

# Ceramic & Glass

DECEMBER 2021 • VOLUME 2 • ISSUE 4

## MANUFACTURING

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## WHAT'S NEXT AFTER A RECORD-SETTING YEAR FOR MERGERS AND ACQUISITIONS?

ELCON-UC DAVIS PARTNERSHIP INVESTIGATES DISCOLORATION OF HIGH-CALCIA ALUMINA

OPTICAL GLASS: ADVANCED ROTARY SURFACE GRINDERS DELIVER MORE POSSIBILITIES AND TIGHTER TOLERANCES



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*Review of applications will begin immediately with start dates in either January or August of 2022.*

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# INDUSTRY NEWS



The Cornell Center for Materials Research.

## CORNELL, NORTH CAROLINA A&T PARTNER TO IMPROVE DIVERSITY IN ENGINEERING

The Cornell University Center for Materials Research and North Carolina Agricultural and Technical State University began a research collaboration to increase diversity in the materials science field. North Carolina A&T said the college produces more Black engineers than any other university in the United States. Its students will visit Cornell for its state-of-the-art instrumentation and to work with Cornell faculty in electron microscopy, optics, and electrocatalysis. The National Science Foundation funded the project with a three-year, \$800,000 seed grant.

## ITALIAN GLASS MAKER BUYS A COMPETITOR IN CHINA

Italian technical glass manufacturer Vetrerie Riunite has acquired 70% of the capital of Suizhong Minghui Industrial Technology, a China-based manufacturer of washing machine portholes. Vetrerie Riunite manufactures technical glass for household appliances. The integration of the Chinese company will allow Vetrerie Riunite to improve its market share from 40% to more than 50%.



Vetrerie Riunite manufactures technical glass for household appliances.



Corning invests strategically to support broadband network buildouts.

## CORNING TO EXPAND ITS OPTICAL CABLE MANUFACTURING

Corning Inc. announced it is expanding its longtime collaboration with AT&T. The two companies will extend their investments in fiber infrastructure, expand U.S. broadband networks, and accelerate 5G deployment. Corning said it will invest \$150 million in optical cable manufacturing in North Carolina, initially adding 200 jobs. AT&T previously announced plans to significantly expand its fiber footprint.

## SCHOTT TO INCREASE CAPACITY AT PHARMA GLASS PLANT IN INDIA

SCHOTT will invest 70 million euro to expand its pharmaceutical glass tubing site in Jambusar, Gujarat, India. The expansion will increase its production capacity in India by more than 30%. It is part of a more than \$1 billion investment program through 2025, leveraging the company's pharma tubing and packaging business.



SCHOTT's expansion supports the Indian government's vision to become a global pharmaceutical hub.



O-I to invest in high-growth markets in Latin America, the U.S., and the U.K.

## O-I GLASS PLANS TO INVEST \$680 MILLION IN PLANT EXPANSIONS

O-I Glass announced plans to invest up to \$680 million globally to expand its glass packaging capacity. The Perrysburg, Ohio-based company plans to add up to 700,000 tons of glass packaging capacity by adding up to 11 lines of its Modular Advanced Glass Manufacturing Asset (MAGMA) production process. The investment will include \$100 million to expand one of the company's facilities in Colombia, and up to \$580 million in targeted markets.

## HARBISONWALKER SCOUTING SITES FOR A NEW PLANT

HarbisonWalker International, the largest supplier of refractory products and services in North America, plans to build a manufacturing and service hub for steel customers in the U.S. and substantially increase production of steelmaking products. The facility, which is expected to open as early as the third quarter of 2022, will produce refractories designed for use in low emission electric arc furnaces. The company is assessing site options.



Pittsburgh-based HWI has 18 manufacturing plants and 20 global sourcing centers around the world.



Nobel laureate Novoselov, far left, and National University of Singapore officials announced the launch of a new institute.

## MATERIALS SCIENCE RESEARCH CENTER INAUGURATED IN SINGAPORE

The National University of Singapore (NUS) launched an institute dedicated to the design, synthesis, and application of functional intelligent materials. Co-directed by Nobel-Prize-winning materials scientist Konstantin Novoselov, it will be the sixth research center of excellence in Singapore, and the fourth hosted at NUS. The institute is supported by the Singapore Ministry of Education, which is providing funding of S\$100 million (roughly US\$74 million) and a matching contribution of S\$100 million from the university.

## HERAEUS GROUP PLANS TO ACQUIRE MO-SCI CORP.

Heraeus Group, a family-owned portfolio company based in Germany, announced its acquisition of Mo-Sci Corp., a supplier of medical and specialty glass, and ETS Technology Holdings, a provider of innovative wound care technologies. Both Mo-Sci and ETS are located in Rolla, Mo. Mo-Sci was founded by Delbert Day in 1985, and was led by Ted Day, his son, until his passing in September 2020. Heraeus said it plans to keep the existing Mo-Sci team and facilities in Rolla. Heraeus employs 14,800 people in 40 countries.



Mo-Sci supplies the medical device industry as well as the aerospace, automotive, and electronics industries.

# WHAT'S NEXT AFTER A RECORD-SETTING YEAR FOR MERGERS AND ACQUISITIONS?

By David Holthaus

**W**e're at the close of one of the most active years in merger and acquisition activity in recent memory, as several factors converged to make it a record-setting year for deals.

Low interest rates, a rising stock market, and the availability of capital all contributed to the hot market of 2021, says David Ruf, head of the chemicals and materials investment banking practice at KeyBanc Capital Markets. The biggest factor was COVID-disrupted 2020, he says. The deep uncertainty caused by the global pandemic led to business being put on hold.

"People were saying, 'I don't know if the sky is falling,' or 'I don't know if we still have a world to continue to live in,'" he says. "If I buy something in May 2020, does the world even exist by August?"

Ruf's practice generally focuses on deals under \$2 billion. Heading into 2021, deal activity that had been suppressed due to the pandemic uncertainty opened up as the economy recovered and again showed signs of stability.

"A lot of things that were scheduled to be sold in 2020 never got sold or didn't come to the market in the first place," he says. "As a result, everything that wasn't nailed down and everything that wasn't for sale or didn't come to the market in 2020 was suddenly hitting the market in the second quarter of 2021."

Pitchbook Data, the Seattle-based company that researches the venture capital, private equity, and merger and acquisition markets, reported that dealmaking through the third quarter of 2021 already broke 2019's record for annual deal value, at more than \$787 billion.

"The U.S. private equity industry is storming through 2021, smashing records as investors take advantage of a bullish climate, and remain undeterred by the possibility of inflation and interest rate hikes," the company wrote in an October analysis.

James Bauerle is a cofounder of Renaissance Partners, a Pittsburgh-based investment banking and business advisory firm. His firm's focus is on middle-market firms—ranging from a few million in sales to

\$500 million—and on the lower middle market—ranging from \$1 million to \$150 million. He recently assisted in the sale of the Paul Wissmach Glass Co., a 117-year-old family-owned business based in West Virginia.

He also has witnessed the frothy market for dealmaking. "It's an excellent time to be a seller if you have a good operating business. The multiples that people are paying are as good as they've been in my career of 40 years," he says.



Austria-based Stoezle Glass Group purchased a Monaca, Pa. glass factory from the Oneida Group's Anchor Hocking Glass Co. in August 2021. Credit: Anchor Hocking Glass Co.

In the life cycle of nearly every business there comes a time when the owners reach a crossroads that may demand fundamental decisions: Do we expand or stay the course? Is it time to buy or time to sell? Who's next in line to run the business?

These questions not only need to address the state of the business but also need to be answered in the context of the marketplace, the economy, and the prospects for the future.

Deciding whether and when to sell or buy should be an ongoing topic among business management, Bauerle says.

"People who have companies should be thinking proactively about what their strategy is and whether they should be buying, selling, expanding, or not expanding," he says. "That should be a constant top-of-mind point."

There are many reasons buyers may be looking around. One is to enter new markets, as acquiring can be a quick way to do that if the business to be purchased has built a reliable customer base.

In August, Austria-based Stoelzle Glass Group announced it had purchased a glass factory in Pennsylvania from Anchor Hocking Glass Co. for an undisclosed amount. It is Stoelzle's first glass plant in the U.S., and its first outside of Europe. The acquisition, along with further investment and modernization, will promote the company's goal of "becoming the leading supplier for high-quality glass containers in the United States and North America," the company says in a news release.

Berlin Packaging, the Milan, Italy-based supplier of glass packaging, has expanded around the world through acquisition. In August, it announced the purchase of The Juvasa Group, a family-owned packaging firm based in Spain. The acquisition "continues our efforts to expand our presence in Europe, the Middle East, and Africa," says Bill Hayes, Berlin Packaging's global CEO and president, in a press release.

It was Berlin's sixth acquisition in the Europe, Middle East, and Africa region in 2021 alone, and its sixteenth since 2016.

In February, the company announced the acquisition of Sodis-Uhart, a family-owned glass packaging concern in southern France. It was the company's eleventh acquisition in Europe since 2016.

"Expanding our presence in Europe remains a critical objective for us in 2021," Hayes said at the time. "Targeted acquisitions continue to be an important way for us to execute on our strategic growth plans for Europe."

Kyocera Corp., the global company that supplies components for the auto and electronics industries, and many others, is constantly

scanning the horizon for partnerships, some of which may eventually become acquisitions. "Kyocera is absolutely interested in new technologies and new companies," says Mark Wolf, vice president of Kyocera's Fine Ceramics Group.

Kyocera prefers to work with smaller companies as suppliers or possibly in joint ventures first before considering an acquisition.

"We really like to work with companies first to get to know them before we do anything else," Wolf says. That way, company leaders can determine whether a tie-up will gel before making a bigger investment.

In January, Kyocera completed the acquisition of SLD Laser, a California-based tech company that was started in 2013 by Nobel laureate in physics Shuji Nakamura. SLD had commercialized gallium nitride-based laser light sources that can be used in the production of fine ceramics and in other applications.

"We know innovation is happening across the world," Wolf says. "People are going to come up with ideas and exploit those, and Kyocera is interested in those ideas."

Other recent Kyocera acquisitions include its purchase in 2019 of H.C. Starck Ceramics, an advanced ceramics manufacturer and sales company based in Selb, Germany. That deal gave Kyocera its first ceramic manufacturing facility in Europe, and it brought with it a new processing technology that enabled the production of high-rigidity, large, complex-shaped materials.

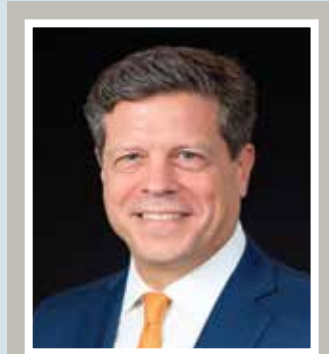
Later that year, Kyocera expanded its presence in Europe with the acquisition of the advanced ceramics business of Friatec GmbH, a 156-year-old business based in Mannheim, Germany.

Private equity firms are often looking to buy or invest in companies with leading-edge technology and superior products, and they have the capital to do that. "There's more than \$2 trillion of private equity that's looking for a home and

good deals," Bauerle says.

Artemis Capital Partners, a Boston-based private equity firm, bought Superior Technical Ceramics in 2018, citing STC's technical advantages in materials and processes, its engineering expertise, and its customer-centric culture, "the hallmarks of scalable growth," the firm said when it announced the deal. Vermont-based STC was founded in 1898 and provides advanced ceramic products used in a range of applications.

Sometimes a family-owned company will transition after a generational event. Mo-Sci Corp. was founded in 1985 by Delbert Day to



David Ruf



James Bauerle



ETS Technologies' first product, a synthetic skin substitute.  
Credit: ETS Technologies

develop and supply specialty glass and ceramic products for specific market applications. The company grew into a leading supplier to the medical device industry with glass microspheres, fibers, and powders. It also provides sealing glass and test services for the aerospace, automotive, and electronics industries.

The company was led by Ted Day, Delbert's son, until he passed away in September 2020 at the age of 59. A year later, Mo-Sci announced it would be acquired by the Heraeus Group, a large portfolio company based in Hanau, Germany. Heraeus is a global Fortune 500 company whose roots date to a family pharmacy started in the 17<sup>th</sup> century. Today, the Heraeus Group includes businesses in the environmental, electronics, health, and industrial applications sectors.

The acquisition also included ETS Technology Holdings, a company founded in 2012 to develop and commercialize a novel, borate-based bioactive glass technology platform for wound care.

"Mo-Sci and Heraeus have been in contact for many years, and prior to his passing, Ted identified Heraeus as a preferred partner to take Mo-Sci and ETS to the next stage of development," says Kimberly Day, the owner of both companies, in a press release.

With 2021 merger and acquisition activity setting records, what does that mean for 2022?

KeyBanc's Ruf expects dealmaking to continue to be robust, but perhaps drop off slightly following this year's torrid market. "I would expect a slightly lower volume of M&A [mergers and acquisitions] in Q1, just because we had everything being pushed through in 2021," he says.

He expects capital to continue to be readily available for borrowing, and interest rates to remain low.

The big question, he says, is what will happen to tax rates if a big spending package is passed by Congress. The tax rates on capital gains could go up significantly, he explains, which might make prospective sellers wait. Or conversely, it could make them jump into the market before any new rates take effect.

There are several tailwinds that could help propel a robust market in 2022, according to a September report from UBS Global Wealth Management. They are

- Low interest rates and government stimulus packages that are still working their way through the economy,
- Record levels of capital available in both the private and public markets,
- Pent-up supply and demand from both sellers and buyers,
- The feeling that the worst may be behind us as it relates to the pandemic, and
- Possibly speeding up exit planning due to uncertainty related to capital gains and corporate taxes.

"Companies that performed well over the COVID period are trading at attractive valuation levels and are in demand by buyers," says Alan Felder of UBS Investment Bank.

Companies planning to sell should review their operations and get them in shape before going out on the market, Bauerle says. "It's no different than selling your house," he says. "You want a house that people look at and say that's a house that I'd like to live in and I'll pay fair value for."

Steps to take could include reviewing senior management and making sure the right people are in the right roles, and creating a succession plan. Bauerle recommended finding an independent set of eyes to evaluate the business to determine what value could be expected in a sale, and what needs to be done to tune up the enterprise, both operationally and financially.

Ruf advises sellers to prepare well and prepare deeply because momentum matters in a deal. If the seller needs to gather information while the deal is in process, a delay could raise doubts, he says. "Invariably, everybody's going to wonder why the process slowed down, what problem is occurring," he says.

Crafting the story of the business and describing what sets it apart from others in the field is critical, he says. That includes describing the quality of the customer base, the product differentiation, intellectual property, and the speed and quality of service.

"We spend a lot of time with management in advance of doing anything in the capital markets, months and months of gathering data, refining the story, putting that into a single package that makes sense," he says.

Decades of working with small- to midsized manufacturers like the Paul Wissmach Glass Co., whose colored glass is shipped from Paden City, W.Va., to customers around the globe, has shown Bauerle what their story is: "It's people who know how to do what they do, and go about it without a lot of fanfare, and whose products are valued all over the world."

And that's something to take to the bank any day. ▀



# STONY BROOK'S CENTER FOR THERMAL SPRAY RESEARCH CELEBRATES A MILESTONE

The Center for Thermal Spray Research (CTSR) at Stony Brook University (Stony Brook, N.Y.) has reached the significant milestone of 25 years.

The Center was established in 1996 when a team led by professor Herbert Herman, along with professors Christopher Berndt and Sanjay Sampath, converted a fledgling but successful academic activity in thermal spray materials processing into a major, multidisciplinary materials research program. A multiyear, \$4 million grant from the National Science Foundation Materials Research Science and Engineering Center (MRSEC) program provided the necessary support.

The team's premise was that thermal spray allows materials to be synthesized from extreme conditions with novel microstructures that allow important functionalities in engineering systems.

The research included contributions from scientists at the National Institute of Standards and Technology, who applied small-angle, X-ray and neutron scattering to study porosity and interfaces in layered materials. A parallel effort used neutrons to conduct depth profiles of residual stresses.

Working with colleagues at MIT, studying the mechanics of layered, defected materials offered new insights into the mechanical behavior of nontraditional materials systems. A partnership with the Stony Brook Geoscience Department allowed examination of the role of the high pressures generated during impact formation of metastable materials. Researchers also studied particle dynamics both during the melting and deposition phases.

NSF renewed the program for a second, five-year term to expand into new strategies including studies of liquid feedstock to synthesize novel chemistries, and applications of the process into electronic, magnetic, and sensor functions.

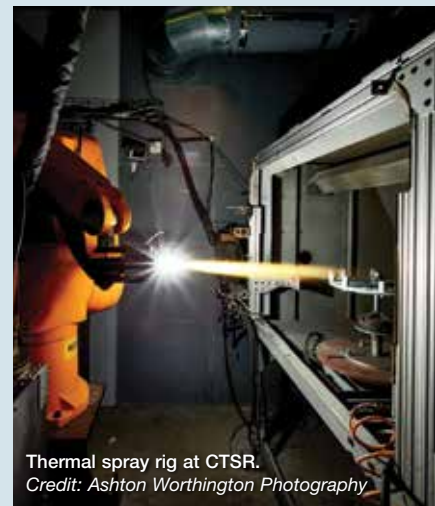
An Industrial Consortium for Thermal Spray Technology was established in 2002 with 10 companies, which allowed knowledge transfer from fundamental research to industrial practice. The Consortium continues to thrive today with 30 contributing members.



The Center's output is significant: some 50 Ph.D. students, 40 M.S. students, and 30 postdoctoral researchers were trained. Hundreds of undergraduates learned to handle complex materials processing equipment and characterization methods. More than 500 K–12 students participated in field trips. The Center's results include more than 400 refereed publications, 12 book chapters, seven patents, and three licenses.

CTSR plans a celebratory workshop in 2022 to mark this milestone, which coincides with the 20<sup>th</sup> anniversary of the Consortium partnership.

For more information, visit [www.stonybrook.edu/ctsr](http://www.stonybrook.edu/ctsr) or contact Sanjay Sampath at [sanjay.sampath@stonybrook.edu](mailto:sanjay.sampath@stonybrook.edu) or 631-632-8480. ▀



# ELCON–UC DAVIS PARTNERSHIP INVESTIGATES DISCOLORATION OF HIGH-CALCIA ALUMINA

By Tim Dyer and Nikki Do

As a high-tech manufacturing company that produces precision components for critical applications in several industries, Elcon Precision (San Jose, Calif.) is always investing in new technologies and developing better processes to not only meet customer specifications but also satisfy scientific curiosity.

One puzzle that Elcon has encountered for many years is discoloration of some alumina compositions during ceramic metallization, a service that Elcon offers. In this process, a proprietary thick film moly-manganese paint is applied to bare ceramic substrates to prepare them for subsequent brazing into assemblies. After metallization, parts undergo wet hydrogen firing at around 1,400°C. For aluminas with high calcia concentrations (1–2%), greyish discoloration is often observed on the surface of the ceramic (Fig. 1). This phenomenon is often called nucleation.

Although nucleation does not reduce bond strength or affect the part's physical or electrical properties, it is a cosmetic issue many customers prefer to avoid. Yet, to our knowledge, there is no published research on why this discoloration only occurs in certain aluminas and how it can be prevented.

In the spring of 2021, Elcon had the opportunity to investigate this question when a team of undergraduate students at the University of California, Davis, reached out to Elcon to collaborate on a project. Rebecca Salcedo, Elcon's process engineer, and Tim Dyer, Elcon's president, agreed to support a project with six students from professor Subhash Risbud's EMS 188 course: Rachel Altovar, Clayton Braga, Miranda Bell, Nicole Shuman, Ethan Suwandi, and Jiaying Li.

The students were excited to explore the question of nucleation and discoloration in high calcia alumina. As Shuman explains, "although our courses discussed topics such as viscosity and brittleness, there weren't any courses where we focused on ceramics or polymers. The attraction for all of us with this project was the opportunity to broaden our knowledge and skills working with ceramics." The team took to the project enthusiastically and, with a 10-week project timeline, assigned roles best suited to their strengths—project manager, literature research, material characterization, computer modeling, and experimental design.

The team focused on 97% and 97.5% aluminas from two different manufacturers that had 1–2% calcia concentration. Commonly used in defense and electronics applications, these aluminas contain calcia because the calcia acts as an alumina flux and reduces the sintering temperature significantly by formation of a calcia-alumina eutectic, which in turn reduces firing cycle times.

At Elcon, it often takes one to two weeks to get a sample run for a research and development project because resources are reserved for production. However, that approach would not have worked if the project was to meet its deadline, so the Davis team decided to start with computational modeling.

"Modeling allows you to test things before they actually happen," Suwandi says. In the case of ceramic microstructures, which are very complicated systems, understanding the composition of the material and its reactive properties under simulated conditions can pave the way to running much faster and smoother experiments.

To develop an accurate model, the team reviewed academic papers by Klaus et al.,<sup>1</sup> investigating the phase formation and thermal stability of the  $\text{CaO-Al}_2\text{O}_3\text{-MgO}$  system under different sintering temperatures and times. These papers showed that the ternary hexa-aluminate phases CAM I ( $\text{C}_2\text{M}_2\text{A}_{14}$ ) and CAM II ( $\text{CM}_2\text{A}_8$ ) can form at a narrow temperature range of 1,400–1,700°C. In addition, Martinez et al.<sup>2</sup> found that hibonite can form as well in calcia-containing alumina materials processed between 1,150–1,500°C. These phases function as an interlock in the alumina matrix and strengthen the bonds of compounds, enhancing the substrate's thermal and mechanical properties. This microstructure observation of an aluminate ceramic system under different sintering temperatures and times pointed the team to consider these factors as the cause of discoloration.

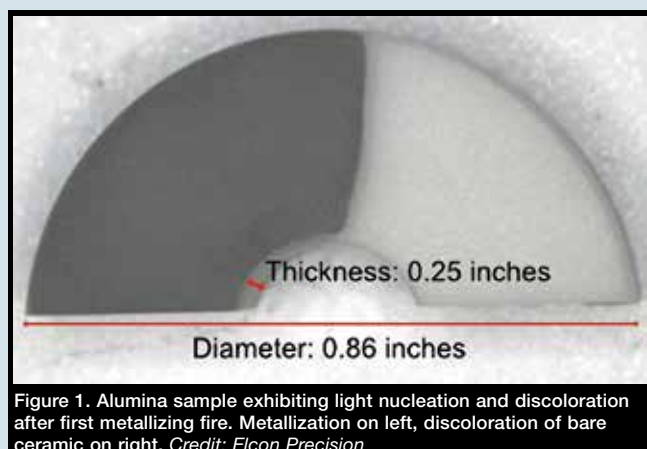


Figure 1. Alumina sample exhibiting light nucleation and discoloration after first metallizing fire. Metallization on left, discoloration of bare ceramic on right. Credit: Elcon Precision

The team used Thermo-Calc, a modeling and prediction tool commonly used in industry, in conjunction with CALPHAD (CALculation of PHase Diagrams) to produce high-resolution phase diagrams (Fig. 2). CALPHAD uses a database of experimental and theoretical values including phase compositions at equilibrium to calculate the Gibbs free energy for a specific phase. Though Thermo-Calc hosts a robust methodology and database, there is little to no experimental data available for the ternary ceramic systems being analyzed. Using Thermo-Calc Python, the team rewrote the script to add flexibility to defining the phase boundaries and necessary kinetics. Having multiple sophisticated resources and systems provided by the university allowed the team to quickly adapt to the project's needs.

Armed with this set of tools, the modeling team input compositions for the high calcia alumina samples ( $\text{Al}_2\text{O}_3$ ,  $\text{SiO}_2$ , and  $\text{CaO}$ ) into the program using the metal oxide ceramics database.<sup>3</sup> Modeling was performed in both atmospheric (1 atm) and vacuum conditions ( $1 \times 10^{-7}$  atm) with a temperature range of 200°C to 1,750°C to create ternary phase diagrams. Alumina samples included both discs and thin boards of 97.5% alumina (Sample A) and 97% alumina (Sample B).

Several relevant phases were identified in the high calcia alumina models, including

- **Corundum ( $\text{Al}_2\text{O}_3$ ):** Dominant phase. Colorless.
- **Anorthite ( $\text{CaO} \cdot \text{Al}_2\text{O}_3 \cdot 2\text{SiO}_2$ ):** Forms in most phase regions. White to grayish.
- **Hibonite ( $\text{CaO} \cdot 6 \text{Al}_2\text{O}_3$ ):** Forms in both samples above ~1,000°C. Brownish/black
- **Mullite ( $\text{Al}_6\text{Si}_2\text{O}_{13}$ ):** Forms in phase regions adjacent to 97% alumina at all temperatures. Colorless, but other technical ceramic papers show a graying effect around 1,400°C.

A significant finding from these phase diagrams was that hibonite developed in the firing temperature range where the surface discoloration occurs. Hibonite is an alumina-calcia phase that is known for forming brown and grey colors between 1,150–1,500°C.<sup>2</sup> Furthermore, due to composition variations, the calcia-containing alumina samples have the disposition to form both mullite and hibonite. These findings led the team to form an early hypothesis that the discoloration was due to hibonite and/or mullite formation at temperatures above 1,000°C.

The team used these phase diagrams, the literature review, and historical production data provided by Elcon to design their experiments around this hypothesis. Designing the investigation around the phase diagrams and material compositions allowed the team to have a more directed approach while also applying their theoretical knowledge to a relevant experiment.

Suwandi says that “Within the simulation and microstructure characterization research that I do, there’s a propensity for computational

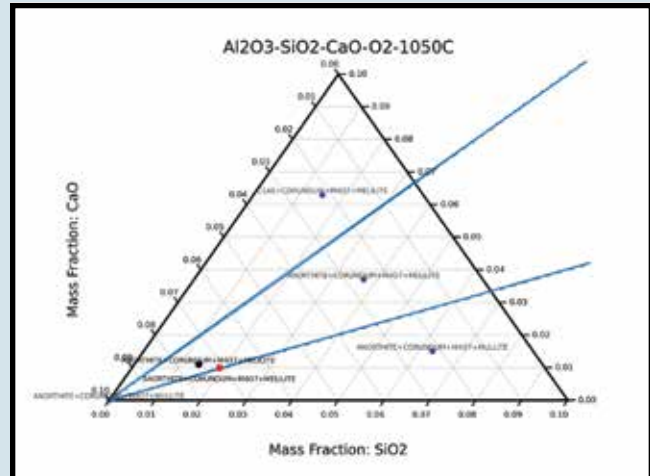


Figure 2. Phase diagram produced using Thermo-Calc for high-calcia alumina at 1,050°C and a pressure of 1 ATM (760 Torr). Credit: Elcon Precision

people to get stuck in their own world. Although you’re dealing with complex models, at the end of the day, if they’re not implemented into an experimental setting or connected to one, it kind of exists on its own. This project allowed us to apply these models to industry and pushed me onto a more specialized path, which consists of microstructure characterization and reconstruction.”

Conducted at Elcon Precision and Prairie Ceramics (San Leandro, Calif.), the experiment consisted of making adjustments in the thermal profiles, i.e., various holds under high temperatures, quenching the ceramics with rapid and slow cooling rates, and subjecting the substrates to different heat treatments. In addition, thin 99.9% pure alumina boards were painted using mixed silica and calcia glazes to serve as proxy samples to study the phase composition of the ceramic surfaces over a wide range of chemistries (Fig. 3). Lastly, there were a few trials in which the alumina disks were coated with a pure calcia wash, manipulating the surface composition.

It is important to not only understand the phases present in the ceramics, but to also understand the phase dependence and the properties of each phase. This understanding can be accomplished with tools such as X-ray diffraction (XRD) and scanning electron microscopy (SEM). Using these methods can shed light on the origins and properties of the discoloration such as phase, thermostability, and temperature dependence.

To understand the different phases present before and after metallization sintering, the alumina



Figure 3. Ring sample cross sections demonstrating nucleation-based discoloration extending far below the original surface. Credit: Elcon Precision

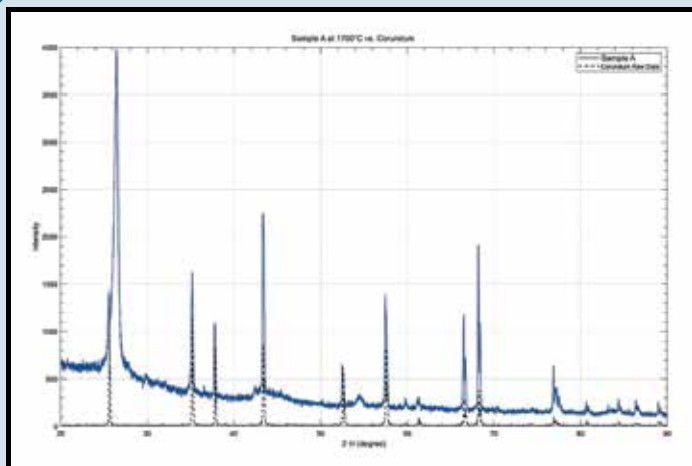


Figure 4. XRD diffraction data shown with overlapping peaks of sample A (97.5%) fired at 1,700°C with corundum. Credit: Elcon Precision

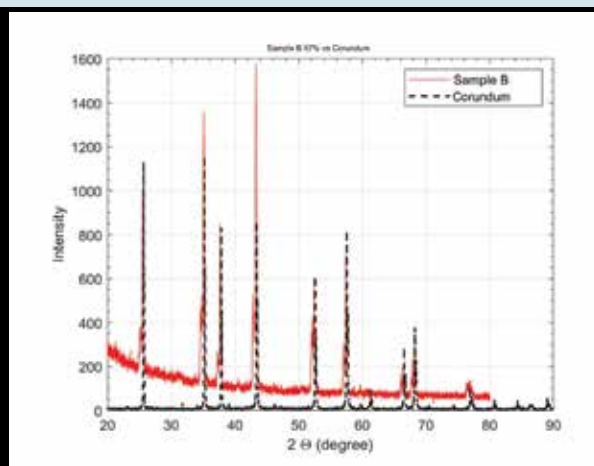


Figure 5. XRD diffraction data shown with overlapping peaks of sample B (97%) fired at 1,450°C with corundum. Credit: Elcon Precision

samples were characterized through XRD and SEM carried out in the Advanced Materials Characterization and Testing Laboratory at UC Davis. The unmetallized ceramic contains four major ternary compounds: gehlenite ( $\text{Ca}_2\text{Al}_2\text{SiO}_7$ ), anorthite ( $\text{CaAl}_2\text{Si}_2\text{O}_8$ ), clinopyroxene ( $\text{CaAl}_2\text{SiO}_6$ ), and grossular ( $\text{Ca}_3\text{Al}_2\text{Si}_3\text{O}_{12}$ ).<sup>4</sup>

The diffraction patterns of the alumina samples generated by XRD were compared with the expected phase's diffraction patterns to determine the phases existing in the samples. Diffraction patterns produced for sample A (97.5%) at 1,700°C and sample B (97%) fired at 1,450°C matched almost perfectly with that of corundum, suggesting that corundum is the major phase present (Figs. 4 and 5). Because it is a very common phase, identifying it prompts the hypothesis that a small amount of another phase is influencing the nucleation-based discoloration.

To improve XRD characterization of potential phase formation above 1,200°C, 99% alumina substrates were painted with a calcia-silica wash and then analyzed after metallization sintering. The diffraction patterns of some samples lined up closely with that of hibonite. This finding lends some support to the hypothesis that hibonite formed at specific temperatures, causing the discoloration.

SEM analysis of each alumina sample identified possible phases present on the surface. Based on these results, potential minority phases were identified—*anorthite*, *mullite*, and *hibonite*. These findings correlated with the phase diagrams generated from Thermo-Calc and also supports the *hibonite* formation hypothesis.

The team discovered that the discoloration created by metallization firing could be cleared by air sintering above 1,700°C followed by rapid cooling. A possible explanation for this solution is that *hibonite* is kinetically outcompeted by *anorthite* and *corundum* grain growth, possibly altering the local composition faster than *hibonite* can form.

Though the team accomplished the goal of exploring and disentangling the nucleation-based discoloration phenomenon, this academic–industry partnership sparked an even more significant realization. The culmination of literature reviews, computational modeling and characterization, and

practical experiments not only accelerated learning, but it is a powerful problem-solving strategy that many companies still overlook. This team showed that using skills and expertise from both universities and companies collaboratively can improve materials processing performance.

When the students were asked what they wished to see more of regarding academic–industry partnerships in the future, Braga says he would “like to see more companies branch out and use university hires.” Supporting that, Suwandi believes that “there are a lot of opportunities for small companies, especially in the materials industry,” that should leverage the fact that “our curriculum is very theoretical, so we lack industry experience.” Suwandi adds that this project gave them an “experience with an entirely different set of rules and expectations than what goes on in the research side in a lab.”

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# OPTICAL GLASS: ADVANCED ROTARY SURFACE GRINDERS DELIVER MORE POSSIBILITIES AND TIGHTER TOLERANCES

By Carlo Chatman, Power PR

To combat the loss of seasoned operators to retirement, glass job shops are turning to more modern automated surface grinders.

Older flat glass grinding equipment has limited mechanical controls and can require significant expertise, as well as time and labor to accomplish a task. For instance, such machines often use large wheels and dials to control the grinder's movement, meaning that the soft touch of an expert machinist is required to run them instead of programmable machine controls.

However, experienced operators who can successfully run such equipment are in increasingly short supply, and this shortage presents challenges to companies that rely on the older equipment.

"When I started almost 20 years ago, we were still using old, rotary surface grinders from the 1940s and '50s. They are tried-and-true, but not very accurate without an experienced machinist using them," says Brennan Cipro, chief engineer of Worcester, Mass.-based Howard Glass Company, which specializes in glass grinding and polishing for industries such as optics, biomedical, electronics, and aerospace.

Howard Glass focuses on 2D glass shapes, so factors such as thickness, parallelism, and surface condition are very important. Cipro notes that the glass materials provided by factories have varying degrees of standard thickness, meaning that glass materials often must be ground to smaller, precise dimensions. When using older grinding equipment, achieving such precision often requires the use of another machine to provide the final grind and polish, which adds hours to the fabrication process and contributes to inefficient production.

Modern automated rotary surface grinders offer advanced sensors and controls that can reliably achieve tighter dimensional tolerances, flatness, parallelism, and surface finish in much less time. The equipment can be used to grind flat glass to precise dimensions before polishing, significantly reducing intermediate lapping steps as well as preventing breakage of what is often a high-value product.

"The possibilities are endless with the new automated grinders," says Cipro. "Operators can enter the specific requirements, for example, 712 RPMs on the spindle, 22 RPMs on the table, with a down-feed

rate of 0.003 inches a minute, with a certain dwell cycle. Essentially, operators can program the machine to do whatever they want."

Three years ago, Howard Glass had the opportunity to purchase a used, vertical spindle rotary table surface grinder from another shop that had completed a project and no longer needed it. The IG 280 SD from Winona, Minn.-based DCM Tech, a designer and builder of industrial rotary surface grinders, has a 24-inch, variable speed table and a 20-horsepower, variable speed grinding spindle motor.

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Modern rotary surface grinders like those from DCM Tech offer advanced sensors and controls that can reliably achieve tighter dimensional tolerances, flatness, parallelism, and surface finish in much less time. Credit: DCM Tech

In this machine, grinding is not performed by the peripheral edge of the wheel but rather by the entire diameter of the abrasive surface. In addition, digital technology allows for an interface with easy-to-use touchscreen controls. When combined with automation, the surface grinder operators no longer need to be highly trained individuals.

"The IG 280 from DCM Tech had a digital readout, memory, and could remember where 'zero' was, so it was an important upgrade that helped with efficiency, accuracy, and surface finish," Cipro says. "It enabled us to grind the glass very close to the final dimensions, so only a tiny bit had to be removed in the polishing process, which saves tremendous time."

After a decades-old traditional surface grinder stopped working, Howard Glass decided to invest in a new IG 280, and shortly thereafter a larger format IG 380, which comes with a 36-inch, variable speed table and a 30-horsepower spindle motor. Cipro says he was immediately impressed with the automation and refinements made by DCM since the early version of the IG 280.

One example of innovation involves the automation of the initial contact between the wheel and the part. Traditionally, this contact had to be finessed by the operator, but with the new machine, the advanced sensor technology senses vibration. In addition, it automatically fine-tunes not only the pressure of the spindle motor but also how quickly it moves the abrasive wheel down onto the part.

When the machine senses the abrasive wheel has contacted the part, it automatically begins the grind cycle, which helps to minimize the potential breakage of sensitive glass or crystal parts. This capability is important in loud manufacturing facilities where operators cannot rely on listening for the sound of initial contact between the abrasive wheel and the part. Given that many such parts are high value, an operator coming in too aggressively and breaking a part can cost the company hundreds or thousands of dollars.

"I was amazed at the refinements and tighter tolerances now possible," Cipro says. "Previously, when precision down to ten-thousandths of an inch was required, it could take three hours to remove the excess on our interim machine. Now, we can grind down to ten-thousandths of an inch quickly and effortlessly without extra steps."



DCM Tech automated rotary surface grinders can be used to grind flat glass to precise dimensions before polishing, significantly reducing intermediate lapping steps as well as preventing breakage of what is often a high-value product. Above, glass discs before and after grinding. Credit: DCM Tech

In addition to reducing the needed number of finishing steps, the process repeatably achieves high throughput and eliminates variability, which enables job shops to achieve high-quality final parts, batch after batch.

Making parts in less time does no one any good if half of the parts do not pass the final inspection and cannot be used. So, the more job shops can optimize the upfront glass grinding process, the less polish time is required, thus improving not only the cycle time but also lowering costs and increasing revenue.

Perhaps even more important to Howard Glass were improvements in flexible processing that allow operators to enter virtually any requirement into a touch screen with programmable human machine interface controls. Cipro adds that, with this kind of flexibility, if a piece of glass breaks, it is easy to back any factor down a little to prevent the issue from reoccurring.

He points out that for routine processes, the use of different grind "recipes," with sets of parameters for specific parts, can further speed production, enhance quality, and aid in quick changeover.

"If the glass is a little off in the first pass, the DCM grinder can be programmed to take corrective actions on subsequent passes. There is no need to pick up the glass and measure it after every move, as with older machines," he says.

As the tolerances for glass and crystal grinding become stricter and production requirements more demanding, job shops that take advantage of advanced, automated rotary surface grinders will stay competitive even as experienced operators retire.

"Every day I hear my operators discussing ways to improve our glass grinding process because of the versatility of the advanced equipment. We are still discovering its potential," concludes Cipro.

For more information, visit [www.dcm-tech.com](http://www.dcm-tech.com) or send an email to [info@dcm-tech.com](mailto:info@dcm-tech.com).

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