COLOR & GLASS WORLD

FERRO
Where innovation delivers performance

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THIS ISSUE

Cool Buildings with Ferro Technology

HIGHLIGHTS

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EXHIBITIONS 2022

Ambiente
Frankfurt, Germany, 11-15 February

Deco '22
Columbus, USA, 2-3 April

GlassPrint
Dusseldorf, Germany, 5-6 April

China Glass
Shanghai, China, 13-16 April

Mir Stekla
Moscow, Russia, 6-9 June

Ceramitec
Munich, Germany, 21-24 June

glasstec
Dusseldorf, Germany, 20-23 September

Glass Build America
Las Vegas, USA, 18-20 October

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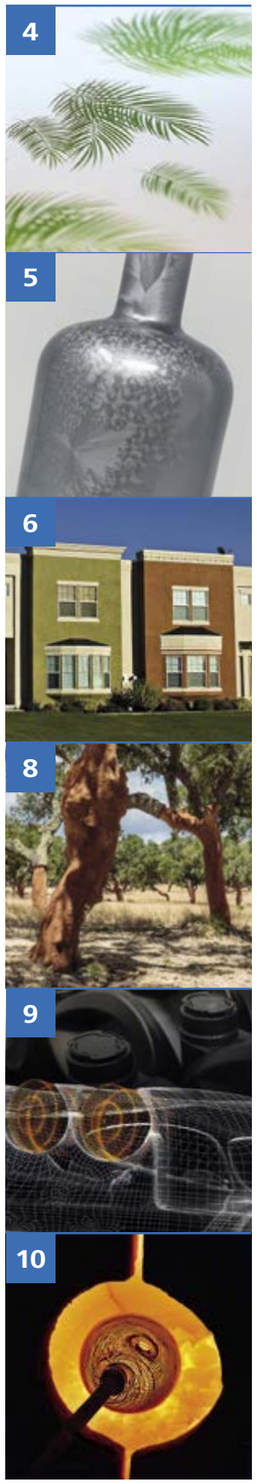

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FOREWORD

BUSINESS AS USUAL

On behalf of all my colleagues, I would like to welcome you to the latest edition of Color & Glass World, our newsletter designed to keep you up to date with the latest developments inside Ferro.

It's a real pleasure for me to have this opportunity to introduce myself, following the retirement of my predecessor, Dieter Binder, at the end of 2020. Special thanks to Dieter who served the colors and coatings industry for over 30 years, and who has been a tremendous support to me personally in ensuring a smooth transition of responsibilities. I wish him good health and enjoyment in his retirement.

Much has been happening in the world of Ferro these last few months! During the first quarter of this year, we completed the divestiture of our Tile Coatings business to Pigments Spain, S.L. Additionally, many of you will have seen the announcement in May that Ferro has entered into a definitive agreement to be acquired by Prince International Corporation, a portfolio company of American Securities LLC. In conjunction with the closing of the transaction, the company will combine with Chromaflo Technologies, a premier global provider of colorant technology solutions and also an American Securities portfolio company. The combination of Ferro, Prince and Chromaflo will result in a global diversified business with sales of approximately $2 billion. On September 9th, Prince's offer was officially approved by Ferro shareholders.

The combination of Ferro, Prince and Chromaflo, each a leader in their respective markets, will create a global technology powerhouse in color solutions, functional coatings and specialty minerals. There are a lot of synergies created from the merger of these companies and I am excited by the possibilities; the combined operations will deliver a company with unmatched competencies in particle engineering, glass science and color technology. Our ability to deliver state-of-the-art products and innovative solutions that enrich everyday life will be significantly enhanced. The transaction is expected to close during the first quarter of 2022, subject to the satisfaction of customary closing conditions, including applicable regulatory approvals.

In the meantime, inside Ferro we are continuing to operate very much as "business as usual". I want to emphasise that my new management team and I recognise the importance of continuity and consistency, and we remain committed to offering you outstanding products and the best possible service from all our locations around the world.

As I write these notes, whilst restrictions to our lives due to the pandemic are continuing to some degree, vaccination programs in most of the major global economies have expanded rapidly. This is helping drive economic recovery around the world, and our business is well placed to capitalise on this economic growth, as we move into a post-pandemic world. At the same time, post-pandemic supply chain issues have threatened to slow the global recovery and are proving to be a challenge both in our own plants and for our customers. As an example, computer chip shortages have shut down car production factories and are expected to continue to do so into 2022, effectively increasing lead-times for new cars to 10 months.

We remain focused on innovation and are committed to addressing customer needs with creative solutions and market-leading products and services. Inside this edition, we are highlighting some of our latest product developments covering automotive and flat glass coatings and holloware glass decoration. In addition, we are focusing on our work in helping to improve energy efficiency in new buildings and renovation. We are also previewing 2022, which was recently declared by the United Nations as the International Year of Glass; there will be a number of events taking place next year dedicated to raising the profile of glass and celebrating the contribution glass has made to our world throughout history.

I sincerely hope that you will find this edition informative and enjoy the read!

Andre Noppe
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NEW TECHNOLOGY FOR DINNERWARE DECORATION

DIP-TECH DIGITAL PRINTING OF DECALS

Dip-Tech - the pioneer of ceramic digital printing on glass - joined the Ferro family in 2017, since when we have continued with our mission to improve the quality and scope of digital printing technology. Launched in 2020, our FR-1 printer is the first ever digital printing solution for ceramic decals applications, opening new opportunities for both ceramic and glass tableware production. We believe this new technology will bring dinnerware manufacturers more freedom in terms of design, fast response and production flexibility.

Compared to screen printing, which has been the traditional process for multi-color decoration and/or decal production, going digital makes everything faster, from the very early stages of the design and file preparation, all the way to delivering a final product. A specially developed software avoids time consuming file preparation, which leads to better printing results. Avoiding the use of screens for these prints not only reduces the machine setups and frees up storage space, but considerably reduces ink wastage, which converts the whole operation into a much more sustainable production process. Overall, it is less labour-intensive, generates less waste and allows for a faster release of decals to market.

Furthermore, traditional printing technologies are restrained from printing several colours simultaneously, which slows down production. In contrast, digital decal printing allows up to eight colours to be printed at once, which is great news for highly customised and short batches that require different sets of designs. Colours can either be mixed digitally or premixed and loaded as spot colour on the machine. For designers, this means faster sampling and prototyping, a key element for a successful product launch and for management, this means a faster time to market. Digital printing provides dinnerware companies with a whole new world of design possibilities, including smoother gradients, artistic effects, depths and outlines, and of course, high-resolution photorealistic images.

The Ferro ceramic inks supplied with the FR-1 printer are backed by our more than 60 years' industry leading experience of supplying colors to dinnerware and decals manufacturers around the world. This means all materials are tested to the strictest industry standards in terms of quality, safety and reliability.

Ivan Rebello, Director, Zenan Glass, Canada says: "*We have been using Dip-Tech's new technology to produce decals for some of our customers in the beer and liquor industry. I like the process because there is no need for screens and to a large extent, most of the colours we need can be matched. Compared to other processes we've used, it saves time and we've found it very good to use on urgent tasks and short run jobs. Dip-Tech's after-sales service has been very good so far as well*".

Digital printing is revolutionizing the decal and dinnerware industry, and it is here to stay. Our goal is to make sure manufacturers and designers can fulfil their creative and financial needs by having access to a whole window of technological possibilities, updating their line of work for a much more complex and customised production, and keeping up to speed with current and future demands, and global trends.

To join the revolution, please visit us at Ceramitec, Munich, Germany in June 2022 or talk to our experts at **dip-tech.com**.

dip TECH
A FERRO COMPANY

Image courtesy of Zenan Glass

WATER-BORNE ORGANIC COATINGS INNOVATION

Rainbow

Ice Flower

Crystallized

Through a combination of organic growth and strategic acquisitions, Ferro is fast becoming a global leader in the supply of eco-friendly waterborne organic coatings for the glass market. Pinturas Benicarlo, with its manufacturing site in Benicarlo, near Valencia in Spain and Diegel Creative Coatings, headquartered in Alsfeld, Hessen, Germany, were acquired in 2016 and 2018 respectively. Both companies have a long history of supplying waterborne organic coatings for application on glass substrates, which has made them an excellent fit with Ferro. These products now form the core of our waterborne organic coating brand with offerings for container glass, tableware and other consumer products applications where painted glass packaging communicates brand identity.

Being close to customers, we are proud of our ability to quickly and effectively service customer needs by providing highly formulated products and technical solutions. We have developed many improvements and optimizations to fulfil changing market demands and satisfy critical refinements to technical specifications. Over the years, we have built a strong reputation as a reliable supplier of decorative organic coatings and inks - offering outstanding service and product innovation - and are continuing to excite with a range of glass coating innovations for container glass and tableware, three of which are illustrated in this edition.

Imitation luster or "Rainbow" effect is an interesting organic alternative to traditional high temperature luster. Requiring a very thin layer of 2-5 microns and curing at 180°C compared to 500-700°C for ceramic lusters, our organic rainbow effect organic coating is an extremely cost-effective option, which works well on automatic decoration lines.

"ICE Flower" effect is proving to be extremely popular with customers and is usually applied with a layer thickness of 130-150 microns and cured at 180°C for 15 mins. This product has good resistance for cosmetic and beverage bottles, as well as decorative glass objects such as vases and tea-lights.

Thirdly, our "Crystallized" effect is a 3-component system which can be over-painted with colored lacquers.

Our waterborne organic coating special effects can be applied on decorative glass items like vases and votives, container glass such as flacons and cream jars, as well as kitchen and dining tableware. For more information, please contact your local Ferro service team or visit **ferro.com**.

COLOR & GLASS WORLD

COOL BUILDINGS WITH FERRO TECHNOLOGY

FERRO TECHNOLOGY HELPS IMPROVE ENERGY EFFICIENCY IN BUILDINGS

The world around us is changing fast – smarter, greener cities, advanced connectivity and new models of mobility. Increasing demand for sustainable living is being supported by major advances in technology, glass being one example of a material that is playing its part in these developments.

As the devastating loss of life and habitats caused by climate change continues to increase, many countries and businesses are responding by setting bold commitments to reduce emissions significantly by 2030, with targets to reach net carbon zero by 2050.

According to the International Energy Agency (IEA), buildings consume about 30% of the world's energy and contribute around one third of global man-made CO_2 emissions. Efficient buildings can help improve the quality of life of millions of people because they are often higher quality buildings with greater comfort and improved indoor and outdoor air quality. Additionally, building renovation can provide further potential for efficiency improvements; existing buildings represent significant energy saving opportunities because their performance level is frequently far below current efficiency potentials.

Building sustainably will result in healthier and more productive environments.

Ferro materials are found in products used on and all around the home, as well as on and inside offices, residential blocks, hotels, shopping malls and other buildings…. from rooves, roof tiles, vinyl sidings and cement stucco to architectural, solar and spandrel glass, Insulated Glass Units (IGU's), glass furniture and glass packaging; from ranges, cookers, stove-tops, and microwaves to sanitaryware, hot water tanks and household goods such as cookware and dinnerware.

Our materials play an important part in the drive to reduce heat loss and improve energy efficiency in buildings. In fact, our materials are involved in more ways than you might imagine, in home renovation as well as with commercial buildings and construction, some of which we highlight here.

Due to the increasing demand for energy efficiency, we developed our so-called "cool colors" glass enamels, which are available also as dark color shades, for example blacks, greys, blues (which are typically heat absorbers). At the wavelength of light visible to the human eye (380-780nm), these colors demonstrate the reflection and absorption of conventional glass enamels. However, at the IR spectrum of light (>780nm) – which means heat radiation – these enamels are highly reflective, which creates a better energy efficiency class for use in architectural glass facades. Additionally, such functionality can also provide significant benefits for kitchen appliances such as glass oven doors, due to the heat energy reflected into the oven rather than absorbed by the glass.

Energy efficient glass offered by all the major float glass producers (Low-E glass) is coated typically with multiple layers of metal and/or oxide coatings that deliver the energy efficiency improvements required on clear glass. Such layers can be problematic for application of glass enamels for decoration purposes. However, we have found that our flat glass System 140 line of decorative glass enamels work well and are fully compatible with the coatings used to produce Low-E glass.

Our Coverlink insulation materials, which are highlighted in our story on p8, are an exciting new range of cork spray coatings that can be used for both new build and renovation projects. These eco-friendly coatings provide best-in-class insulation properties and can be used to coat walls, rooves, terraces and a multitude of complex-shaped surfaces, both outdoors and indoors. Combining these coatings with other Ferro IR-reflective (IRR) materials would result in a revolutionary approach to building insulation in hot climates.

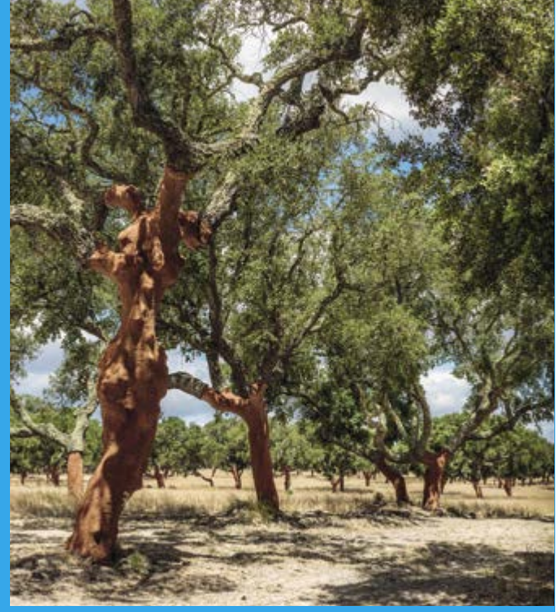
In the solar power market, Ferro's high reflectivity glass enamels enhance the solar efficiency of PV-modules and are finding increasing use for double-glass PV integrated building modules (BIPV), providing clean and sustainable energy. Designed to be compatible with most conventional glazing systems for facades and skylights, they are particularly suitable for construction of car-park facilities and bus stops, shopping malls, sports facilities and greenhouses.

We have developed glass sealants for use in vacuum insulated glass applications, used for skylights in flat and pitched rooves. We use our "cool" pigments to provide IR heat-reflective properties in our brick and roof tile ceramic glaze and engobe formulations.

Ferro is a global leader in the development of IRR "cool" pigments. Such pigments are typically based on mixed metal oxide technology with the ability to reflect the IR fraction of the solar radiation in higher % than conventional pigments. The IR part of the solar radiation is the main contributor to heating of surfaces and hence the main driver of high energy bills in residential and commercial buildings. Increasing the use of materials in the building envelope (roof, walls) that reflect the IR wavelengths will lower the heat build-up and reduce the energy bill. Our pigments are used in roof applications, typically asphalt shingles, coil coatings and concrete roof tiles as well as on walls, for example vinyl sidings, architectural paint, cement stucco and exterior insulation (EIFS). The most challenging colors to reduce heat build-up are the darkest shades - blacks, greys, dark browns, dark greens and dark blues. Independent studies using our technology for roof coatings or walls highlight that the reduction in energy bill can be from 3-25% depending on the project.

Our R&D teams are continuing to work closely with our customers and partners to bring to market new materials that will support global efforts to reduce energy consumption and cut greenhouse gas emissions. Please talk to our experts to review your individual needs.

Image courtesy of PLC, Canada



BUILDING THE FUTURE WITH COVERLINK INSULATION MATERIALS

ECO-FRIENDLY SPRAY CORK COATINGS FOR BUILDING AND CONSTRUCTION

Coverlink, based in Castellon, Spain, was acquired by Ferro in 2017 and manufactures a range of eco-friendly technical coatings for the construction industry. The highlight is the development of a sustainable, revolutionary line of Spray Cork textured coatings, which are designed to improve energy efficiency in buildings.

The cork industry generates a sustainable non-polluting economic activity that offers the world market a natural and eco-friendly product. The cork is extracted from oak trees without damaging the trees and removing it will release oxygen into the atmosphere. In addition, removing the cork contributes to extending the life of the trees by hundreds of years. The total area currently occupied by cork oak forests in Europe is around 1.44 million hectares, especially in the Iberian Peninsula. The cork forests help to capture CO_2, making a great contribution to the reduction of greenhouse gas emissions and to the sustainability of the planet.

Cork is one of the best natural insulators that exists, with a resistance to heat passage 30 times greater than concrete. Cork is 100% natural, recyclable and renewable. In addition to its low heat transfer and excellent thermal insulation, it is light and highly elastic and flexible, with good waterproofing and sound-proofing properties. It offers durability, stability, flexibility and fire resistance.

Building on cork's fundamental properties, Coverlink's spray cork is formulated using the highest quality cork from the bark of oak trees forested in Spain and mixed with water-based resins that are non-toxic, to create a pure eco-friendly product. Our unique water-based formulation is easy to apply with improved performance, delivering thermal insulation, waterproofing, high flexibility and superior crack prevention in use. Our products are designed for cost-effective spray application on walls, terraces, rooves and all kinds of different shaped surfaces, and are formulated to use on both outdoor and indoor surfaces.


Image courtesy of Liquid Kurk, Belgium

In addition, we supply a wide range of colorants, called INKERCORKS, that extend the coloring potential of our spray corks. Our coatings are applied in 2 layers with a total layer thickness of 2-3mm, creating an application weight of 2kgs/sq.m.

Coverlink spray cork's energy-saving and water-proofing properties are popular to insulate buildings in both warm and cold climates, to keep heat in or out. Our spray cork coatings are perfect for renovation and new build projects in residential buildings, industrial construction, hotel and retail markets. Our spray cork also provides a perfect solution to repair and protect all kinds of metal surfaces such as ships, boats, shipping containers and bridges, among many other uses.

With a network of distributors worldwide, our spray cork coatings are gaining international recognition. Please contact our Ferro Coverlink experts on **coverlink@ferro.com** for more information on how we can help your building or construction projects.

LATEST GENERATION AUTOMOTIVE SILVER PASTES

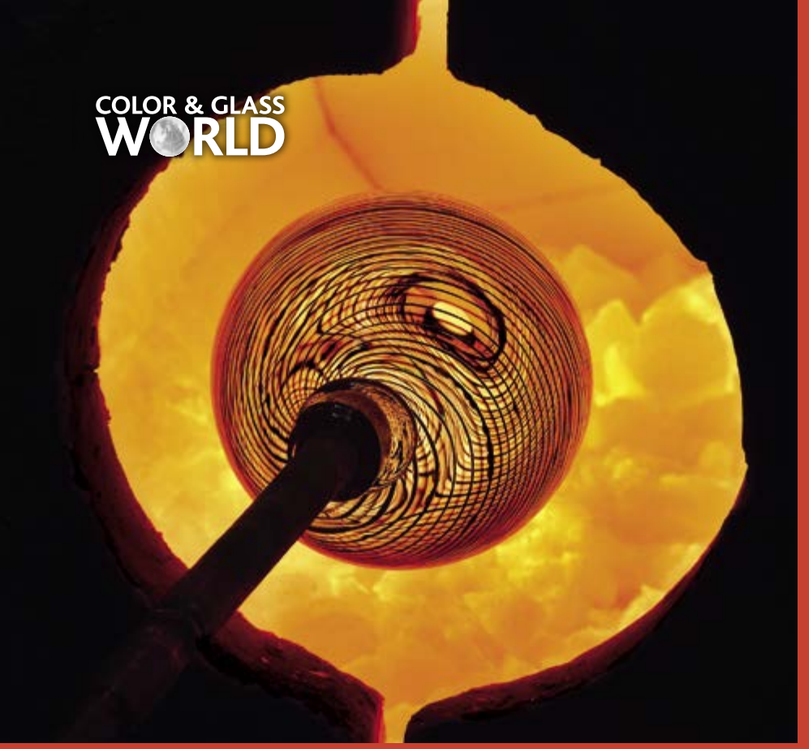
NEW IMPROVED HIGH DURABLE SILVER PASTES FOR LEAD-FREE SOLDERING

In automotive glazing, the connectors for the heat grids and antennas are joined to the fired silver print by soldering. Following the EU directive for end-of-life vehicles (ELV 2000/53/EC), the lead-free soldering process for all new tempered automotive glass developments was implemented in 2016 as a mandatory standard process. The European target to ban the lead-containing soldering process from all new laminated windshield models from 2020 onwards had to be postponed, as many automotive glass producers experienced big difficulties to fulfill the continuously increasing demands of the car manufacturer, in combination also with the challenges of the lead-free soldering processes.

These new automotive glass specifications include an increasing number of test cycle times for different temperature treatments to the automotive glasses from -40°C to +120°C under electrical and physical load with humidity exposures >96% RH, as well as demands for higher chemical durability of the silver pastes. The special challenge here is to combine these increasing demands with the different process conditions of the laminated automotive glasses manufacturing processes. The firing of the thinner windshield glasses is done at much lower temperatures compared to the tempered glass production, which is highly influencing the final properties of automotive glass enamels and silver pastes.

So, on the one hand very good adhesion properties of the silver pastes to the black enamel and glass surface are required, especially at low firing temperatures, to fulfill the request for higher chemical durability. On the other hand, a strong and ductile connection between the silver and the different lead-free solder alloys is needed to overcome the common difficulties of the different lead-free soldering processes with blistering or brittle solder alloys. During the connector soldering process to the silver surface, the thinner laminated glasses are exposed to much higher stress levels inside the different material combinations.

As a global market and technology leader for many glass and electronic applications, Ferro has been able to develop new frit and silver formulations to create a new silver paste generation, fulfilling the highest OEM specification standards. Ferro has successfully introduced its new silver pastes series SP206x to the market and received many positive customer feedbacks about the outstanding performance of this brand-new silver paste system, for application on laminated as well as tempered glass. These new product families with a wide working range provide very stable layout resistances and good solderability that now enables many customers to fulfill the new OEM requirements, as well as to optimize their production processes and efficiency to the next level.



UN INTERNATIONAL YEAR OF GLASS 2022

Following an intensive process, the United Nations recently declared 2022 as the "International Year of Glass". Since 2018, influencers from several leading organizations, including the International Commission on Glass (ICG) and the Community of Glass Associations (CGA), have campaigned tirelessly to turn their vision into a reality. EU ambassadors and many other experts and sponsors from around the world were also influential in championing the special and unique properties of glass, along with its benefits to society.

The International Year of Glass (IYOG) steering committee's vision and application to the UN centered on promoting the history of glass and its future potential, as well as highlighting how the glass community is supporting the UN developmental goals for its '2030 Agenda'. In an interview with Glass Worldwide, Prof. Alicia Duran, President of the ICG, notes that "*Container glass is infinitely recyclable and an important example of a circular economy. There is a revolution in architecture and the carbon neutrality glass can bring to buildings. Glass is also a very significant material in the progress of technologies such as the optical fibers that permit the development of the internet and 5G; new paradigms that are the physical base of globalization. Glass is also a base resource for green energy with applications in solar, wind power and many more. And last but by no means least, in health applications, bioactive glasses have many different uses and of course as highlighted by the covid-19 pandemic, pharmaceutical glass is the container of choice for vaccines. Glass is everywhere and is a material fundamental to sustainable development.*"

The resolution outlining the IYOG committee's ambitions emphasizes that glass is one of the most important, versatile and transformative materials in history, which has accompanied humankind for centuries, enriching the quality of life of millions. According to the resolution, "the International Year of Glass, 2022 will underline the technological, scientific, economic, environmental, historical and artistic role of glass in our societies, emphasizing the rich possibilities of developing technologies and their potential contribution to meeting the challenges of sustainable development and inclusive societies, achieving world economic recovery, and building back better from the coronavirus disease (COVID-19), and bringing together the threads of technology, social history and art through educational programs and museum exhibitions."

There are many events already planned for 2022. IYOG's opening conference will take place in Geneva on February 10-11. In addition to lots of local events, conferences will be staged by ICOM, the Contemporary Glass Art Association and the Corning Museum of Glass, and there will be a US Glass Day in Washington. The Spanish Research Council, CSIC will stage two exhibitions, one centered on sustainable development and the other, supported by FEVE, ANFEVI and the Friends of Glass, will focus on the circular economy and recycling. CSIC will also be publishing a celebratory book.

Here at Ferro, we feel closely connected to the themes and objectives of IYOG. Glass is one of our core sciences and has been part of Ferro's DNA since our foundation. Our R&D laboratories and production facilities around the world are creating and smelting glass formulations every day for our functional coatings and decoration colors that are used on glass, ceramic and metal substrates, and in electronics applications. Glasses are at the heart of our technical solutions and performance materials for architectural, automotive, appliance and furniture glass markets, as well as telecommunications, electronic materials, dentistry, glass packaging, cookware and tableware.

In 2022, IYOG will feature at China Glass, glasstec, glasspex India, and the ICG Congress in Berlin, and will also participate at Vitrum 2021, Milan in October. We are really looking forward to supporting many of the events slated to celebrate the International Year of Glass.

FERRO TODAY

Ferro Corporation is a leading global supplier of technology-based functional coatings and color solutions. Ferro supplies functional coatings for glass, metal, ceramic and other substrates, and color solutions in the form of specialty pigments and colorants for a broad range of industries and applications.

Ferro products are sold into the building and construction, automotive, appliances, electronics, household furnishings, and industrial products markets.

Headquartered in Mayfield Heights, Ohio, USA, the Company reported 2020 sales of $959 million, and has approximately 3,700 associates worldwide.

Our associates work in 30 countries, speak more than 17 languages and bring a wealth of knowledge and cultural perspective to our offices, laboratories and plant facilities every day. While we learn and benefit from the unique experiences that arise from our diversity, we also share a common set of core values and operating philosophies. We believe that our long term success will be determined by who we are and how we act.

Our core values apply equally to all interactions with customers, suppliers and colleagues:

- **Customer Focus:** Our customers are why we exist; we want to build trusting relationships that make customers successful.
- **Accountability for Performance:** We work to achieve the highest performance standards, to create value for customers and shareholders.
- **Innovative Thinking:** We seek new ideas for technologies and business processes, and are always striving to improve and serve our customers better.
- **Teamwork and Collaboration:** we are committed to a work environment of trust and respect, working together to consistently deliver value to customers and shareholders.

Where innovation delivers performance.

	KEY PRODUCTS	END-USE APPLICATIONS
FUNCTIONAL COATINGS & COLOR SOLUTIONS	Porcelain enamel coatings; Structural and fine ceramics coatings; Glass enamels; Digital inks; Conductive metal pastes, powders and flakes; Forehearth colorants; Specialty colors and glasses; Organic coatings and inks; Dispersions and pigment blends; Electronics packaging materials and multilayer materials; Inorganic colored pigments; Organic pigments; Surface finishing materials	Appliances; Dinnerware; cookware; Roof tiles; sanitaryware; Water heaters and industrial products; Automotive, architectural, furniture and container glass; Dental products; Electronics packaging; Semi-conductor wafers and capacitors; Paint & plastics; Vinyl siding, pipe and flooring; Touch sensitive displays; Ophthalmic lenses; Textiles and cosmetics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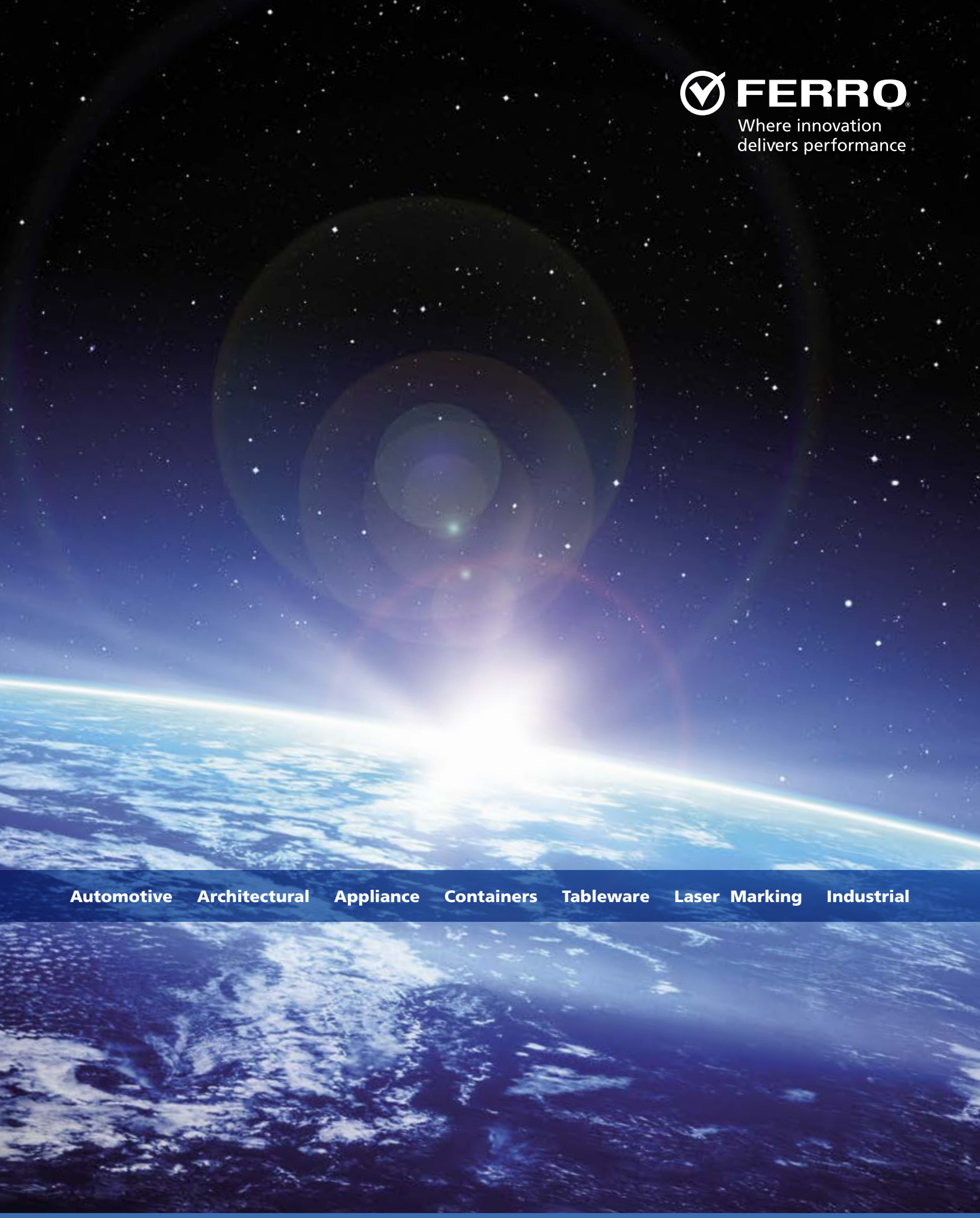

For outstanding color and coating technologies – both decorative and functional – Ferro are global market leaders.

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