Matting Optimization: Achieving High Quality, Ultra-Low Matte Radiation Curable Wood Coatings

Mike Toth
BYK USA
Wallingford, CT
USA

Trends to Low & Ultra Low Matte Finishes

In modern wood coatings, UV curable technologies are growing worldwide. High quality aqueous, solvent-borne and solvent-free UV coatings exist to protect consumer wood (and non-wood) products such as hardwood flooring, kitchen cabinets, millwork, store fixtures, LVT flooring, and office and residential furniture. Traditionally formulated for clear systems with typical gloss ranges from satin to high gloss coatings, recent consumer wood coating trends have gravitated toward much deeper, in some instances, ultra-low matte finishes. In today's market, some consumers seek the appearance of bare wood with deeply matted finishes, but simultaneously demand superior surface durability and optical appearance that only high quality finishes can provide. Can formulators provide a flawless surface with the scratch, stain, chemical and UV fade resistance properties that consumers desire in a low matte finish? The answer is yes, if the coating is:

1.) Properly formulated with dispersing additives that are efficient at reducing processing viscosity and enabling Newtonian flow behavior, while accepting the addition of heavy silica or matting agent loading.
2.) Able to incorporate compatible technologies like wax dispersions or mixed mineral synthetic clays, to compliment silica based matting agents resulting in an improved surface finish.

Dispersant Requirements to Achieve Low Gloss Stability and Improved Flow

In order to attain deeper matte radiation-curable wood coatings, the efficient "wetting" of broad pigment varieties is of paramount importance to achieve the lowest gloss and best "hiding" power possible. These dispersants must be compatible in a broad range of commonly used solvents, co-solvents, monomers and oligomers and with a variety of treated and untreated grades of silica(s). To address these demands, advancements in dispersant technology have led to improvements in particle wetting, pigment stabilization and flow in UV coating systems containing silica-based matting agents (Figure 1). Commercially available hyper-branched co-polymer dispersants with pigment affinic groups enable heavy loading of matting agents while enabling Newtonian flow behavior in the coating during both production and application.

Figure 1: Example same 100% UV formulation, at 12% silica loading, hyper-branch co-polymer dispersant on right has superior flow

How Hyper-branched Co-Polymer Dispersants Work

Customized hyper-branched co-polymers with pigment affinic groups work to de-flocculate matting agents by means of steric stabilization (Figure 2A). Steric stabilization can be described as a 3D network of weak intermolecular attractions and repulsions. The anti-flocculation "effect" of the dispersant helps to reduce pigment settling and thereby improves the storage stability of the coating, often mitigating the despised "hard-pack" settling outcome of matting agents left to the natural forces of time, temperature, and gravity. Undoubtedly, the most beneficial result of this chemical interaction between dispersant and the deflocculated matting agents is a Newtonian flow behavior of the now heavily matted coating. Enabling for Newtonian flow provides a significant reduction in processing viscosity and can help to improve the surface leveling characteristics and pigment orientation of the matting agent present in the coating's film (Figure 2B). These custom hyper-branched dispersant technologies often share the same active ingredient, but whose delivery form (carrier) is modified for use in different coating technologies such as aqueous, solvent-borne or solvent-free coating systems.

Figure 2A:

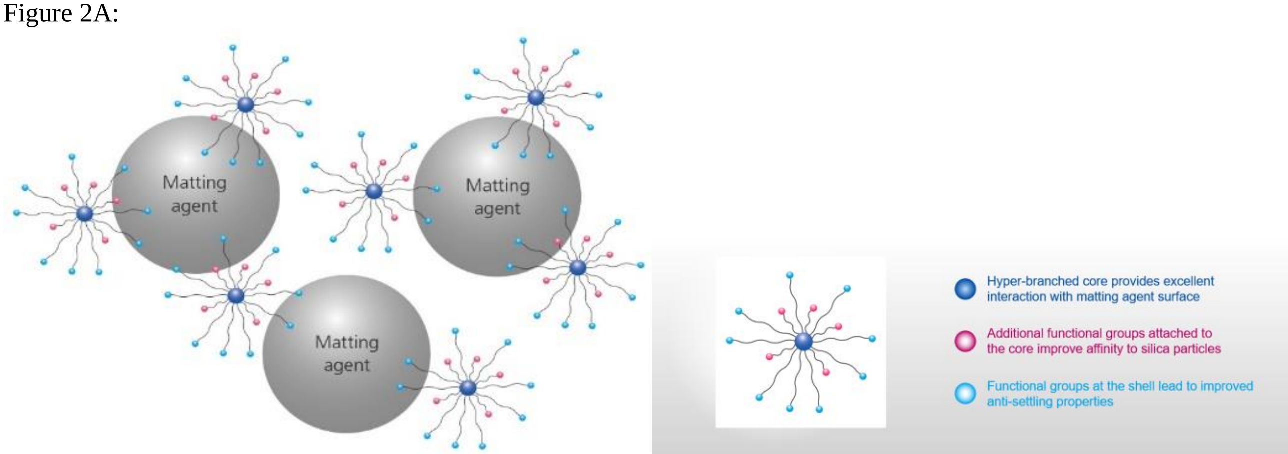
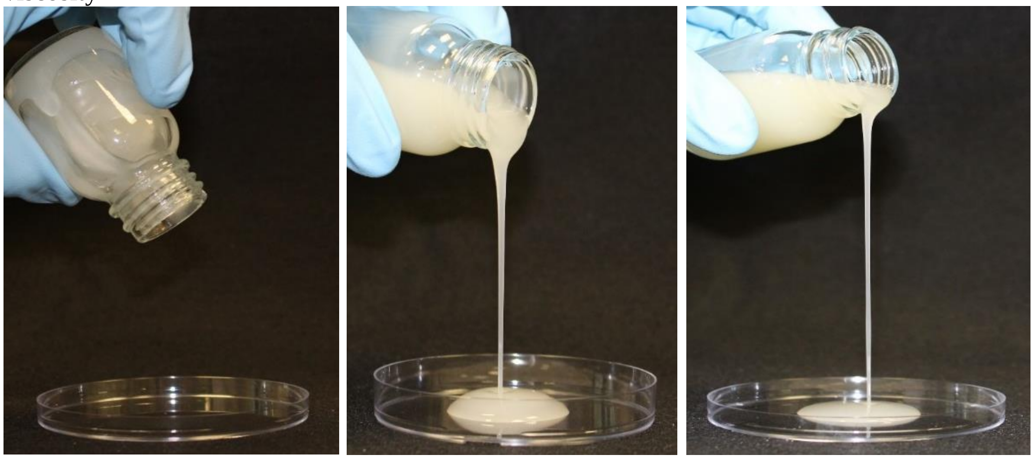
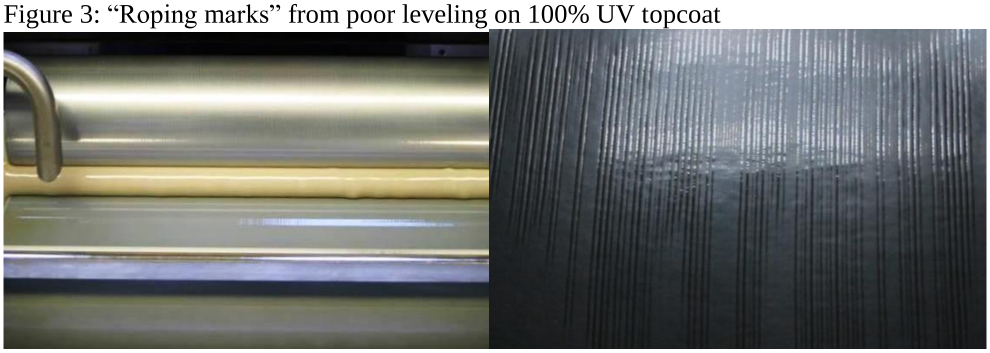


Figure 2B: 100% UV. Left = No dispersant, Center= Standard, Right= optimized flow from hyper-branched results in lower viscosity



Additionally, during roll-coat application (Figure 3) with heavily matted UV coatings, the use of a hyper-branch co-polymer dispersant can improve silica orientation and flow, which helps to eliminate roller marks or "roping" issues caused by poor flow behavior and leveling on the applicator roll. "Roping" on the applicator roller is detrimental to the finish quality as it transfers to the coated part.

Figure 3: "Roping marks" from poor leveling on 100% UV topcoat



Silica-Based Matting Agents Advantage/Disadvantages

UV coatings, especially higher solid and solvent-free UV systems, can be difficult to matte. The higher the resulting shrinkage during film formation, the better the matting efficiency will be. Therefore, aqueous or solvent-based technologies like nitrocellulose lacquers or low solids acrylic aqueous emulsions are often easier to matte. In contrast, high solids, solvent-free, and 100% solids UV coating systems can be a challenge to matte due to the very minimal-to-no film shrinkage that occurs during the expedient curing process with UV lamps. Silica-based matting agents are no doubt very effective with matting; however, silica based matting agents (especially fumed silica) are typically more difficult to handle in manufacturing environments than other matting agent options.

During the manufacturing process, the addition of a silica can cause significant clouds of "dusting" particulates, which can require extra housekeeping, and can be a challenge to ensure all silica particles reach their desired location – the manufacturing vessel. Furthermore, as processing viscosities rise, the addition of silica can cause the coating to have a tendency to "climb" up the vertical shaft of the mixer, complicating the dispersion and particle "wetting" process. Additionally, due to the "fluffy", less dense nature of silica-based matting agents, significant processing time may be required for the addition of powdered silica into manufacturing batches in order to ensure sufficient particle wetting. Another challenge with low matte coating formulations that contain surface treated silica matting agents can be the generation of excessive foam, which may require a higher dosage of defoamer, air release and/or surface additives to correct and may existentially impact the total cost of the formulation.

Other Desirable Performance Characteristics for UV Coatings

Beyond achieving low gloss stability and improved flow, the heavy pigment loading and rapid cure times associated with UV coatings can present additional challenges to formulators who seek to optimize these coatings. Additional formulary considerations to help address market demands for superior UV coatings may require improved clarity, scratch and abrasion resistance, soft feel effect (haptics), stable defoaming action (during production and application) and superior chemical and stain resistance qualities. In order to meet these special requirements, other additive technologies like wax dispersions and micronized waxes, and/or synthetic mixed mineral clays (MMT) can be used in conjunction with different silica types and hyper-branched co-polymer dispersants to achieve high quality results.

Considerations for Wax Dispersions and Micronized Waxes

As previously mentioned, silica-based matting agents are excellent for obtaining matting efficiency in ultra and lower matte coatings but generally have inferior surface performance characteristics for scratch, mar, stain and chemical resistance when compared to wax dispersions or micronized wax additives. Particle size, polarity, and melting point are key factors for the surface performance of a wax. Alternate technologies, such as a liquid wax dispersion or micronized (powder form) wax exist as viable options to compliment silica-based matting agents commonly used in UV formulations. These wax additives can provide some additional matting effect, but more importantly, can significantly help to improve mechanical resistance, chemical resistance, scratch resistance, abrasion resistance, water repellency, and anti-blocking of a coating by being active at the air/surface interface. It is very important to consider the final properties you wish to achieve. (Figure 4A and 4B). Fine particle size micronized waxes in the 5 - 10 micron range that can match those particle sizes of common silica-based matting agents will help contribute to the desired lower optical matting properties.

Figure 4A: Wax additives selection criteria

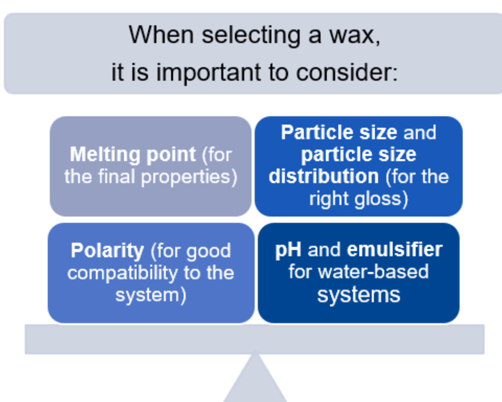


Figure 4B: Surface improvement properties derived from wax chemistries

Furthermore, friendlier "green" technologies and select grades of micronized biodegradable and bio-renewable organic polymer additives exist. The use of "green" organic polymers can be marketed as such while reducing negative impacts to the environment. Since improved distinction of image (DOI) and optical clarity are desirable features to consumers of wood coatings, new advances in micronized wax technology can help provide superior clarity in coating films when compared side by side to silica-based matting agents (Figure 5A, 5B and 5C).

Figure 5A: Micronized organic polymer wax, excellent transparency with matting

Figure 5B: Silica-based matting agent at same dose and gloss level

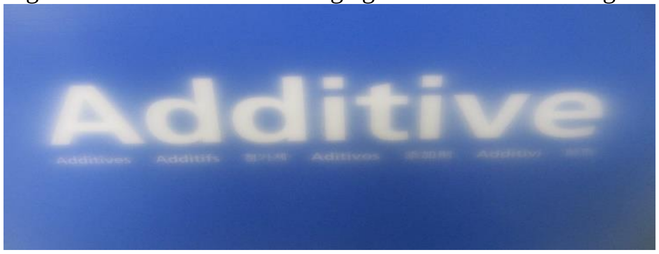


Figure 5C: Micronized wax matting agent at same dose and gloss level

Another common wax-based chemistry for micronized wax products is PTFE (Teflon® containing) wax. Recent European regulatory concerns regarding a substance known as PFOA (perfluorooctanoic acid), which can be present as a processing aid or "emulsifier" in PTFE waxes, is currently listed as a substance of concern. The more PFOA a PTFE wax contains, the easier it is to incorporate. To address regulatory concerns, PFOA-compliant versions are now commercially available. Micronized waxes create a microstructure on the film's surface that mechanically lowers the CoF (coefficient of friction), hence improving mechanical resistance and therefore less likely to mar or "burnish". PTFE waxes provide a strong reduction to the CoF, and therefore offer remarkable mechanical and chemical resistance at lower dosages. Taber testing cycles for wear resistance are generally improved. If additional "slip" is not desired, (i.e. hardwood flooring applications) larger particle size texturing grades exist. Waxes can impart hydrophobic properties to the film, which can ultimately hinder the ability of stains to penetrate. This hydrophobic benefit can ultimately lead to improved surface resistance to common household stain reagents such as mustard, red wine, iodine, food dye, and Sharpie® markers. Another benefit of micronized wax additives is they are easy to incorporate into batches (usually with low to moderate shear forces), have little to no effect on viscosity, and certain grades can produce highly transparent coatings.

Often polyethylene (PE) and ethylene vinyl acetate (EVA) co-polymer wax additives can help improve and delay the settling tendencies of a coating by keeping the silica from accumulating on the bottom of the container (Figure 6A). Many commercially available rheological (PE) or (EVA) wax dispersions help to improve the orientation of pigments, which positively contributes to the matting efficiency of silica-based matting agents. In summary, wax additives can be a **highly effective partner** to silica-based matting agents, providing improved surface, matting, and rheological control properties (Figure 6B).

Figure 6A: Anti-settling example show casing different wax chemistries

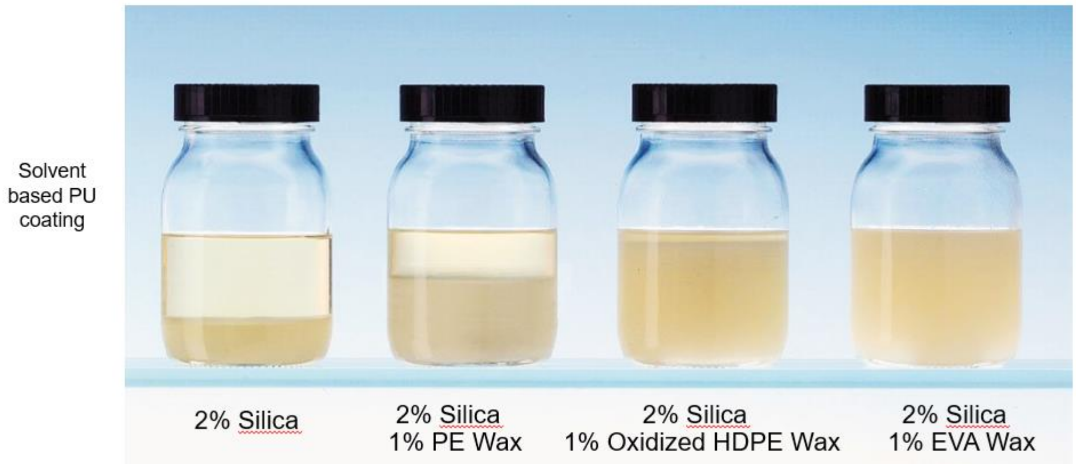
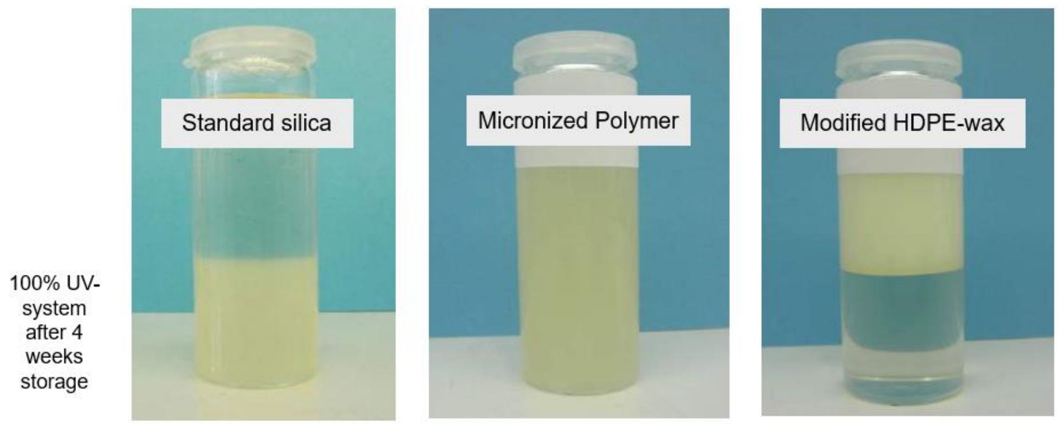


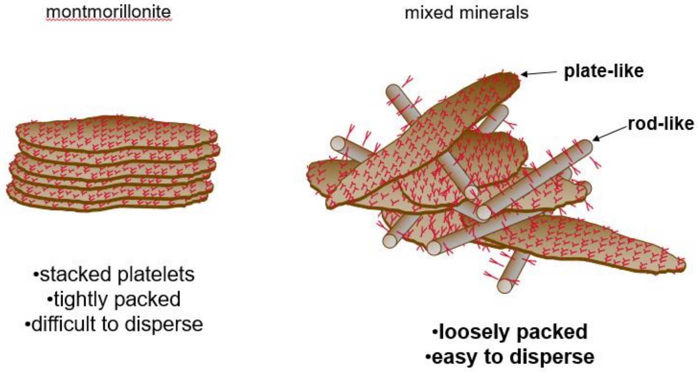
Figure 6B: Micronized organic polymer; homogeneous distribution and excellent storage stability



Benefits of Mixed Mineral Thixotrope-Based Synthetic Clays for UV Coatings

Another matting consideration that helps to provide rheological benefits for use in UV coatings is to incorporate a Mixed Mineral Thixotrope (MMT) additive, also referred to as a synthetic clay (Figure 7). MMT clays typically have a good performance-to-price ratio, have an affinity for matting and promote a pseudoplastic flow behavior in the coating. Pseudoplastic flow promotes sag resistance and anti-settling in coatings, viscosity in the low shear range, and will recover quickly from shear forces that deform the fluid’s structure.

Figure 7: Structural difference between montmorillonite and a mixed mineral clay



One additional, but very important feature of MMT clays is the reduction in bulk density compared to traditional silica matting agents (Figure 8).

Figure 8: Same pigment weight, different bulk densities of Pyrongenic Fumed Silica (left) vs. MMT (right)

Due to the heavier particle size density of MMT clays compared to fumed silica, they provide for less “dusting”, which result in improved productivity and increased manufacturing efficiency of a solvent-free coating. Moreover, the use of MMT clays, in comparison to traditional Montmorillonite Organoclays, offer added performance improvements. They do not require a polar activator, they allow for easier activation due to the loosely packed platelets, help improve pigment orientation, and help to control the flooding and floating of pigments. MMT clay technology options exist across the polarity spectrum for non-, low, mid and highly polar coating systems, and synthetic clay derivatives exist for use in aqueous, solvent-borne and solvent-free UV coatings.

Conclusion

The ongoing advancements to hyper-branched co-polymer dispersant additive technologies plays an integral role in the successful development of ultra-low matte UV radiation cure coatings. The ability to achieve and retain Newtonian flow properties throughout the manufacturing process with addition of silica-based or other type matting agents is paramount to achieving low matte coatings. The considerable reduction in viscosity achieved by means of incorporating hyper-branched co-polymer dispersant technology allows for heavier pigment loading of silica-based matting agents. Thus, formulators can achieve low to ultra-low matte coatings with decreased processing viscosities that are capable of being applied using common industrial wood application methods such as roll-coat or spray applied finishes.

The performance trade-off in the use of silica is that other matting agent options like waxes and clays tend to compromise less matting efficiency but do offer other tangible benefits that silica alone cannot provide. Surface enhancement is the operating window where wax additives really shine. Used in conjunction with silica-based matting agents, wax additives help contribute to a matting effect while providing the superfluous benefit of improved surface characteristics and manufacturability. Additional considerations for the incorporation of MMT synthetic clays in conjunction with the use of silica-based matting agents should be explored in order to optimize the coatings surface and rheological performance properties. To further achieve extraordinary surface characteristics, the use of high quality defoaming, air-release, and surface additives used in conjunction with a modern dispersant, wax dispersion, micronized wax, or MMT synthetic rheological additive undoubtedly produces a world class, high performance UV wood coating. High performance wood coatings in all sheen variations are aesthetically pleasing to consumers, provide durability, character, and uniqueness to wood products, and most of all they result in customers who are delighted with their purchase; therefore, the formulator has achieved the goal.