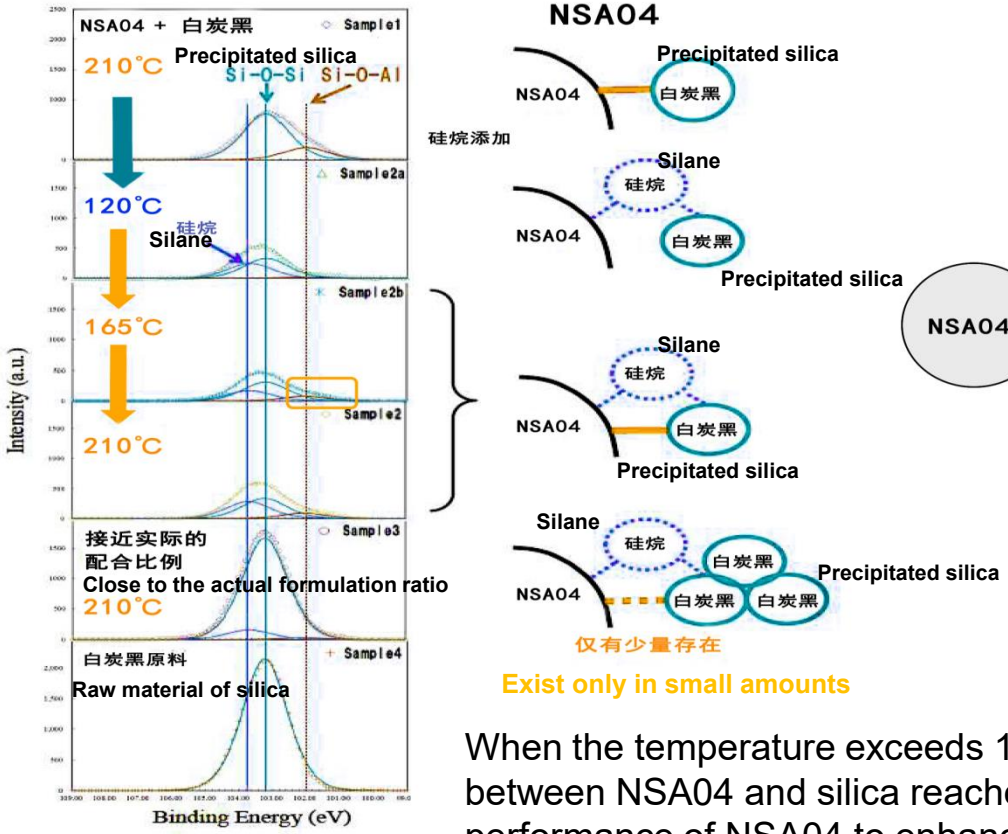
XPS spectra showing the relationship between binding energy and intensity under different conditions. The spectra reveal that when the temperature exceeds 165° C, aluminosilicate bonds form, explaining the superior wear resistance of NSA04.

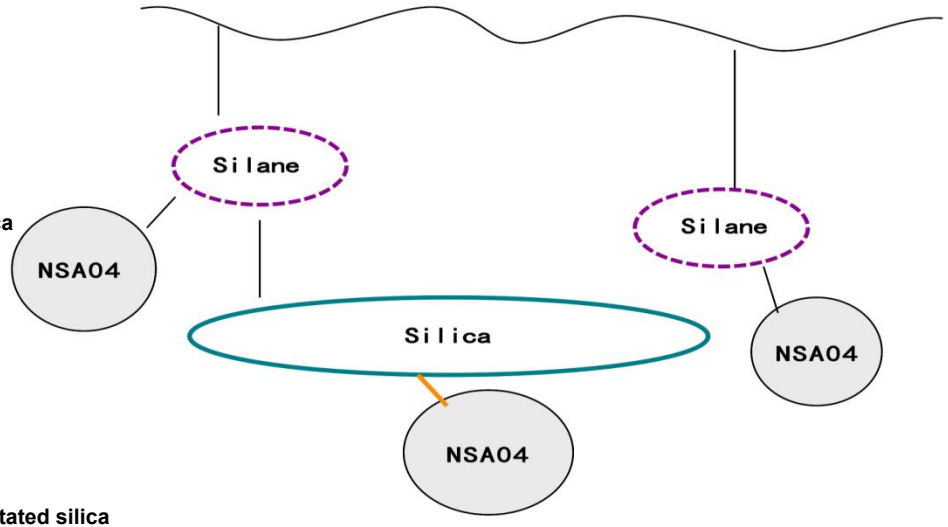
X-ray Photoelectron Spectroscopy

XPS 即 X 射线光电子能谱



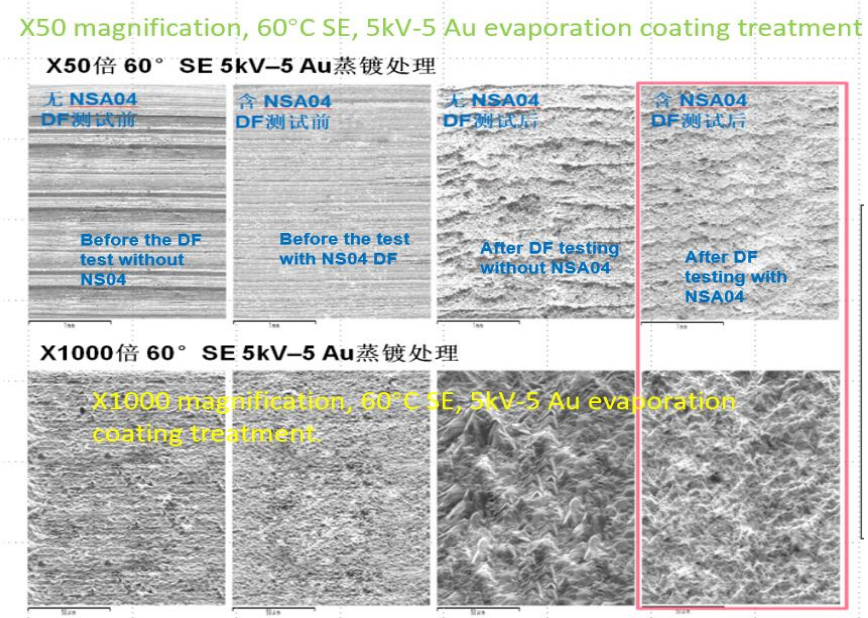
NSA04 Nano Silica-Alumina Alloy： XPC

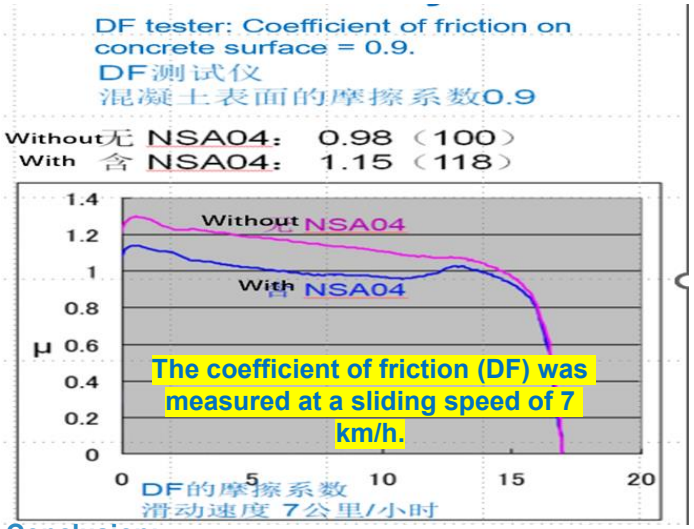




When the temperature exceeds 165 ° C, the formation of aluminosilicate bonds between NSA04 and silica reaches its highest efficiency, fully activating the performance of NSA04 to enhance wet grip, reduce rolling resistance, and improve abrasion resistance.

NSA04 Nano Silica-Aluminum Alloy：Wear Resistance (DF Tester)





➢ **Conclusion:**

Incorporating NSA04 (nano silicon-aluminum alloy) resulted in a 17.3% improvement in the coefficient of friction.

1.Surface Roughness:

The surface of NSA04 (nano silico-aluminum alloy) exhibits finer (smoother) roughness after the DF test, compared to surfaces without aluminum compounds.

2.Coefficient of Friction:

The surface of NSA04 shows a higher coefficient of friction, but with less variation across different sliding speeds, indicating better frictional stability.

3.Conclusion:

This study demonstrates that the addition of NSA04 (nano silico-aluminum alloy) significantly improves the tribological properties of the surface, resulting in smoother texture and enhanced frictional stability. This is particularly important for applications that demand low friction coefficients and high wear resistance.