nanophase technologies corporation

INNOVATE. PERFORM. SUCCEED.

Enhanced Wear Protection of UV-Cured Clear Coats using Sub-Micron Aluminum Oxide Additives

RadTech, 30 April 2012

Outline

- Nanotechnology/UV-cured coatings
- Properties of sub-micron alumina particles
- Alumina dispersion development
- Scratch and abrasion resistance
- Optimization
- Summary

Waterborne UV-Curable Coatings

- High performance, high value coatings
- Can be applied to many different substrates and are used in many different markets
  - Wood: Furniture, cabinets, flooring
  - Plastic: Electronics, consumer goods
  - Paper: Graphic arts, foil, packaging
  - Metal: Automotive, can coatings

- The waterborne UV-curable coatings market has a high growth rate, largely due to:
  - Low VOCs
  - High performance compared to traditional waterborne formulations

Enhanced Wear Resistance

- In many applications, waterborne UV-curable coatings are used to protect substrates from wear-related damage
- Additives are often used in the formulations to improve the level of surface protection: e.g. silicas, waxes, silicones
- Each of these additives are limited in their effectiveness and may lead to other undesirable side effects
- An ideal wear resistant additive would offer protection at low loading levels, have little to no effect on transparency, and not negatively affect other properties of the coating

Approach:

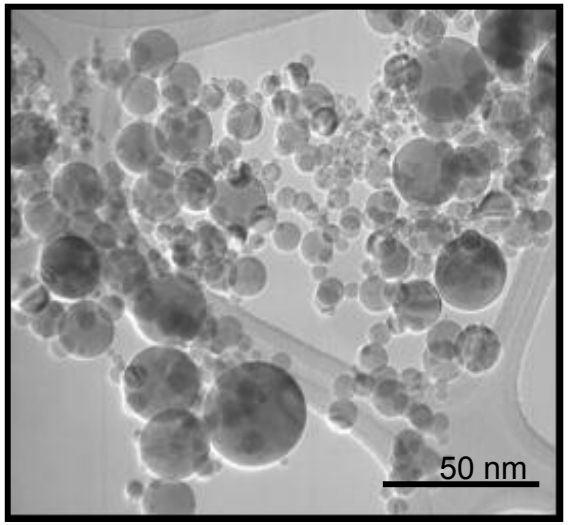
Employ nanotechnology to improve the wear resistance:

- Utilize the high hardness of aluminum oxide
- Take advantage of nano and sub-micron size particles to minimize light scattering (maintain clarity) of the coating
- Engineer the particle surface treatment to ensure compatibility and performance with the coating formulation
- Optimize the particle size and loading level to achieve maximum performance

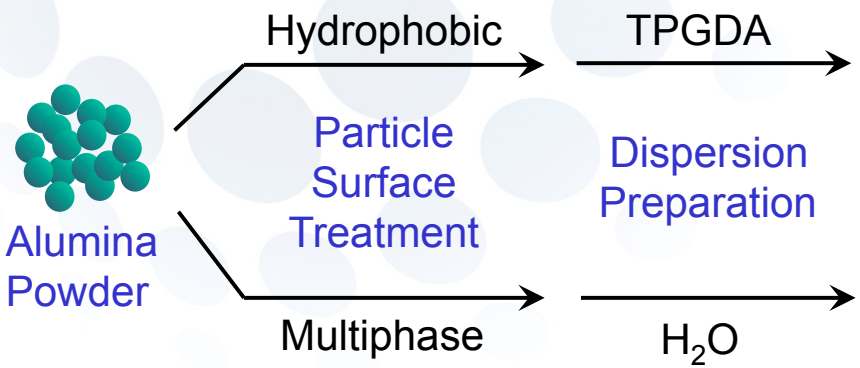
Alumina Particles - Properties

Plasma Arc Alumina:

- Non-aggregated discrete particles
- 8-9 Mohs hardness
- Dispersible at high concentration in water, solvents, and acrylate monomers
- Non-migratory in coatings
- Effective for scratch/abrasion resistance at low loadings
- Minimal impact on coating clarity
- No appreciable impact on coating viscosity, adhesion, flexibility, coefficient of friction, etc.



Formulation Compatibility



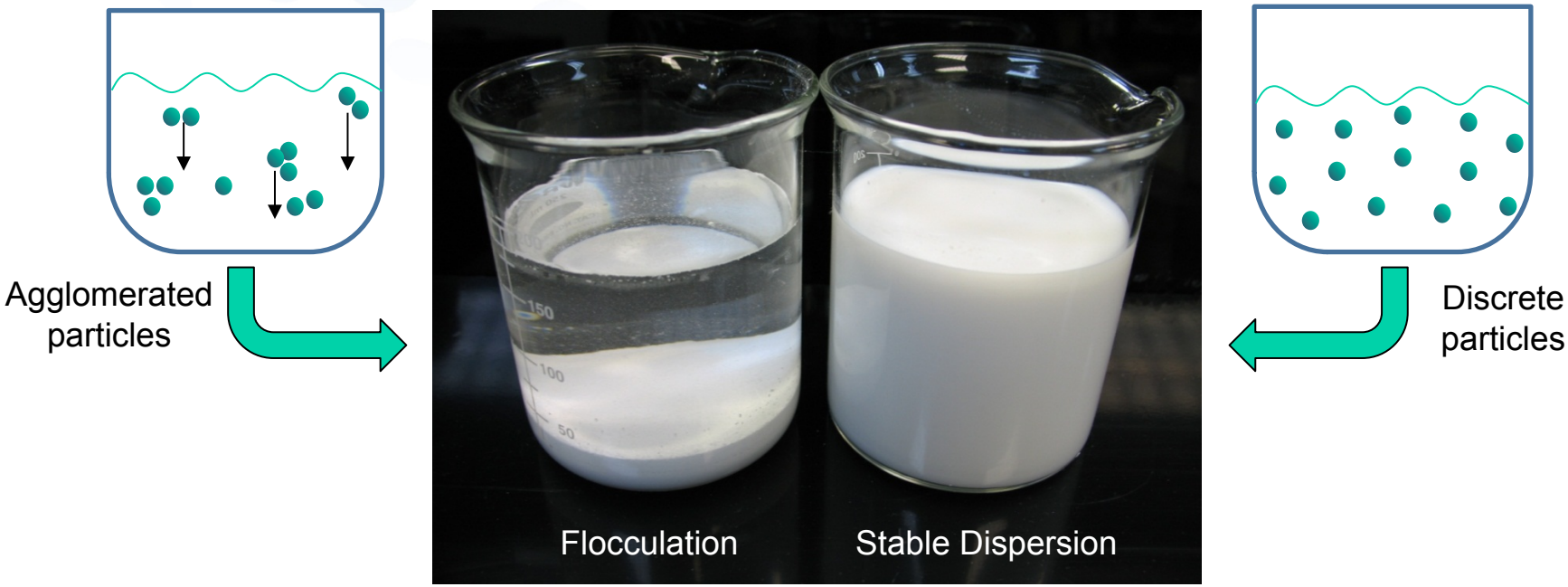
The concentrated alumina dispersions can be added directly to the coating formulation without the need for grinding, milling, or high shear dispersing

Particle Size, nm	Alumina, wt% in TPGDA	Alumina, wt% in H_2O
20	30	30
40	30	50
150	45	45
250	55	55
800	55	55

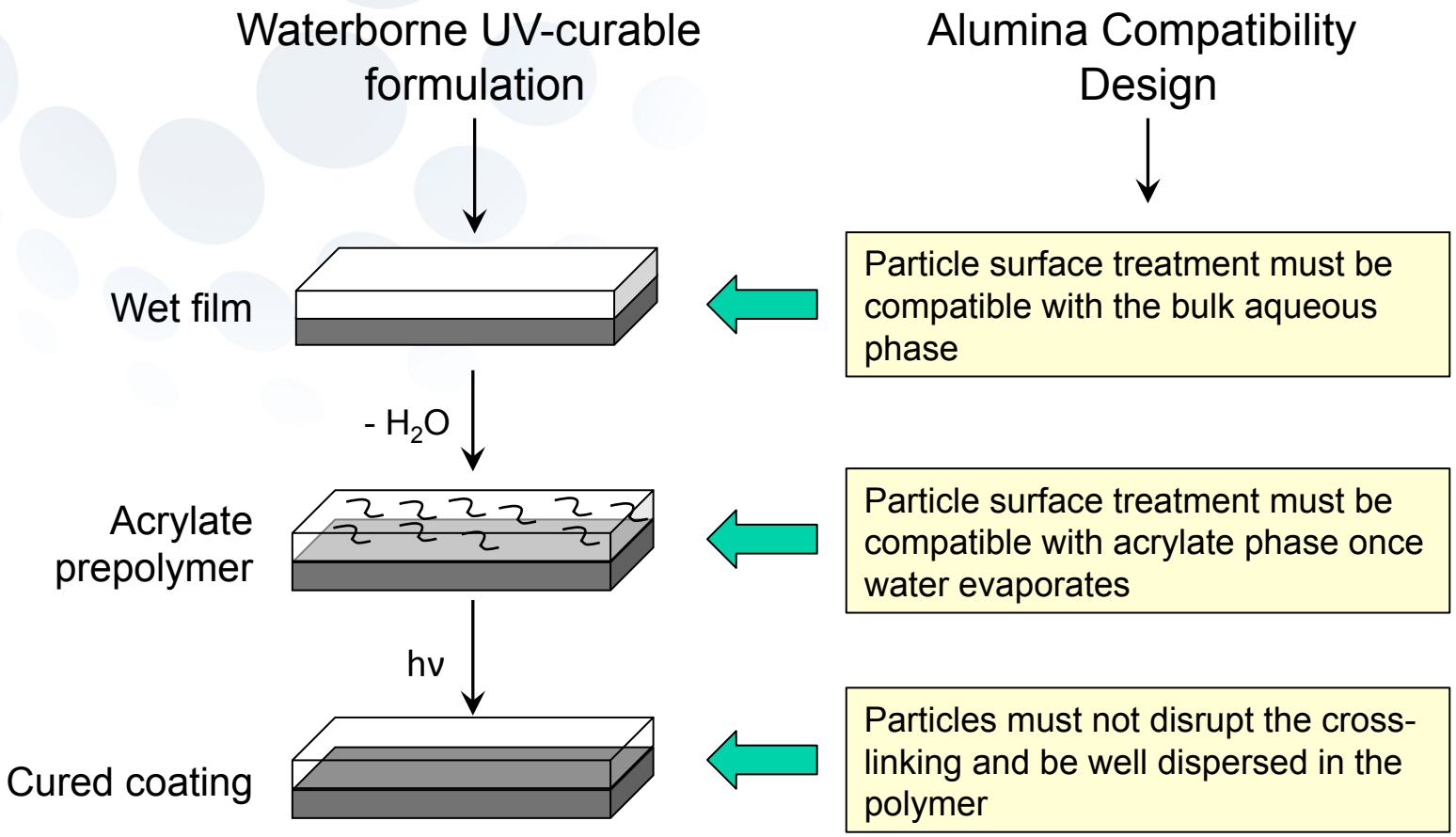
Alumina Dispersion Stability

Concentrated alumina dispersions with long-term stability

- The surface treatment must be specifically designed for the dispersion solvent to avoid particle agglomeration
- The particle surface treatment must also be compatible with all the components of the coating formulation

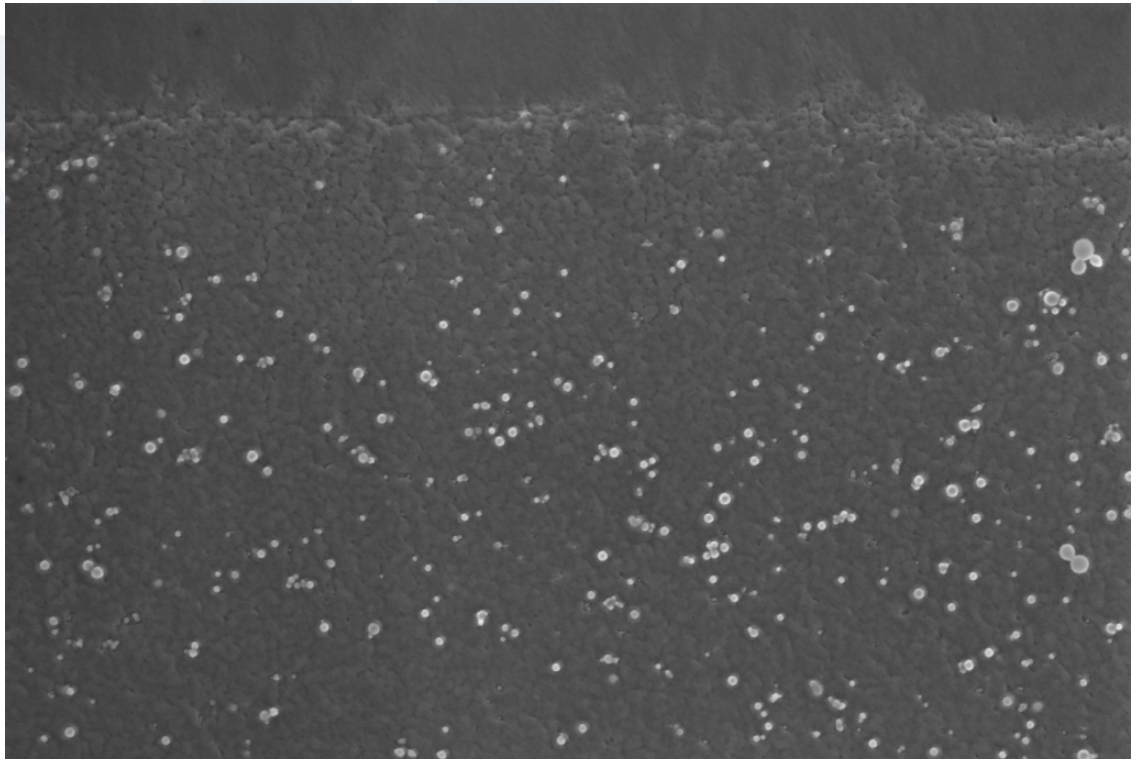


Design for Waterborne UV-Curable Formulations



Nanoparticle Dispersion in UV-Curable

SEM cross section of waterborne UV-cured wood topcoat



← Coating surface

1 wt% 40 nm alumina particles

Wear Resistance in Waterborne UV-Curable

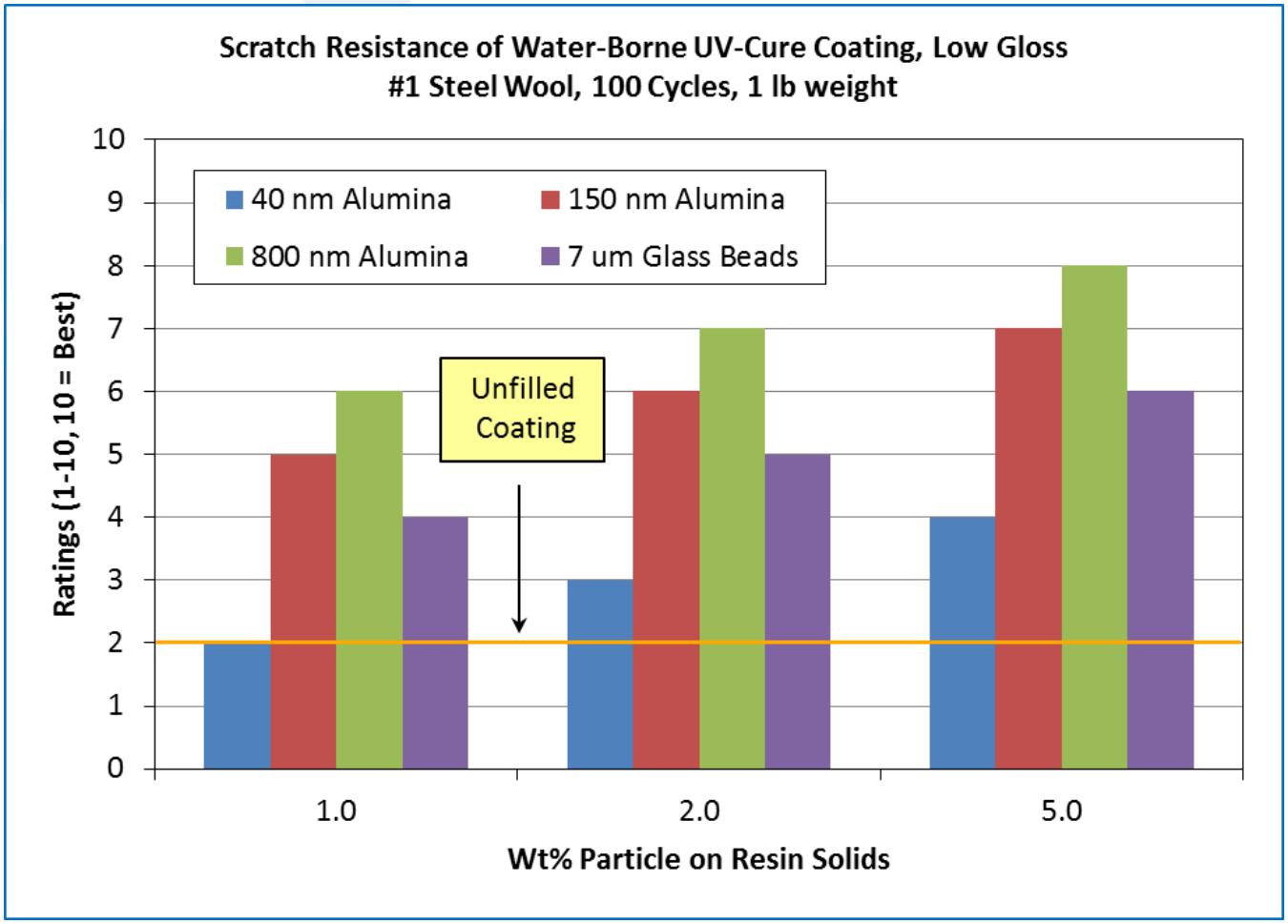
- Investigate the impact of pre-dispersed alumina additives on:
  - Coating clarity
  - Scratch resistance
  - Abrasion resistance
- Coating System
  - Waterborne low-gloss wood topcoat, 40% solids
  - Aqueous alumina dispersions post-added to the full coating formulation with stirring
  - 3 mil wft, cured at 1.8 J/cm^2
- Variables
  - Particle size: 40, 150, 800 nm
  - Particle loading level: 1, 2, 5 wt%

Waterborne Low Gloss Wood Topcoat

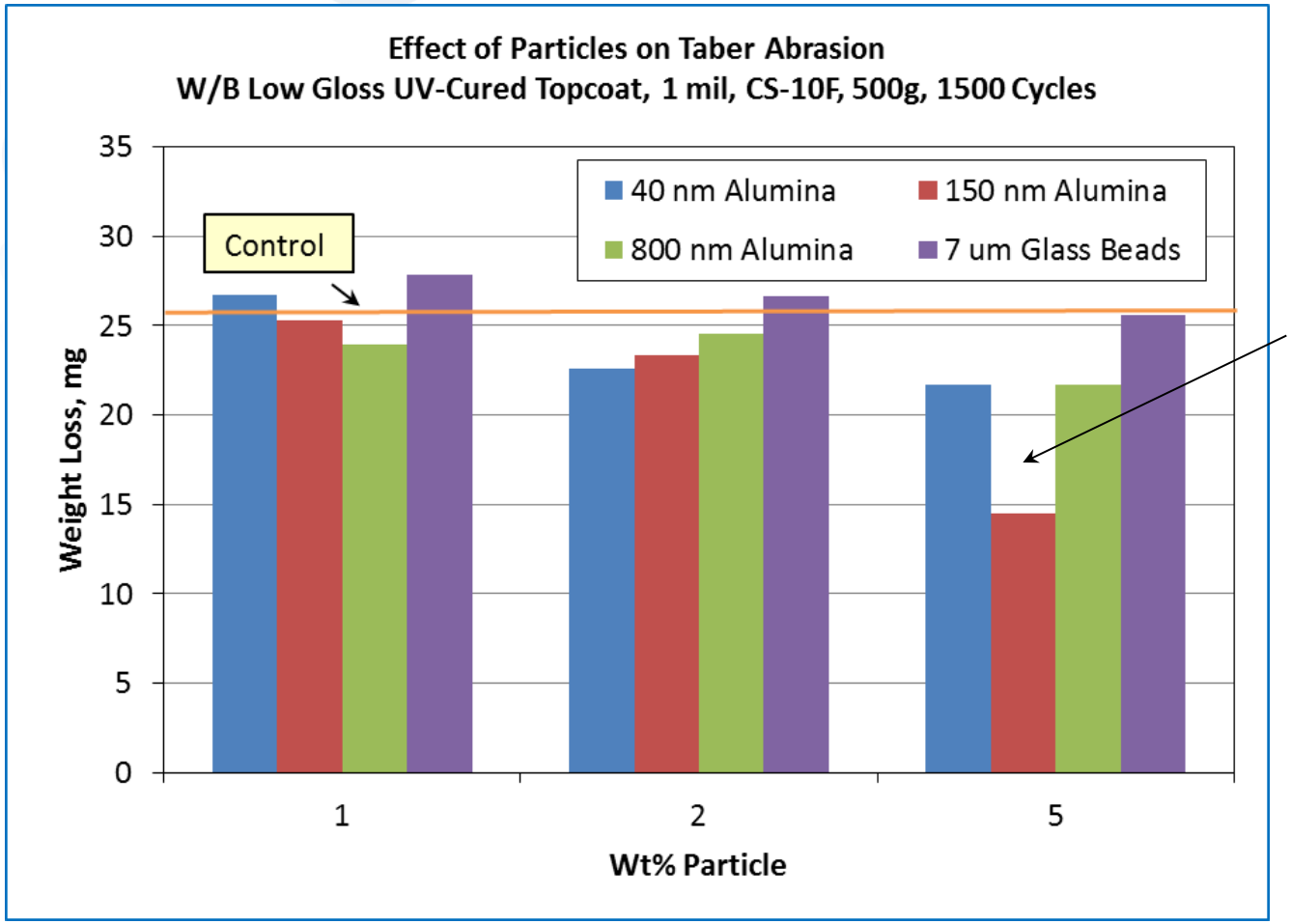
- Reciprocating Linear Scratch Tester
  - Drawdowns on black gloss cards
  - #1 steel wool, 8 g/cm^2 pressure, 100 double rubs
  - Visual rating of coatings

- Taber Abrader
  - Drawdowns on clear PET substrate
  - Taber abrader, CS-10F wheels, 500g each, 1500 cycles
  - Measure weight loss and haze gain with cycles

Scratch Resistance – Waterborne Topcoat

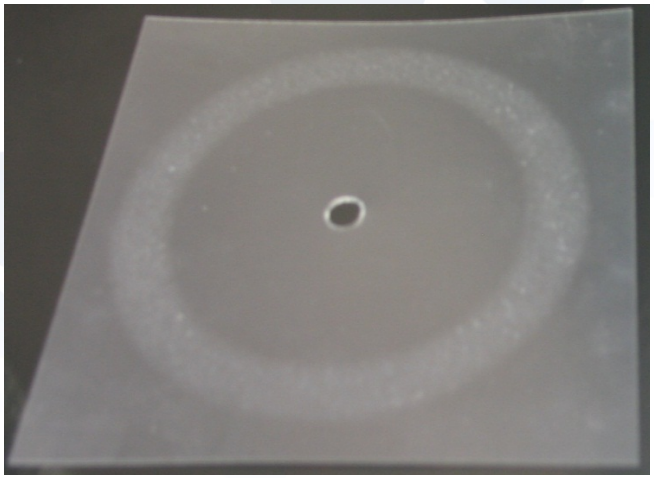


Abrasion Resistance – Waterborne Topcoat

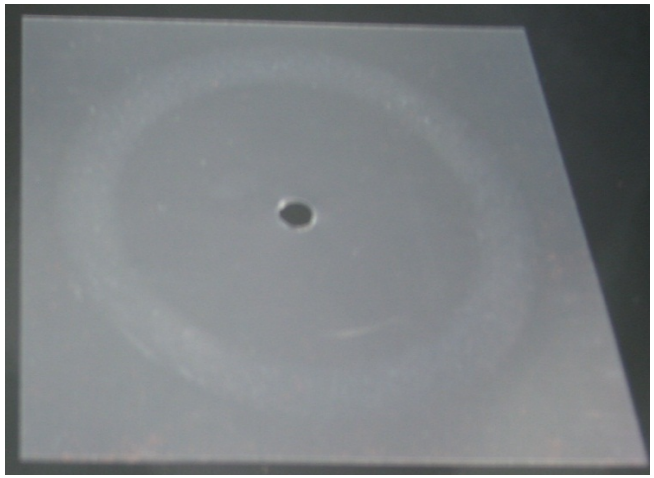


25-40% improvement with 150 and 800 nm alumina

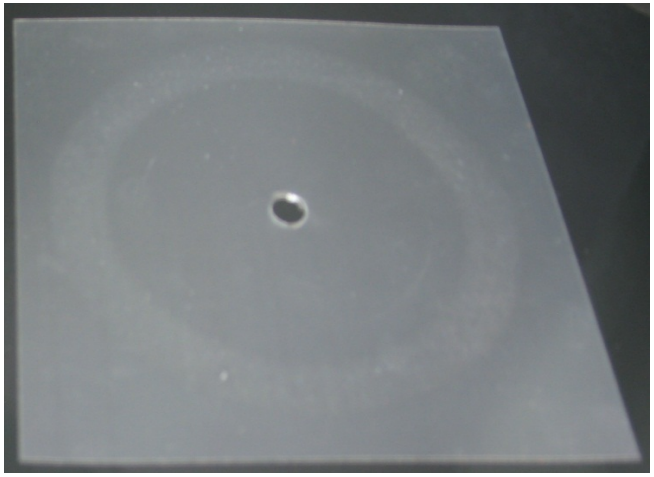
Waterborne Topcoat – Taber, 25 Cycles



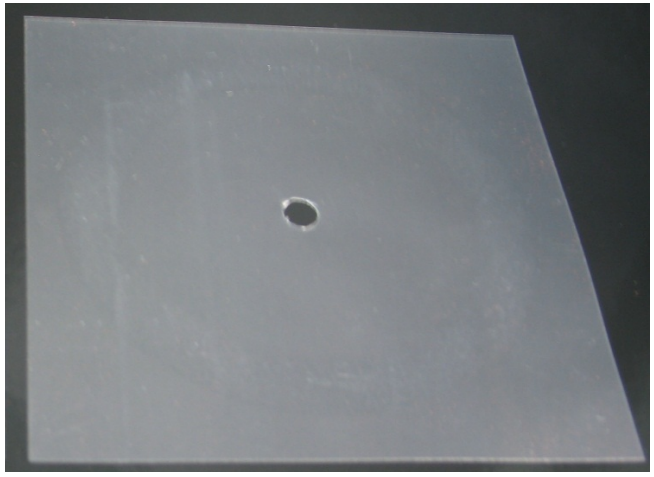
Unfilled Control



40 nm Alumina, 1 wt%



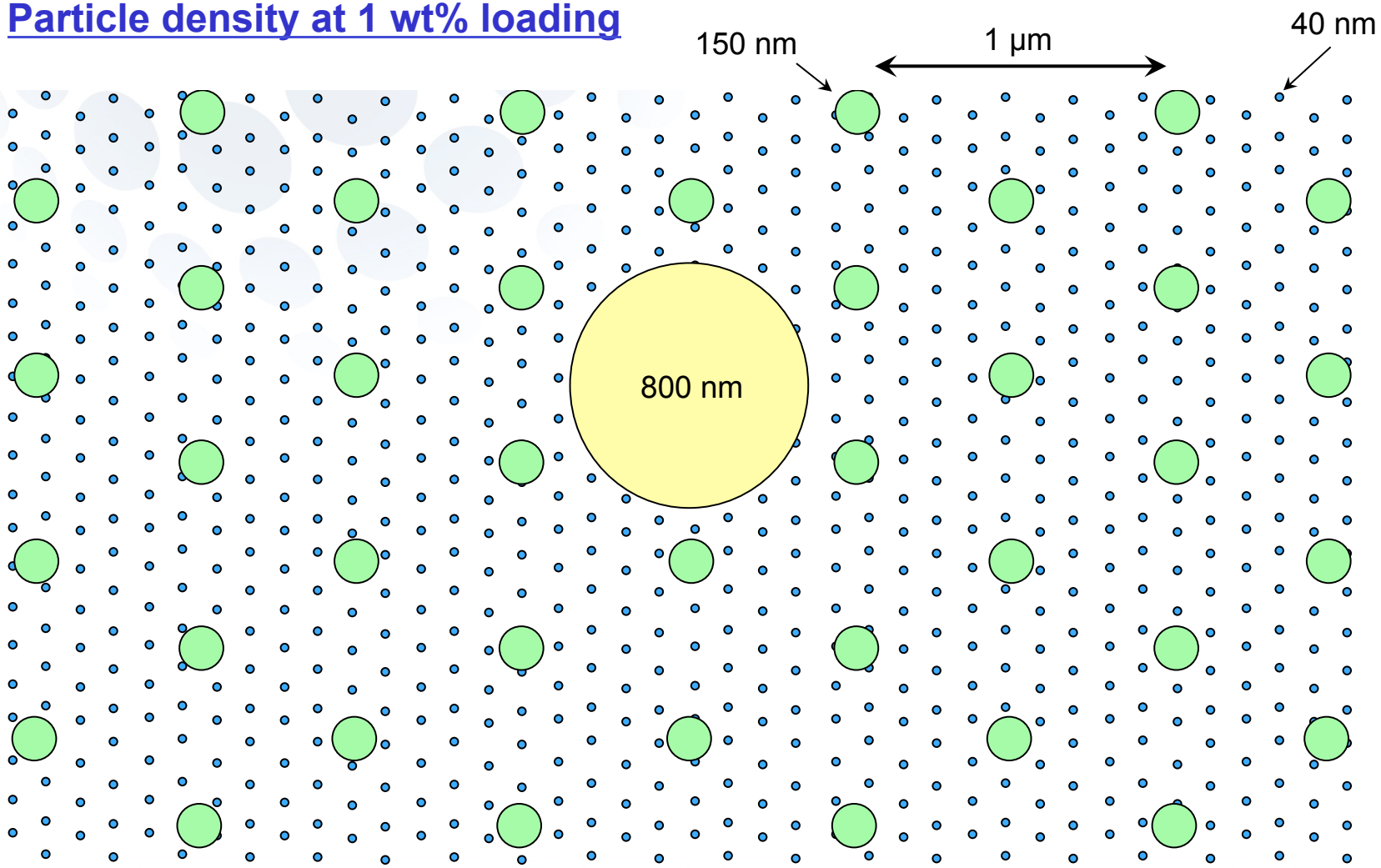
150 nm Alumina, 1 wt%



800 nm Alumina, 1 wt%

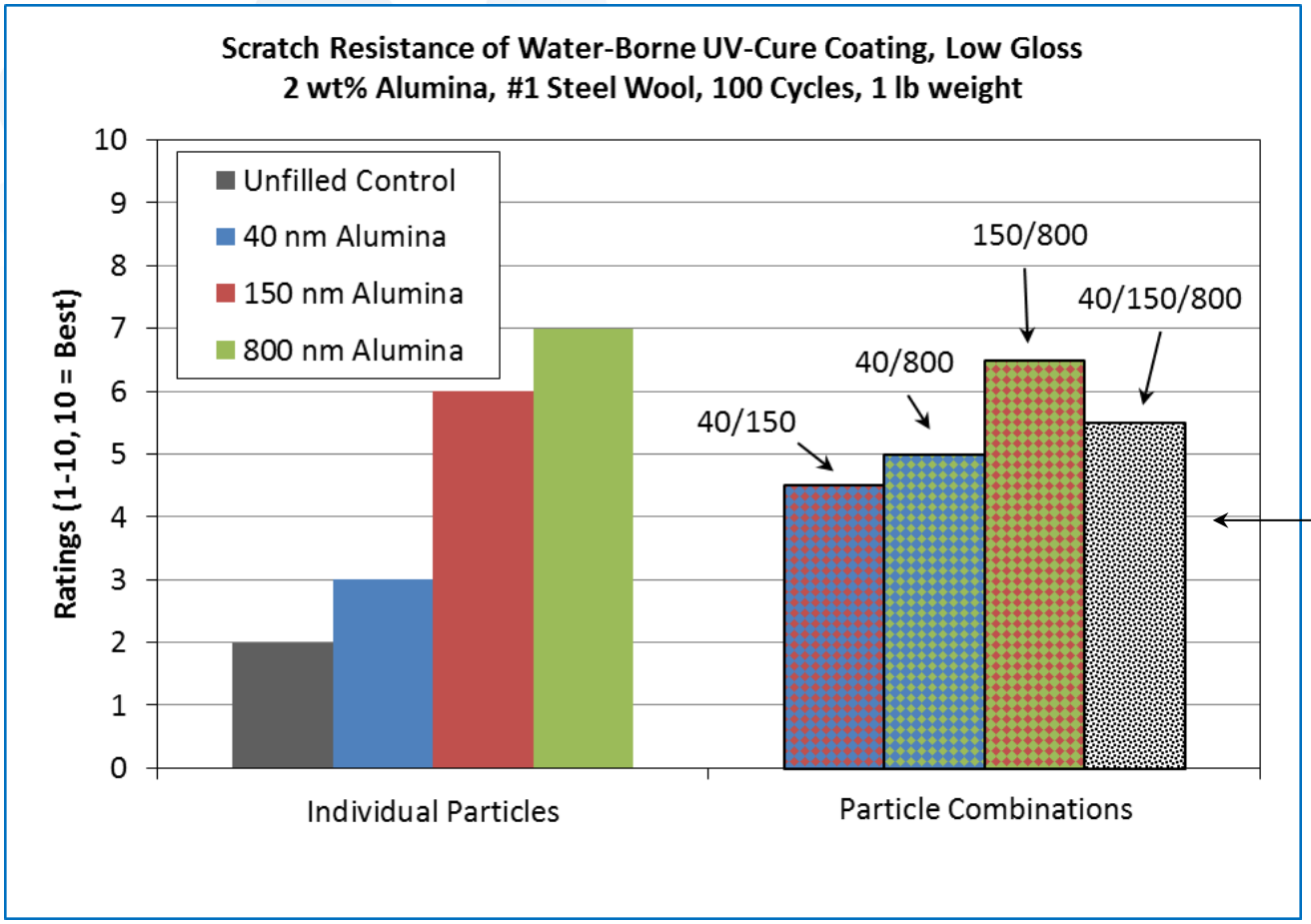
Alumina Particle Size Combinations

Particle density at 1 wt% loading



Scratch Resistance – Waterborne Topcoat

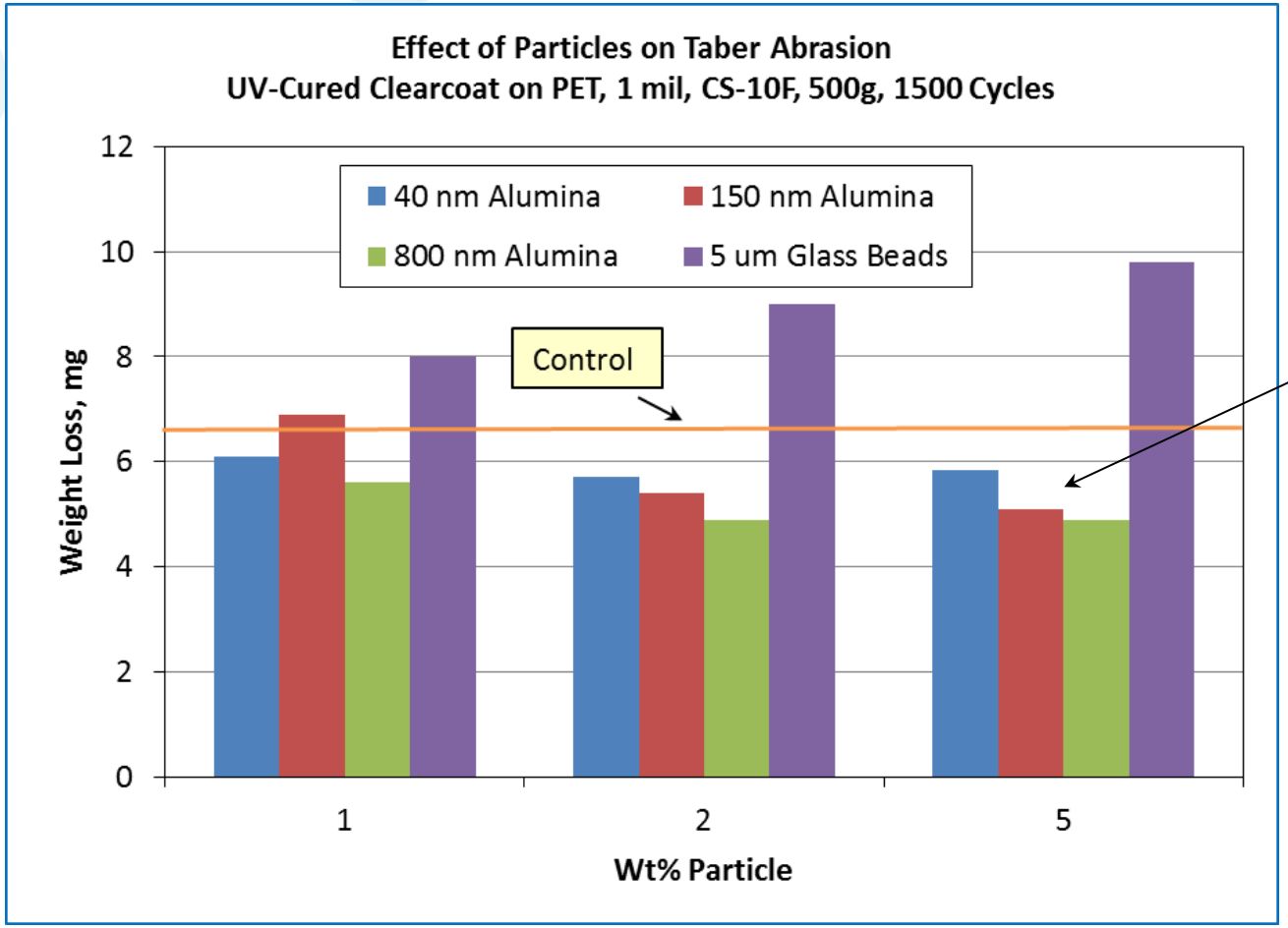
Combinations of alumina particle sizes for scratch resistance



Effect of Alumina on 100% Solids Coating

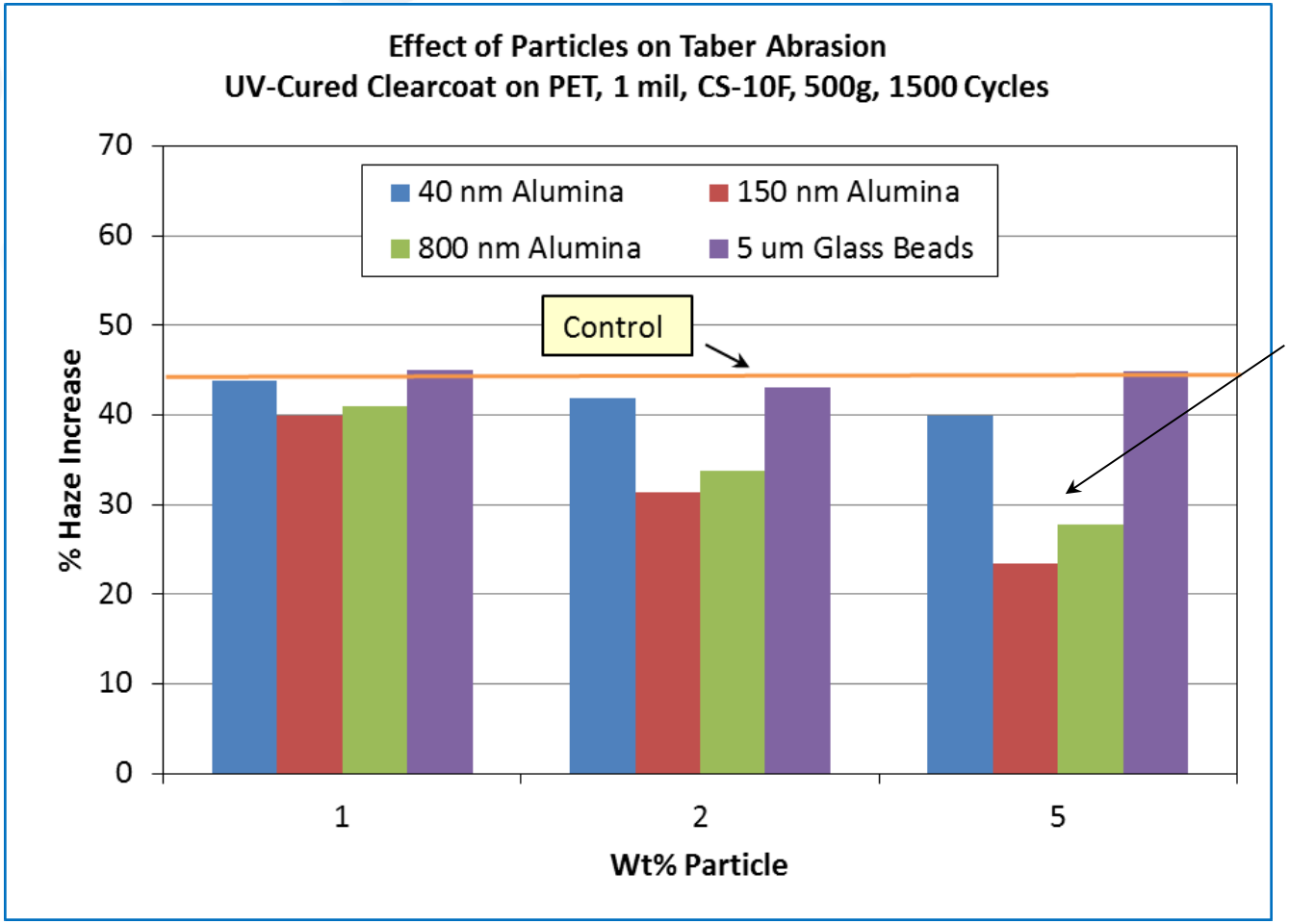
- Coating System
  - 100% solids high gloss urethane clearcoat
  - 1 mil dft
- Taber Abrader
  - Drawdowns on clear PET substrate
  - Taber abrader, CS-10F wheels, 500g each, 1500 cycles
  - Measure weight loss and haze gain with cycles

Abrasion Resistance – High-Gloss Clearcoat



20-25% less weight loss with 150 and 800 nm alumina

Abrasion Resistance – High-Gloss Clearcoat



50% less haze build with 150 and 800 nm alumina

Optimization Parameters

Critical coating requirements:

- **Clarity:** What type of substrate is being used and what degree of transparency is required?
- **Thickness:** What is the final film thickness?
- **Wear:** What level of protection is required; mar, scratch, abrasion?
- **Resin:** What type of flexibility and hardness is demanded in the coating?

Optimize the scratch resistance of the system based on an understanding of the effects of particle size and loading level

Optimization in UV-Cured Coatings

Parameter	Electronics Coating	Plastics Coating	Wood Top Coat	Matted/ Low Gloss
Clarity Need	Very High	High	Low	Very Low
Thickness	Thin	Thin	Thick	Variable
Wear Type	Scratch	Scratch	Abrasion	Scratch/ Abrasion
Resin	Very Hard	Soft	Hard	Variable
Recommendation				
Alumina Particle	40 nm	150 nm	800 nm	150-800 nm
Loading Level	2-4 wt%	0.5-1 wt%	1-2 wt%	1-3 wt%

Summary

- Submicron alumina particles can be surface-treated to be compatible with waterborne UV-curable coating formulations
- Concentrated dispersions of the treated alumina particles can be prepared in water or acrylate monomers
- The alumina particles provide scratch and abrasion resistance at relatively low loading levels (1-5 wt%)
- Overall performance requires optimization of particle size and weight loading based on:
  - Clarity requirements
  - Coating thickness
  - Resin Type
  - Degree of wear resistance desired

Thank You

For additional company and product information please visit our booth or contact…

Nanophase Technologies Corporation

630-771-6709

www.nanophase.com