

# Making abrasive particles with rheology modifiers and partial silane treating for coated abrasive applications

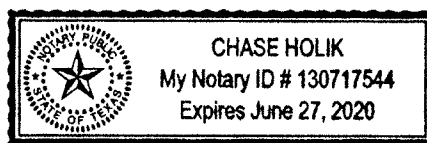
## Background

Particles having prescribed shapes are useful as abrasive particles (“particles”) and are used in a wide variety of material removal applications, including grinding, finishing, and polishing, and can be used in either fixed or free abrasive applications. Particles are individually made so that each particle has substantially the same arrangement of surfaces and edges relative to each other, resulting in particles with a highly repeatable shape. By contrast, particles for use in abrasives not having a prescribed shape, which are usually formed by a comminution process (where material is formed, crushed, and sieved to obtain particles of a certain size), have a random arrangement of their surfaces and edges, and generally a significantly less repeatable shape than the particles described herein.

Two well-known methods for making particles include molding and screen printing. In both of these methods, a boehmite gel is deposited into openings of a tool to form initial particles that, ideally, replicate the shape of the openings. After the initial particles are removed from the openings of the tool, they are sintered to create the final particles.

If an initial particle is not molded well and removed carefully from its opening in the tool, defects can be introduced into the particle that can negatively affect the performance of the final particle. One example of such a defect is a crack on the surface of the particle or within the body of the particle. The viscosity and adhesion force of the gel are important for both filling the openings of a tool and for releasing the particle from the tool.

Once the particles are formed, applying the particles to the coated abrasive with controlled orientation and homogeneity of particle placement is important. Particles are electrostatically projected into a resin-based make layer. The trajectory of these particles and where they land on the make layer can be optimized by adjusting the voltage and frequency of the metal electrodes. Another way to control the layout and orientation of the particles is to modify the surface of the particles, such as by silane coating or partially silane coating the



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particles. Silane treatment influences the electrostatic behavior of particles under an electric field by tending to inhibit the electrostatic attraction. This can influence how particles electrostatically project and orient during production of coated abrasive products. If only part of the particle is treated, then the untreated portion (e.g., the particle tip) will be attracted toward the electrically charged plate. An added advantage of silane treating the particles is that it will help to anchor the particle in the resin used in the coated abrasive, as the silane couples with the resin material as well as, or better than, the underlying particle material.

## **Objectives**

The formation of initial and final particles with desirable shapes and features, and fewer defects, can be improved by modifying the rheology of the gel. In particular, adding starches or other organic materials can improve the viscoelastic behavior of the gel and reduce sticking during removal from tool openings. Then, by partially silane treating the particles after sintering, the orientation of the particles and distribution of the particles on a coated abrasive can be optimized for better grinding performance.

## **Particle Making**

### ***Controlling gel rheology with starches or other organic additives***

Samples can be formed from a gel including approximately 50 wt% boehmite, although the specific content of the boehmite can be adjusted as known by those of skill in the art. The boehmite is then mixed and seeded with 1% alpha alumina seeds relative to the total  $\text{Al}_2\text{O}_3$  content of the mixture. The alpha alumina seeds are made by extensive milling of corundum as taught, for example, in U.S. Patent. No. 4,623,364. The mixture also may include 45-50 wt% water and 2.5 – 4 wt% additional nitric acid. The ingredients are mixed in a planetary mixer of conventional design and mixed under a vacuum (gauge pressure) of 25 inches Hg.

During the mixing of seeds, water, and nitric acid, certain methods can be used that will later reduce sticking and cracking during formation and removal of a particle from a tool. For example, a starch can be added as a binder during gel making to control the adhesion force and porosity of the gel. The starch may be from corn, rice, tapioca, potato, etc. See, e.g., the Journal

of the European Ceramic Society (v. 31, 2011, pp. 2073-2081). The starch may be added in amounts between 0% and 40 wt% of the mixture. The starch may be added to the liquids (water, nitric acid, and seed solution) at the beginning of mixing. Reducing the adhesion force of the gel to a desired level including, for example, an adhesion force of less than 6 kg, will allow the gel to stick less to the tool openings. By adding a starch, it may allow the gel to have better shape retention and strength. Reducing the porosity of the gel can also help to reduce the cracking during drying.

By varying the type and particle size distribution of the starch, the rheology and porosity can be controlled. Rice starch, which has a small particle size, may be a good binder or rheology modifier that may not increase porosity of the final sintered product. On the other hand, a controlled pore size distribution created by starch addition may control crack propagation through a particle. The pore sizes may be unimodal or multimodal based on the particle sizes of the starch particles.

Other means for controlling the rheology and reducing the stress of the gel during drying include using an additive from a sustainable source such as algaenates, guar gum, gum arabic, polysaccharides, proteins (such as soy or casein from cheese making), and polyamides. The additive may be added to the gel in amounts between 0% and 40 wt% of the mixture.

Once the gel is made, the gel mixture is then formed into cylinders 6 inches in diameter and approximately 12 inches long by extrusion with a hydraulic piston press. The gel cylinder is then further extruded into triangular-shaped openings in a tool. Other shapes may be selected based on the shape of the openings in the tool. The triangular-shaped openings have a length of 2.77 mm, a width of 2.4 mm and a depth of 0.53 mm. The tool may be made of metal or polymer. The surfaces of the openings in the tool are coated with a lubricant of olive oil to facilitate removal of the particles from the tool. It will be appreciated that other types of known lubricants, such as vegetable spray oil, may be used.

The portions of the tool containing the mixture are translated to a processing zone for partial drying. The mixture is translated through the processing zone in approximately 30 seconds to 5 minutes. The processing zone includes three heat lamps, namely two M220 heat lamps and one M110 heat lamp made by Heraeus Materials Technology North America LLC of

Chandler, Arizona. The portions of the tool containing the mixture are translated to the processing zone, where heat from the three heat lamps are applied to the tool. The heating power supplied by the heat lamps is 5.2 kW, 5.2 kW, and 2.6 kW, and the temperature of the tool within the processing zone should be approximately 50-60 °C.

### ***Other methods for controlling gel rheology***

Another method to give strength to a seeded boehmite gel and to reduce sticking of the gel in the openings of the tool involves applying ammonia or ammonium hydroxide to the surface of the gel. The ammonia may be applied as a gas in a contained chamber. Ammonium hydroxide may be applied in a bath or as a spray to the gel mixture as it resides in the openings of the tool.

Another method to give strength to the gel involves freezing the gel while it is in the openings of the tool with a material that may change the state of one or more components of the gel. For example, one process can include the application of a freezing agent (e.g., liquid nitrogen) to the gel while it resides in the openings of the tool, and thereafter punching the particle out of the openings with a wheel (i.e., without the application of temperature).

Another method to give strength to the gel involves semi-curing of the gel. The gel residing in the openings of the tool can be passed through a chemical, or be sprayed with a chemical, that allows it to cure. Thereafter, the gel may be released from the openings and moved to an oven to fully cure.

Another method to give strength to the gel involves adding a UV-curable resin to the gel formulation and to UV-cure the gel before releasing it from the openings in the tool. The resin may be added to the gel in an amount of up to 30 wt% of the mixture. Instead of the application of temperature to partially or fully cure the gel, a UV light can be applied instead to the surface of the gel in the openings of the tool, thereby partially curing the gel. Thereafter, the gel may be dried outside of the tool.

After the gel is removed from the openings in the tool, the particles are sintered at approximately 1325°C for approximately 10 minutes to achieve 98% theoretical density. The

body of the particle has a length of 1550 microns, a width of 1350 microns, and a height of 300 microns. The particles have average tip sharpness of 20 microns, a Shape Index of approximately 0.5, and an average shape solidity factor of 31%.

## Making Coated Abrasives

### *Coated abrasive with partially silane treated abrasive particles*

Once an abrasive particle is made, it can be placed in a coated abrasive. Just before inclusion in a coated abrasive, the particle may be partially treated with an agent (e.g., silane) to improve its orientation in a coated abrasive product. Silane treatment influences the electrostatic behavior of particles under an electric field, such that the silane treatment tends to inhibit the electrostatic attraction. This can influence how particles electrostatically project and orient during production of coated abrasive products. If only part of the particle is treated, as shown in Figure 1 below, then the untreated tip will be attracted toward the electrically charged plate. An added advantage of silane treating the particle is that it will help to anchor the particle in the resin used in the coated abrasive, as the silane couples with the resin material the same as, or better than, the underlying particle material.

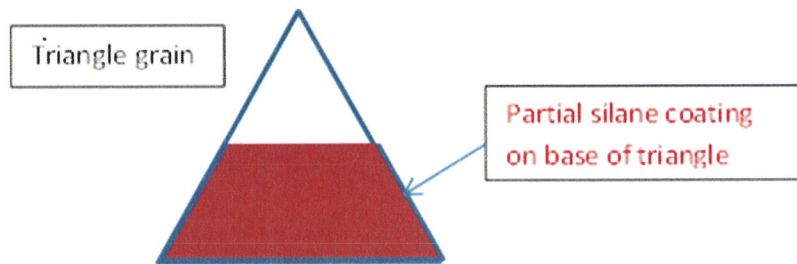


Figure 1. Schematic of a partially silane-coated particle.

### *Process for making coated abrasive with UV resin*

A backing of finished cloth of 10 lbs/ream (up to 70 lbs/ream) is used and coated with a make formulation including a phenol formaldehyde resin as provided in Table 1. It will be appreciated that the make coat is created such that the sum of the components provided in Table 1 equals 100%.

Table 1: Make Coat Formulation

Make Formulation Component	Percentage
Filler NYAD Wollastonite 400	45-50 wt%
Wet Witcona 1260	0.10-.2 wt%
Resin, SI	45-50 wt%
Solmod Silane A1100	0.1-3 wt%
Water	0.1-1 wt%

In certain instances, a radiation curable moiety can be added to the make formulation with a resole phenolic liquid resin along with fillers, dispersants, antifoams, wetting agents, rheology modifiers, and a photo initiator. When the make coat is exposed to actinic (EB or UV) radiation immediately after projecting the abrasive particles into the make coat, the viscosity of the make coat will dramatically increase, which can prevent the particles from leaning over, clustering, and having general loss of perpendicular orientation. Since the resin in the make coat formulation is not fully cured at this point, the volatiles in the resin can still diffuse out to the surface without forming blisters.

Figure 2 below shows an electrostatic coating process, where particles are fed from a hopper to a conveyor belt system on the left. As the particles move to the right on the conveyor belt, they pass between two electrostatic plates where they are projected into a make coat formulation that includes a UV-curable resin. Before the particles on the belt are transported past the roller on the right, a UV light is applied to the make coat formulation and the projected particles. The UV light will cure or partially cure the UV-curable portion of the make coat formulation, thereby keeping the particles mounted in a perpendicular orientation to the belt surface.

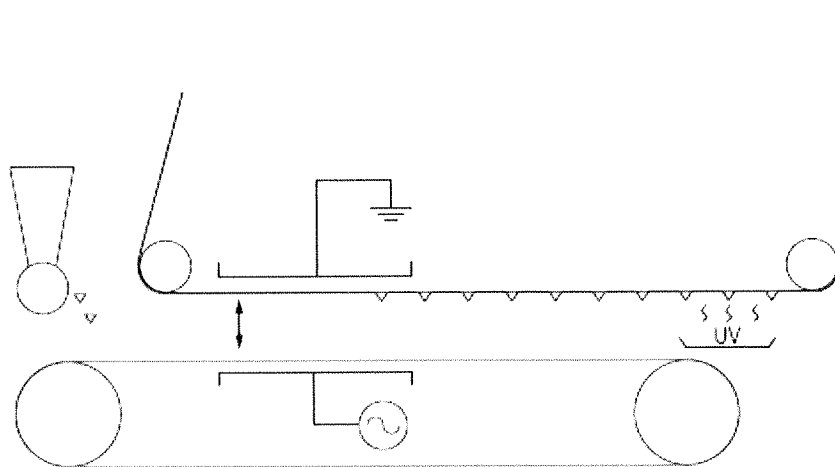


Figure 2. Schematic of electrostatic projection of particles onto a coated abrasive backing.

In a particular example, and using an electrostatic deposition process, at least 10 lbs/ream, and up to 70 lbs/ream, of abrasive particles are applied to a backing with the make coat formulation. The coated structure, namely the abrasive particles on the backing, is transported under a UV light for curing the UV-curable portion of the make coat formulation. This partially cured structure is then transported to a curing oven using the following time/temperature profile: the structure spends 20 minutes at 77°C, 20 more minutes at 88°C, 20 additional minutes at 98°C, and finally 20 minutes at 112°C. The coated abrasive structure is then coated with a size coat having the formulation presented in Table 2. The coated abrasive (i.e., the backing, the make coat formulation, the abrasive particles, and the size coat formulation) is cured in an oven using the following time/temperature profile: the structure spends 20 minutes at 77°C, 20 more minutes at 88°C, 20 additional minutes at 98°C, and finally 740 minutes at 113°C. It will be appreciated that the size coat is created such that the sum of the components provided in Table 2 equals 100%.

Table 2: Size Coat Formulation

Size Formulation Component	Percentage
Dye	2-4 wt%
Solmod Tamol 165A	0.5-2 wt%
Filler Syn Cryolite K	40-45 wt%
Resin Single Comp 94-908	50-55 wt%
DF70 Defoamer	0.1-0.2 wt%
Water	2-4 wt%

A supersize coat having the formulation provided below in Table 3 is then applied to the coated abrasive and processed in the same manner as the size coat (i.e., the curing time/temperature profile used for the size coat formulation is used again for the supersize coat formulation). It will be appreciated that the supersize coat is created such that the sum of the components provided in Table 3 equals 100%.

Table 3: Supersize Coat Formulation

Supersize Formulation Component	Percentage
Dye	1-3 wt%
Solmod Cabosil	0.05-3 wt%
Solmod DAXAD 11	1-4 wt%
Filler Type A	63-67 wt%
Resin PF Prefere 80-5080A	20-25 wt%
DF70 Defoamer	0.1-0.2 wt%
Water	6-10 wt%

## Conclusion

The formation of initial and final particles with particular shapes and features, including fewer defects, is desired. By controlling the rheology of the gel with additives, we may be able to improve the viscoelastic behavior of the gel and reduce sticking during removal from tool openings. By partially silane treating the sintered particles, we may be able to improve the orientation and placement of the particles in a coated abrasive. By using UV-based resins, the particles may be more strongly adhered to the coated abrasive.