Coatings Trends & Technologies Summit

New Insights into Coating Additives to Improve Durability of Waterborne Coatings

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Coatings and Sustainability

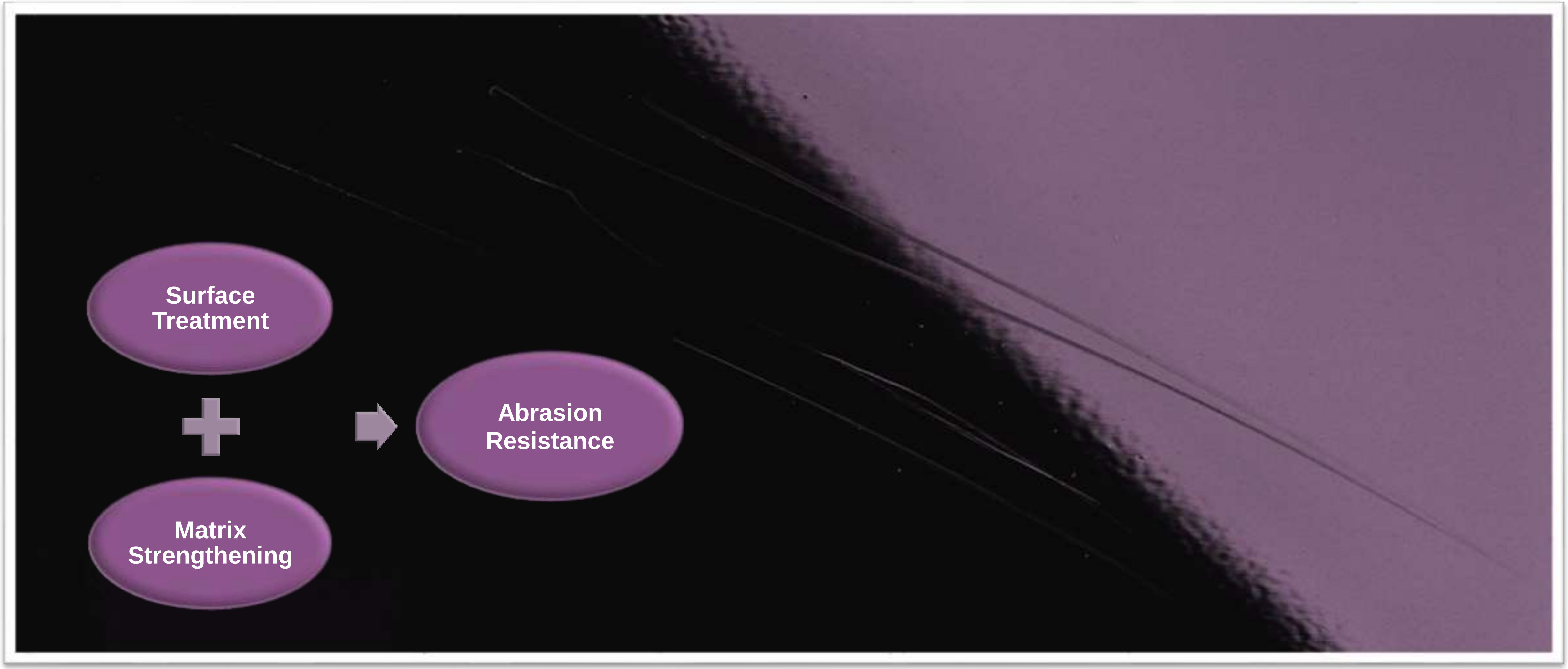
What is abrasion?

Abrasion Types and Abrasion Resistance

1. Mar Abrasion is the permanent deformation that has not ruptured the surface of a coating.
2. Wear Abrasion is usually caused by mechanical actions that remove material from the surface. In most cases, such removal is gradual and progressive due to repetitive actions.
3. Scratch Abrasion, typically seen as a line, is a surface deformation caused by indentation due to the displacement or removal of material by a harder object.

Resistance of a solid material to mar, wear, and scratch is called "Abrasion Resistance".

How to achieve the required abrasion resistance?



An Organic Coating Based On A Polymeric Matrix

Different Approaches for Improving Abrasion Resistance

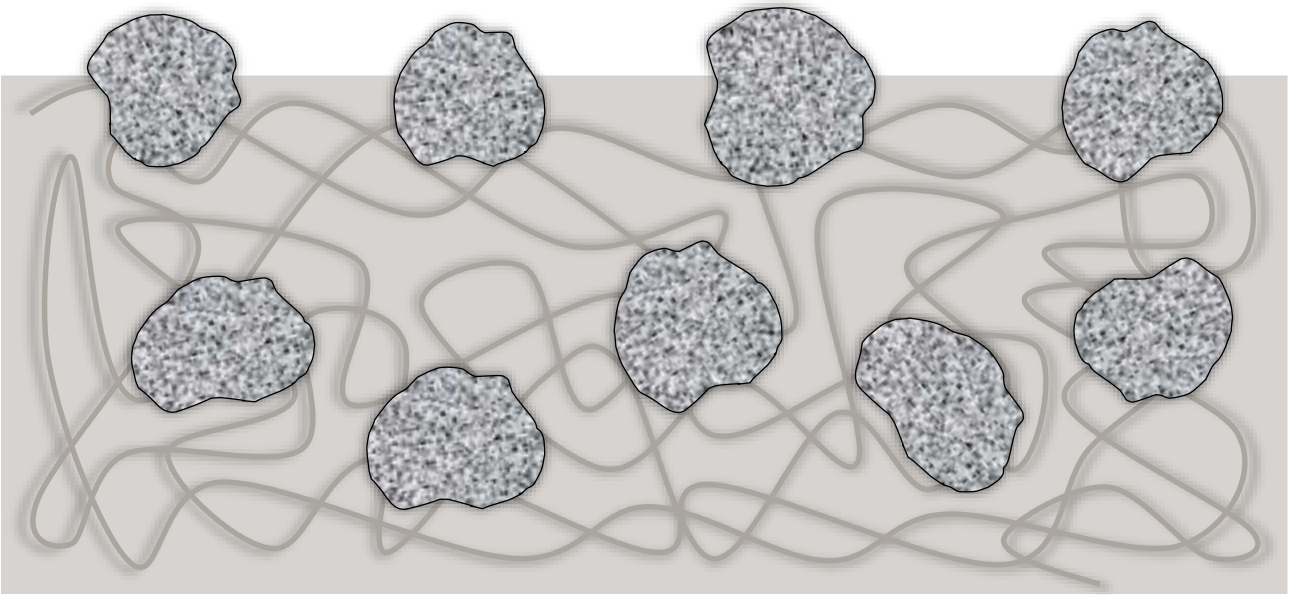
… by matrix strengthening using high T_g polymers

Different Approaches for Improving Abrasion Resistance

… by matrix strengthening through increased crosslink density

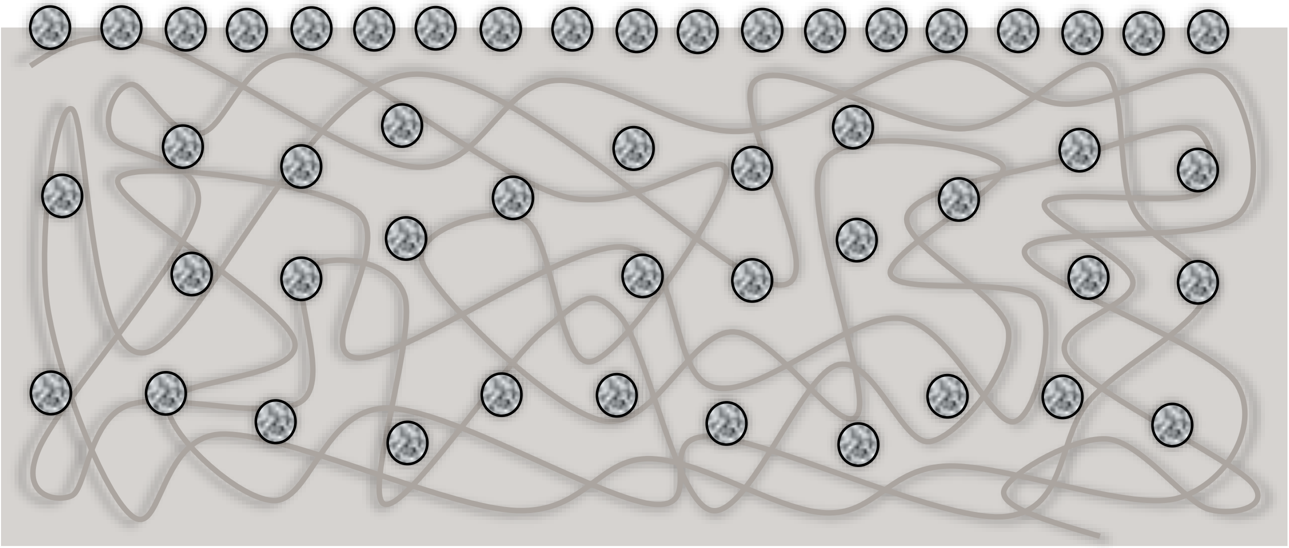
Different Approaches for Improving Abrasion Resistance

… by incorporation of silica particles



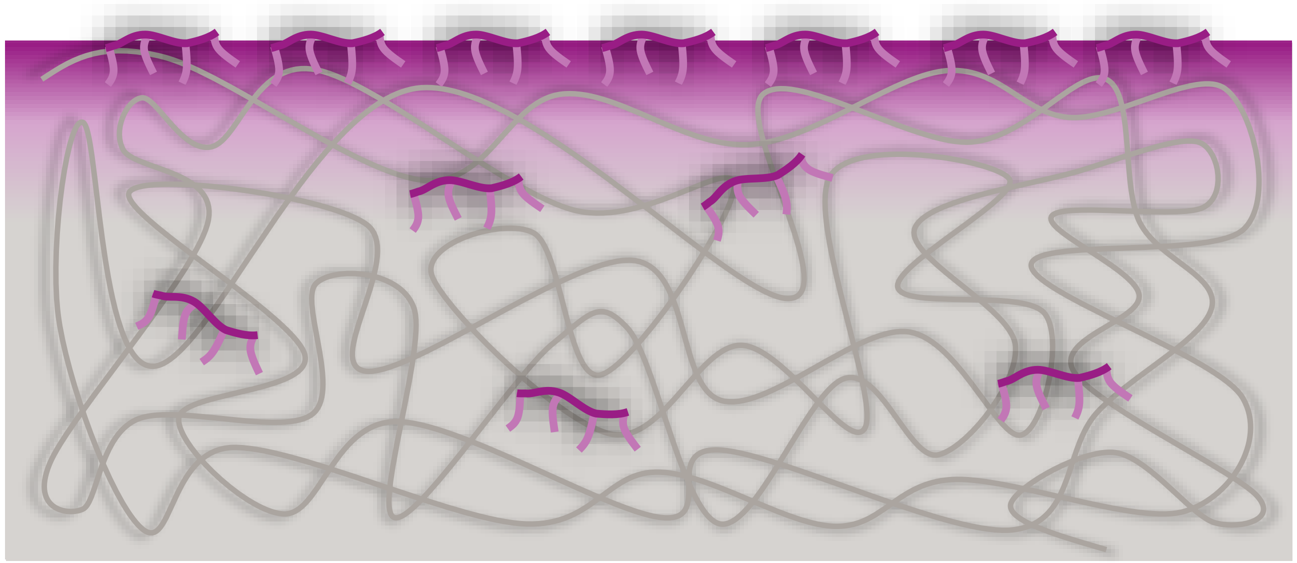
Different Approaches for Improving Abrasion Resistance

… by incorporation of nano-silica particles



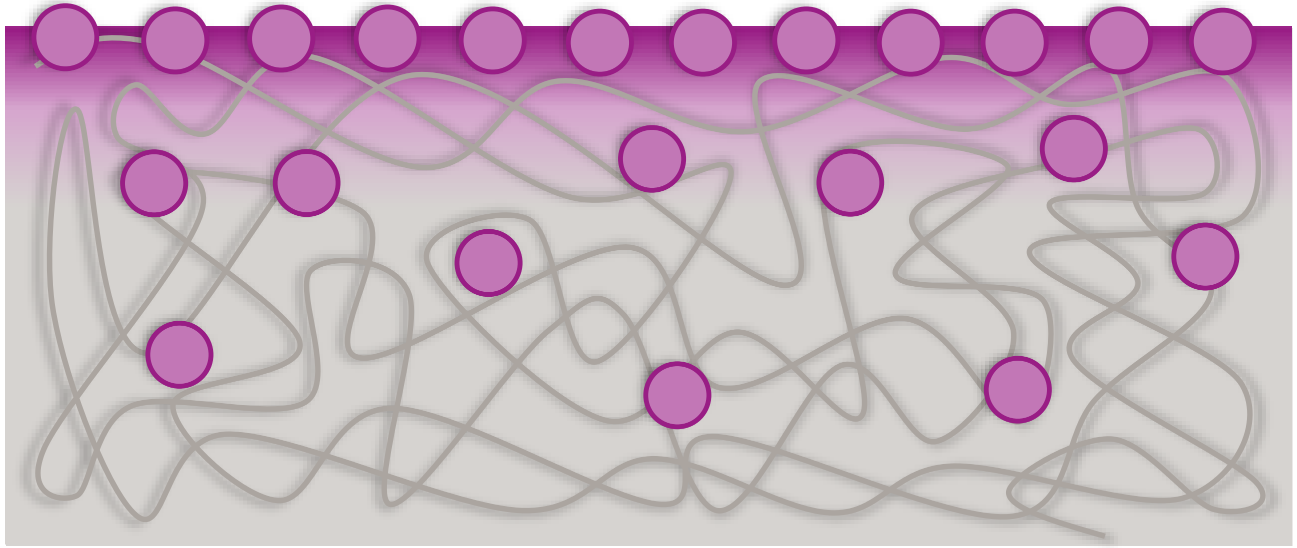
Different Approaches for Improving Abrasion Resistance

… by incorporation of polysiloxane-based surface additives



Different Approaches for Improving Abrasion Resistance

… by incorporation of polysiloxane-based emulsion additives



Different Approaches for Improving Abrasion Resistance

(a) An organic coating based on a polymeric matrix.

Improving abrasion resistance by

b) matrix strengthening using high T_g polymers

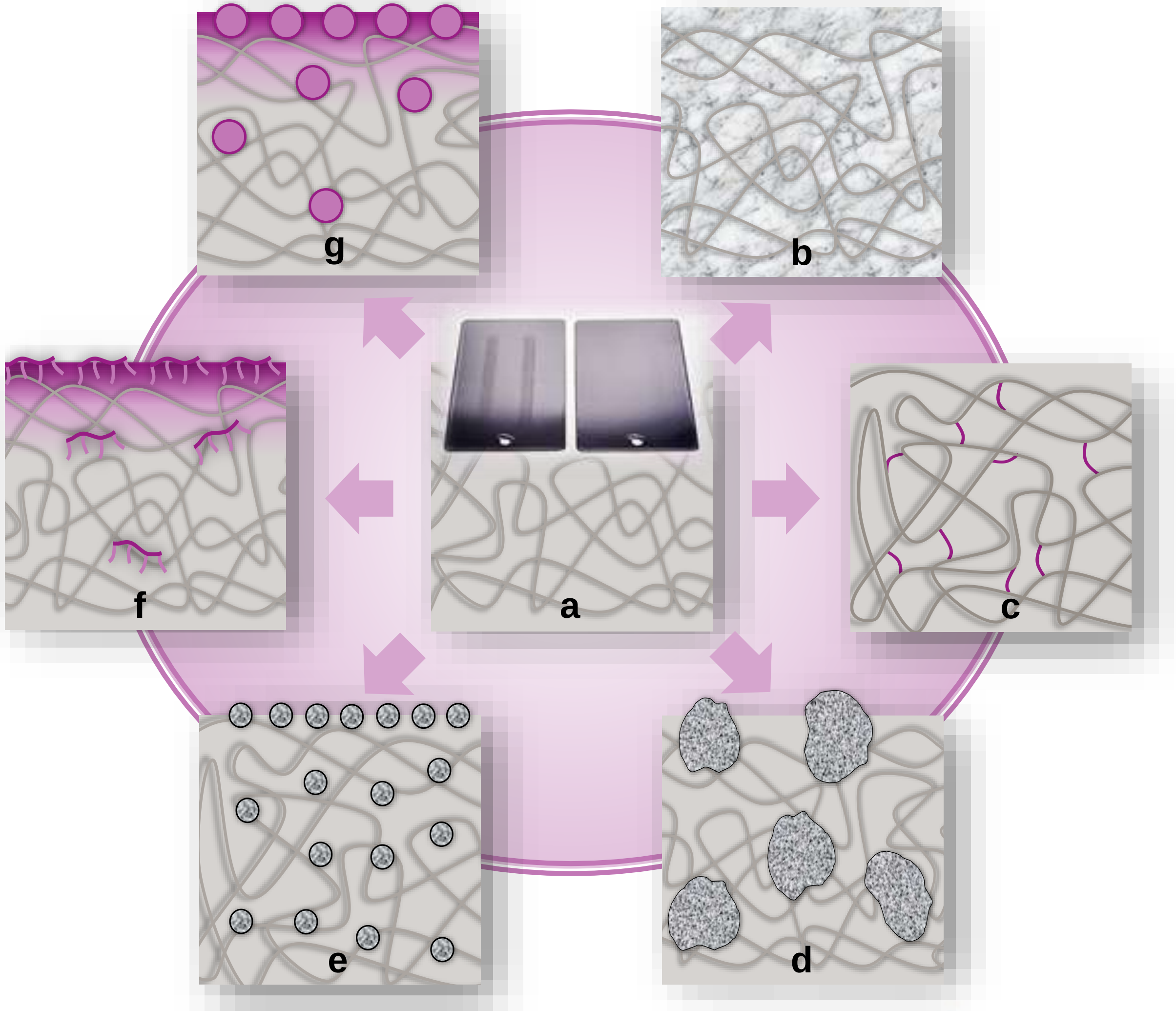
c) matrix strengthening through increased crosslink density

d) incorporation of silica particles

e) incorporation of nano-silica particles

f) incorporation of polysiloxane-based surface additives

g) incorporation of polysiloxane-based emulsion additives



General Formulations of WB Coating Systems A, B, and C

Components	Weight (g)		
	1K WB system A	1K WB system B	2K WB system C
Acrylic emulsion	66.60	0.00	0.00
Self-crosslinkable PUD	0.00	85.71	0.00
OH-functional PUD	0.00	0.00	55.50
Water	27.40	10.29	40.35
Cosolvent	3.00	3.00	3.00
Rheology additive	3.00	1.00	1.15
Hardener	N/A [a]	N/A [a]	22.00
Total	100.00	100.00	122.00
Solid content (wt%)	31.47	30.50	57.00

[a] Not applicable in 1K WB coatings A and B

List of Additives Used in Coating Systems A, B, and C

Additive	Chemical Description	AC [a] (wt%)	Solvent	SSA [b] (m^2/g)	AL [c] (wt%)
SSA-1	Polysiloxane [d]	100	N/A [g]	N/A [g]	0.1, 0.5
SSA-2	Polysiloxane [d]	100	N/A [g]	N/A [g]	0.1, 0.5
SSA-3	PDMS emulsion [d]	65	Water	N/A [g]	0.1, 0.5
SSA-4	PDMS emulsion [d]	65	Water	N/A [g]	0.1, 0.5
NSD	Nano silica dispersion [d]	43	Water	N/A [g]	3.0, 5.0, 10.0
HFS	Hydrophobic fumed silica [e,f]	100	N/A [g]	150-190	3.0, 5.0, 10.0
SPS	Spherical precipitated silica [e]	100	N/A [g]	≤12	3.0, 5.0, 10.0
CBA-1	Polyester dispersion [d]	45	Water	N/A [g]	3.0, 5.0, 10.0
CBA-2	Polyurethane polyol [d]	33	Water	N/A [g]	3.0, 5.0, 10.0

[a] Active Content
[b] Specific Surface Area according to Brunauer-Emmett-Teller (BET) Theory
[c] Addition Level: Solid wt% calculated on the total solid content of the formulations
[d] Delivery form is liquid
[e] Delivery form is powder
[f] Structure-modified easy-to-disperse form
[g] Not applicable

Accelerated Abrasion Testing

Working based on linear motions

- *Multi-Finger Scratch Tester*
- *Scrub Abrasion Tester*
- *Crockmeter*

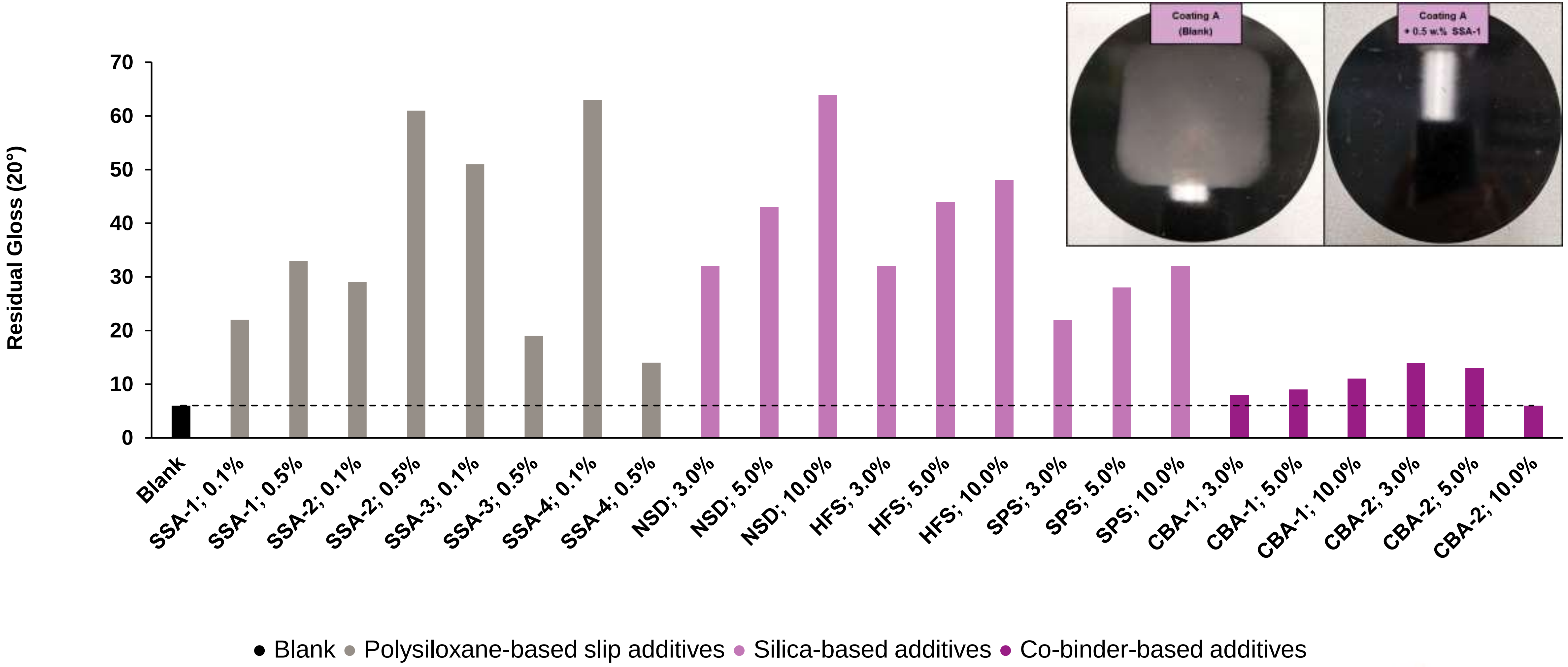
Working based on rotating disks

- *Abraser*
- *Shear Tester*
- *Martindale*

Characterization

Method	Instrument	Description
Rotating Disks	Abraser (Taber Industries)	Side weights of 500 g each and wheels made of CS-10 sandpaper. The weight losses of coated panels were measured after 500 cycles.
Rotating Disks	Shear Tester (Taber Industries)	A specimen rotates at 5.0 revolutions per minute (RPM) and scratching/marring occurs as the specimen comes in contact with either the diamond or carbide tools. An adjustable load is applied to the scratch tool. In general, mar resistance is reported as the amount of weight required to just produce a barely visible scuffing or loss of gloss. In this study, a diamond conical needle was used, and the weight needed to damage the coating was recorded.
Linear Motions	Crockmeter (SDL Atlas)	Equipped with a cloth pad, the pad is loaded with a constant 9 N charge and moved back and forth with a sliding velocity of ~20 mm/s in a straight line.25 The 20° gloss values of the marred surfaces were measured using a micro-TRI-gloss (BYK Instruments).
Rotating Disks	Martindale (James Heal)	After 50 cycles according to standard ASTM D4966.26 The 20° gloss values of the surfaces were measured and recorded before and after the abrasion tests
Indentation	Martens (Fischer GmbH)	This test is based on the principle of forcing the vertex of an indenter into the surface of a coating and measuring the indentation depth under a working force that has been maintained for 30 s.

Residual gloss of coatings based on 1K WB system A measured after an abrasion test by a Martindale instrument



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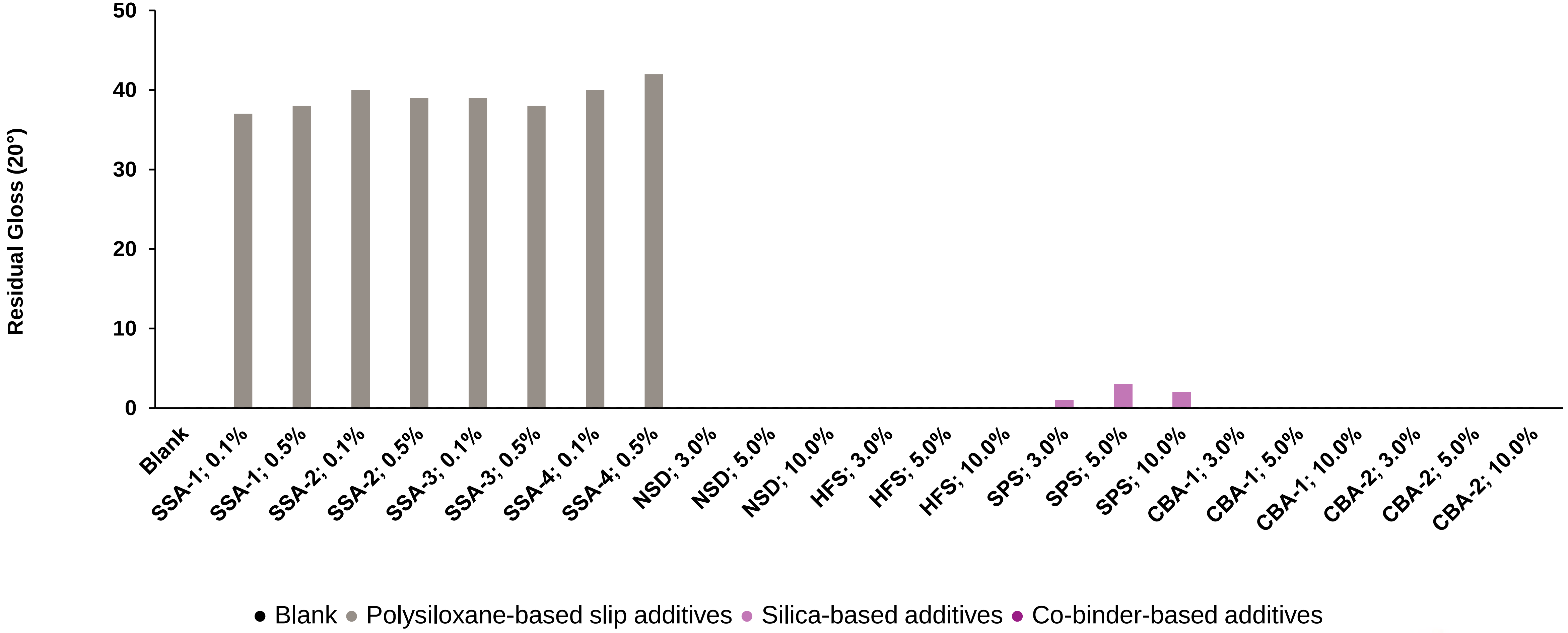
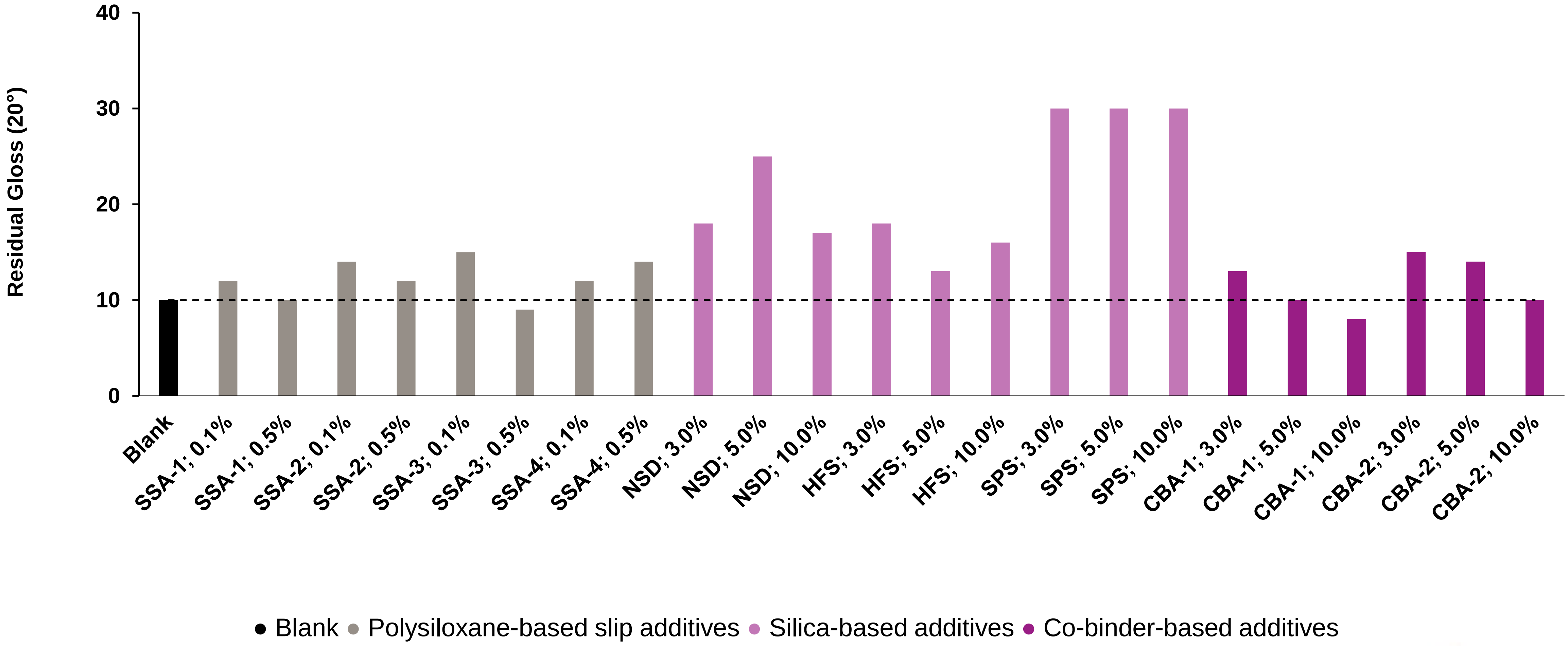
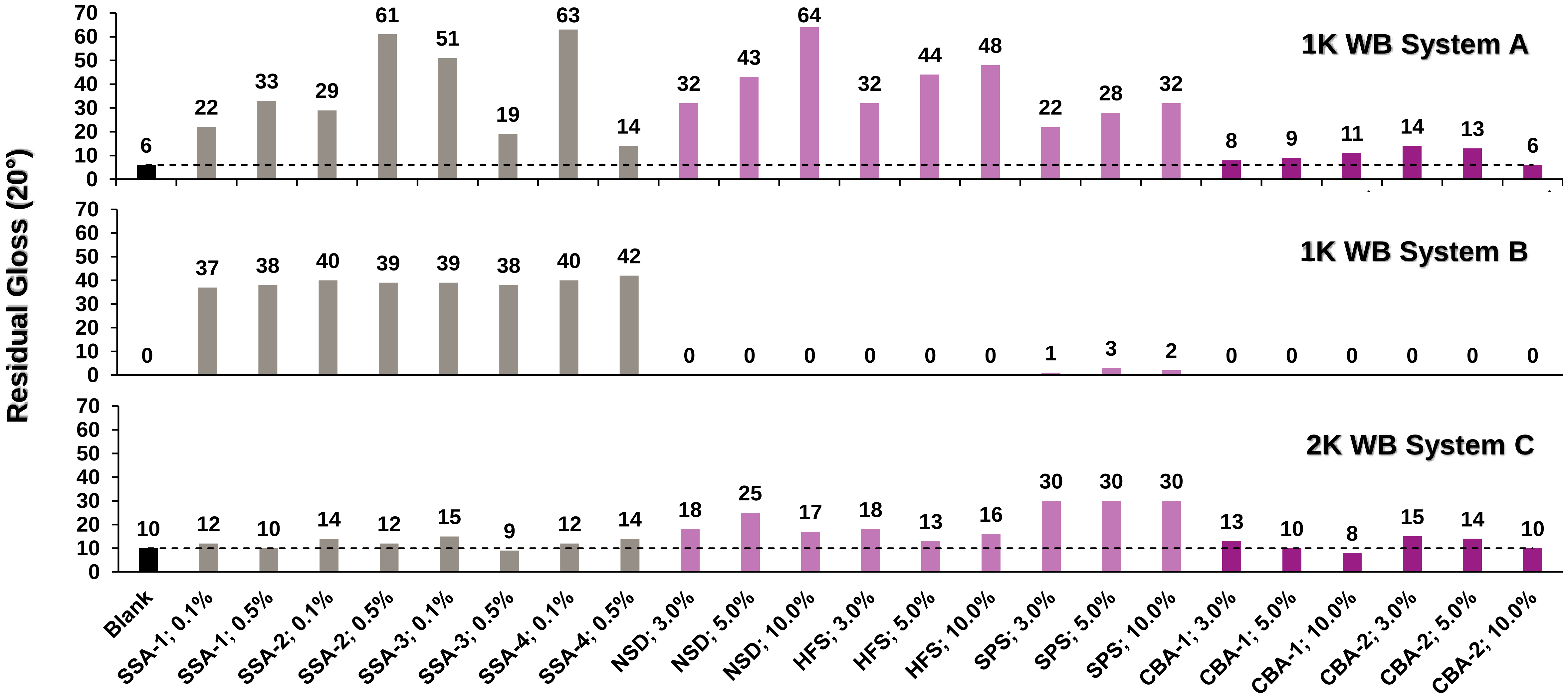
Residual gloss of coatings based on 1K WB system B measured after an abrasion test by a Martindale instrument



Residual gloss of coatings based on 2K WB system C measured after an abrasion test by a Martindale instrument

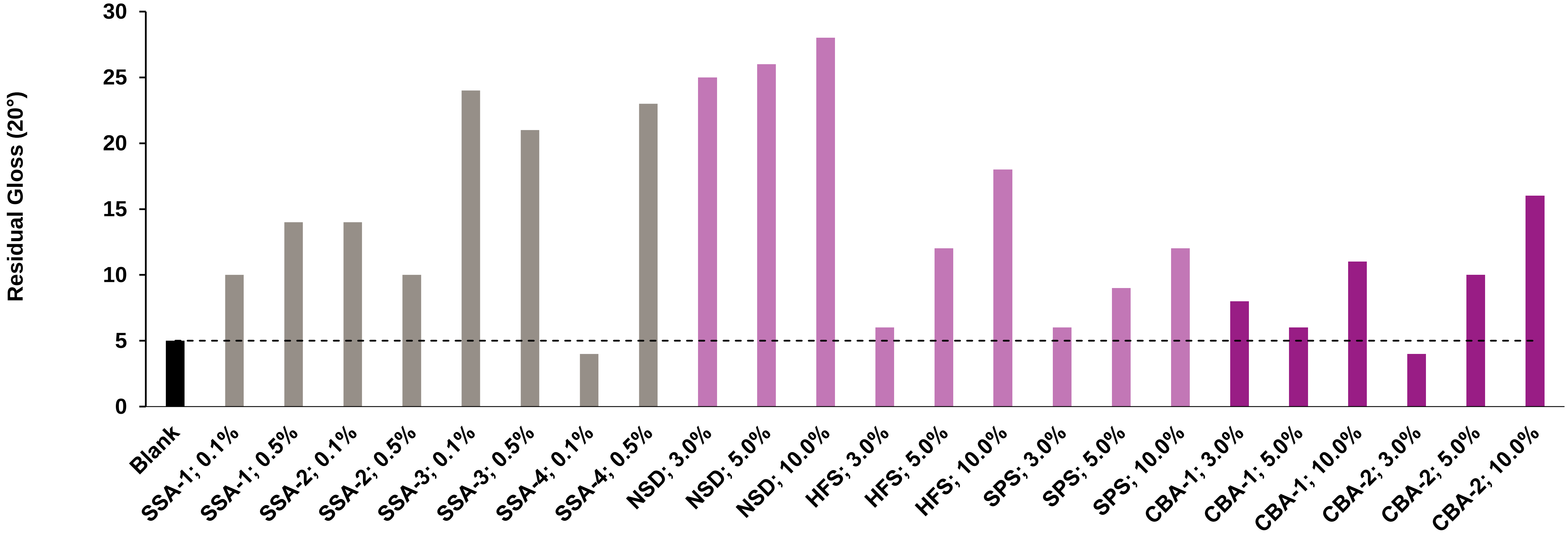


Abrasion test results by a Martindale instrument

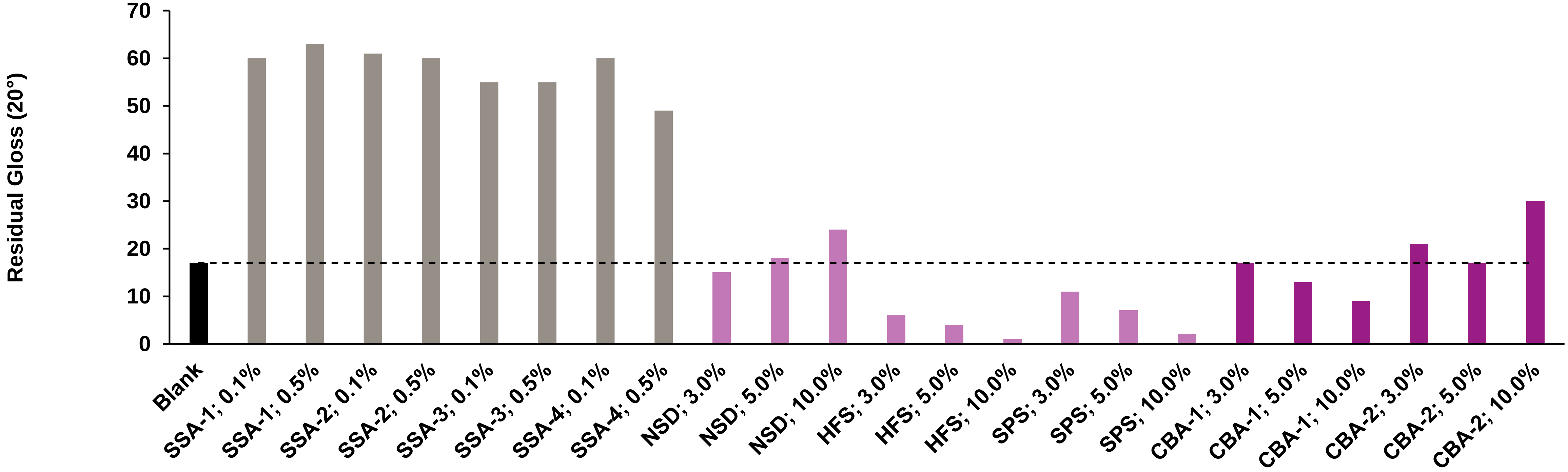


● Blank ● Polysiloxane-based slip additives
● Silica-based additives ● Co-binder-based additives

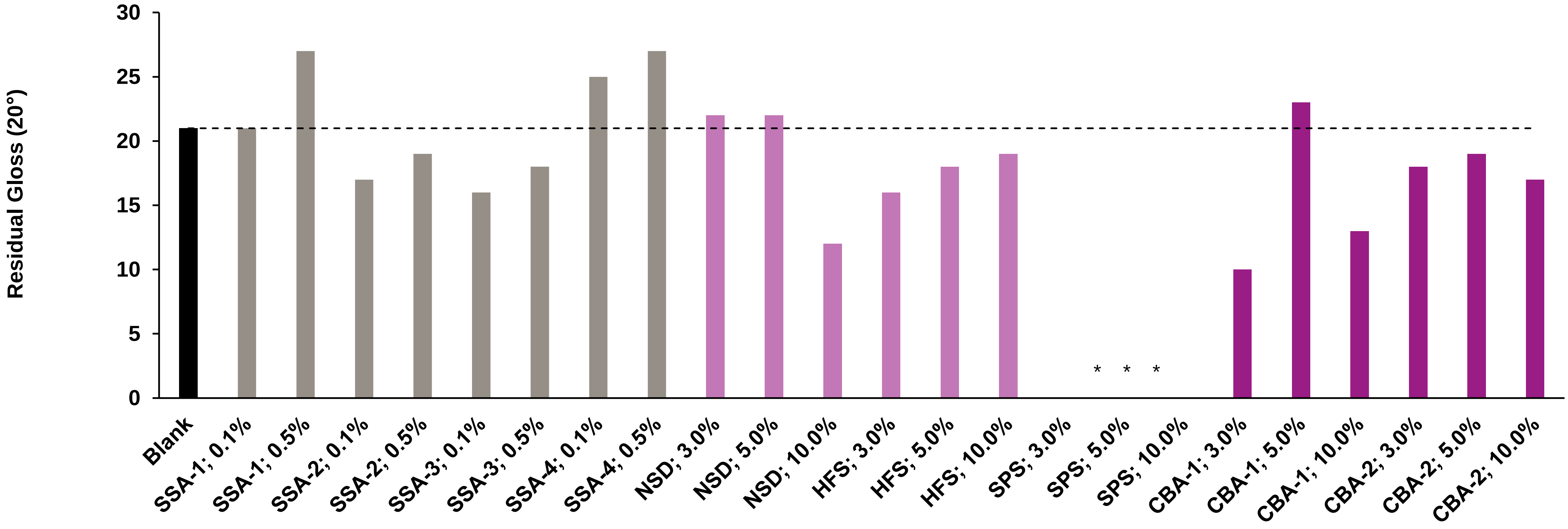
Residual gloss of coatings based on 1K WB system A measured after an abrasion test by a Crockmeter instrument



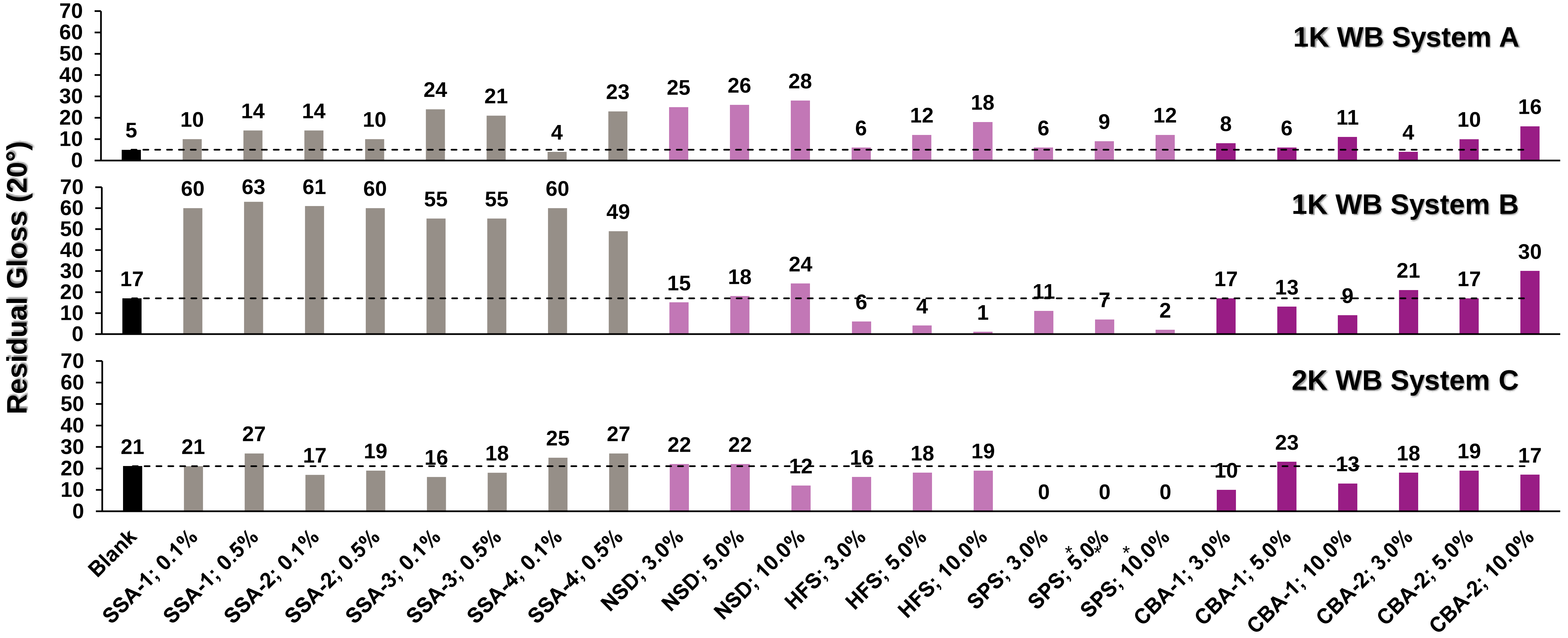
Residual gloss of coatings based on 1K WB system B measured after an abrasion test by a Crockmeter instrument



Residual gloss of coatings based on 2K WB system C measured after an abrasion test by a Crockmeter instrument



Abrasion test results by a Crockmeter instrument



● Blank ● Polysiloxane-based slip additives
● Silica-based additives ● Co-binder-based additives

Conclusions

- ✓ The goal of the present research was to achieve a good understanding of the effects of coating additives on the abrasion resistance of waterborne coatings.
- ✓ In coatings with low crosslink density such as 1K WB coating A, nano-silica dispersion additive NSD as well as high T_g co-binder additive CBA-2 significantly improved the abrasion resistance as determined by results from the Taber Abraser test. However, such a good relationship between the additives type/level and the abrasion resistance was not found in coatings with higher crosslink density such as 2K WB system C. This could be due to the increased hardness of these highly crosslinked coatings, which made the effects of additives less significant.
- ✓ In contrast to the Taber Abraser test, the Taber Shear test did not provide conclusive results. In addition, a significant correlation between the results and coating types was not found.
- ✓ The abrasion results produced by the Martindale, Crockmeter, and Martens instruments were highly dependent on the coating systems tested.
- ✓ As durability becomes an increasingly important performance parameter to improve in waterborne coatings, this study demonstrated that there is no one additive technology to improve durability across all types of test methods.
- ✓ This study demonstrated that specific solutions vary depending on the formulation and specific test method used to assess durability.

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