

The background of the cover is a photograph of a modern building with a prominent glass roof structure. A bright sunburst effect is visible on the left side of the image. The entire image is overlaid with a semi-transparent green filter. The text "ANNUAL REPORT 2023" is positioned in the lower right quadrant of the image.

**ANNUAL  
REPORT 2023**



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# FOREWORD

CRM Group is an independent non-profit organisation that provides technological R&D innovation in the fields of metal and steel production processes, product development and a wide range of metal applications, using a truly holistic product-process-application approach and focusing on industrial implementation of its developments. More than ever, the vast majority of CRM's developments focus on key societal challenges such as the circular economy, energy transition and digital transformation.

CRM Group is supported by more than 45 industrial members, ranging from international steel groups (ArcelorMittal and Tata Steel), raw material suppliers, non-ferrous metal producers, OEM's, metal transforming companies, to members from the chemical, aeronautical, defense, energy and recycling sectors. CRM also delivered various services to more than 300 non-member customers.

At CRM, health and safety is the key priority. In 2023 an increased number of safety events were encountered. A reinforcement of the global safety action plan has allowed to stop the trend. VCA-training for all staff members has been completed and dedicated

Tool Box Meetings are widely deployed. CRM will remain strongly committed to target a sustainable and constant zero accident performance.

CRM considers that it can only realize its full innovation potential by making full use of all talents regardless of gender identity or expression, sexual orientation, religion, age or any other aspect that makes each person unique. At CRM a Gender Equality Plan (GEP) and more broadly a diversity inclusion policy is being applied with notably the realization of an extensive survey amongst staff members.

CRM is committed to reach the Sustainable Development Goals adopted by the United Nations. The SDG's have been integrated in CRM's strategic plan, both at the level of our research programs as on the level of CRM's organization as such. The first phase of the certification procedure to be recognized as a Sustainable Entrepreneurial Organization has been successfully completed in 2023. On top, total carbon footprint according to scope 1, 2 and 3 has been assessed. A carbon footprint reduction plan has correspondingly been defined .

To fulfil its mission, CRM is organised around 6 research units that are backed up by a world class material characterisation laboratory:

- 1 **Metal production and recycling (MPR):**  
Covering raw material processing, carbon neutral iron & steel making, melting & refining, by-products treatment & valorisation.
- 2 **Energy & Low Impact Manufacturing Industry (ELIMIN):** Focusing on the development of energy efficient and low CO<sub>2</sub> emitting production technologies and CCU applications.
- 3 **Metal processing and metallurgy:**  
Including casting & solidification, rolling & thermal treatment, material science & hybrid manufacturing and process control & measurement.
- 4 **Advanced & smart surface solutions (A3S):**  
Ranging from functional coatings and smart surfaces including printed electronics on steel to surfaces for renewable energy applications and hydrogen and electrochemistry.
- 5 **Innovative designs and assembly solutions (IDEAS)** in the fields of Civil engineering, Construction, Assembly & Testing.

- 6 **Industrial solutions (IS):** Embracing in-house Engineering, finishing & metallic coating processes, organic coating and sandwich panels products & continuous annealing and/or coating pilot line.

Just like in 2022, the first half of 2023 was marked by inflationary economy linked, among other things, to the persistent energy crisis. Uncertainty regarding the evolution of energy prices, as well as the level of inflation, prompted the CRM Group to continue budget management with the same caution as in 2022. However, during the second half of 2023, energy prices significantly eased, and inflation decreased significantly to pre-crisis levels. This allowed the CRM Group to regain a healthy financial balance. CRM is still, in spite of the eased economic situation, utilizing negotiation in purchasing and efficiency improvements to increase the value to customers while keeping cost under control.

R&D projects deliverables for both CRM's effective and associated members were successfully attained, providing an excellent customer satisfaction. The research programs and projects are part of the Relaunch & Resilience Plan and also at cruise speed with notably the Reverse Metallurgy program related to circular eco-

nomy activities and the HECO2 program (Hydrogen, Electrification and low CO<sub>2</sub>-emission) aiming at decarbonization of the heavy Industry.

Program renewal was particularly successful in 2023 and early 2024. At the European level, very high success rates were achieved. For example, 3 out of 6 projects submitted to Horizon Europe calls were accepted, and 5 out of 11 projects were accepted in the RFCS call. These 50% success rates in highly competitive calls are unprecedented.

At the level of calls for projects organized by the Walloon Region and the federal government, results were also spectacularly good, notably with the validation of strategic innovation initiatives such as WiN4C and e-Wallonhy, as well as in other calls. These new projects will allow CRM to develop activities in the fields of hydrogen (green hydrogen production, transportation, storage, and utilization), additive manufacturing, circular economy, and digital transformation.

The present annual report highlights the main achievements of the year 2023.

**Thinus Van Den Berg**  
President CRM

**Joeri Neutjens**  
General Manager CRM

# CERTIFICATION IN SUSTAINABLE ENTREPRENEURSHIP

CRM Group has made sustainability a central part of its identity. **“Think & act sustainable and be convinced that the only way to innovate & create value for customers, people and the planet in the long term is to do so in a sustainable way”** is one of its 5 company core values.

In 2023, we also initiated a certification program in sustainable entrepreneurship. This three-year course, overseen by the Chamber of Commerce and Industry (CCI) Liège-Verviers, will culminate in obtaining a certificate in sustainable entrepreneurship issued by UNITAR, the UN agency for sustainable development.

In addition to our research program contributing to achieving CO<sub>2</sub>-neutrality, optimizing raw material usage, promoting circular economy practices and advancing clean energy initiatives; we have initiated 30 actions over the three-year period in favor of sustainability with a stronger focus on 5 of the 17 Sustainable Development Goals defined as priority by CRM Group collaborators:



During the first year, 10 actions ranging from carbon footprint evaluation (including scope 3) to electrical consumption reduction, through biodiversity actions or rainwater collection strategy definition, have been successfully led and validated by the CCI.

This achievement is the outcome of collective endeavors from all collaborators, facilitated by the implementation of a dedicated governance framework for sustainability actions, inspired by the «Swarmwise methodology». This approach places collaborators at the forefront of the initiative.



CRM GROUP GRATEFULLY THANKS ITS INDUSTRIAL MEMBERS AND RESEARCH PARTNERS AS WELL AS THE FUNDING AUTHORITIES FOR THEIR COLLABORATION & SUPPORT.





# CRM GROUP: 75 YEARS OF INDEPENDENT RESEARCH & INNOVATION

“Our 75 years of experience in metallic materials is at the service of multiple sectors to solve your problem and turn ideas into industrial solutions”

Griet Lannoo CTO



In 2023, we celebrated our 75th anniversary, a milestone where we showcased our key competencies, expertise and innovation capacity, applauded by our stakeholders, members, partners and customers.

Founded 75 years ago to foster collaboration and innovation for the steel production, CRM Group's mission remains today centered on enhancing **collaboration and innovation to strengthen the role of metals in the major challenges related to the energy & digital transitions. Sustainability, resource efficiency circular economy and reducing the environmental impact** remain the drivers behind our activities. Therefore, our research program is fully aligned with and contributes to the United Nations Sustainable Development Goals.

With our expertise, laboratory infrastructure and pilot lines we accompany our customers in developing

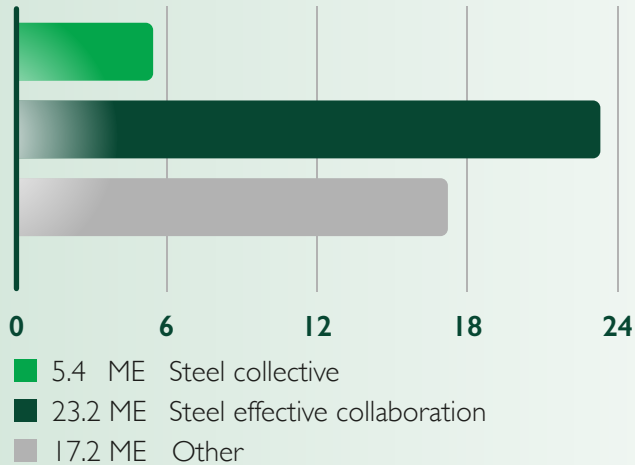
solutions **from the sound scientific background to the industrial implementation.**

We are leading the energy transition, promoting the circular economy and embracing digitalization & advanced manufacturing. Today we serve various sectors including metals industry, energy, nuclear, defense, aviation and aerospace.

By effectively **communicating and disseminating** our results and keeping our partners and customers regularly updated of recent developments, CRM Group is your window to the future. This activity report highlights key achievements of 2023, showcasing our expertise, competencies and tools to support you on your transition journey.

# KEY FIGURES

Income by program



- 3% European grants
- 23% National & regional grants
- 74% Industrial & effective collaboration

**TOTAL INCOME**  
45,9 Mio. EUR



- 45,5% Researchers
- 41,0% Technicians
- 13,5% Administrative staff



- 21,8% Female
- 78,2% Male



- 48,1% Belgian
- 51,9% Foreign

# ENERGY SHIFT

*As the economy rapidly transitions from fossil-based fuels to new green processes and solutions, CRM Group is committed to support its industrial partners in addressing the challenges associated to this industrial shift. This includes addressing issues related to energy efficiency and electrification, alternative fossil fuels and reductants, Carbon Capture Utilization & Storage as well as the integration of renewable energies.*

## EFFICIENT ENERGY USE AND CAPTURE ENERGY LOSSES

The most efficient way to reduce the CO<sub>2</sub> emission linked to the use of fossil fuels processes is to improve the **energy efficiency** of those energy intensive fossil fuels based process.

In 2023 we have been awarded a Horizon Europe project called HURRICANE for energy recuperation at Arcelormittal Ghent's steel rolling mill. The main objective of HURRICANE is to create a sector-coupling circular hub centered around the ArcelorMittal Ghent site. HURRICANE will target efficient resource management together with the recovery and utilization of squandered industrial waste heat and water coming from the different steel mill processes. CRM Group will design and test **new heat exchangers concepts to recover the heat from the product during the hot rolling process (hot strip) and after coiling (hot coils).**

"Butterfly is one of our flagship projects about developing a kiln where we concentrate in our best available technology the CO<sub>2</sub>, making it CCUS compatible, complying with the new objective of tackling CO<sub>2</sub> emissions. This is really one of our flagship projects. We are now under construction of the biggest pilot in the world for that technology, and we are doing that in close collaboration with the CRM Group."

"CRM Group is a key partner for Carmeuse: When you have such a partner with unique assets, infrastructure, and competencies so close to you, with the capability to work on designing, engineering, constructing, maintaining, and operating pilots of big size just related to our target, that's really something we can capitalize on. It's, for me, one of the unique bodies in Europe."

Jean-Yves Tilquin,  
R&D Director at Carmeuse Group



Various heat exchanger concepts, including radiation and conduction, will be developed to use the waste heat for other steel processes (i.e. heating up the pickling bath) with heat pumps, to generate electricity with an ORC engine or to heat up residential buildings near ArcelorMittal Ghent that are connected to the heat grid that will be realized. A coil simulator will be constructed to simulate the hot coils with a surface temperature of 600°C. On this simulator, new IR radiant capturing panels will be tested and evaluated with new coatings. Also, conductive heat extraction heat exchangers will be tested. 3D Heat transfer models will be developed to fit the data obtained from the laboratory trials and will be used to evaluate the industrial feasibility. Other possibilities to recuperate waste heat from coils by water coil cooling or heat radiation from the transfer bar (heat panels) will be studied.

## ELECTRIFICATION OF HEATING PROCESSES

Electrification plays a crucial role in the energy transition by reducing reliance to fossil fuels. Understanding the impact of the use of electrical heating systems on both the process and the product as well as the performance of heating elements is essential for optimizing the performance and reliability of electrified systems. With its expertise in material science and metrology CRM Group is accompanying industrial partners on these aspects in the framework of the HECO2 project portfolio:

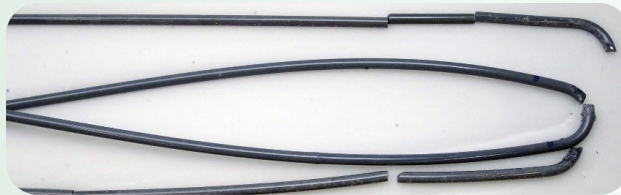
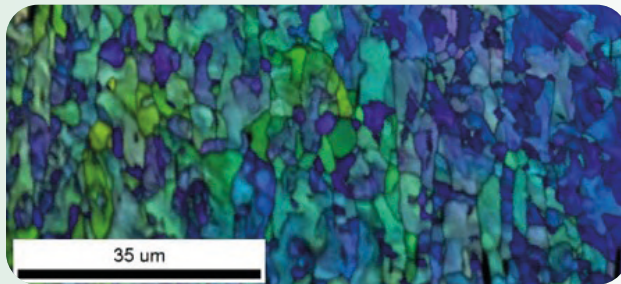
- To assist Aperam in its study of partial electrification of the slab reheating furnace and in addition to the study on the impact on product quality, CRM Group also actively contributes in characterizing the lifecycle of heating elements.

A dedicated instrumented pilot furnace simulating the industrial conditions has been set up at CRM Group for the continuous monitoring of the behavior of the heating elements during operation allowing a detailed end-life analysis.

Laboratory hybrid reheating furnace for continuous monitoring of heating elements during operation



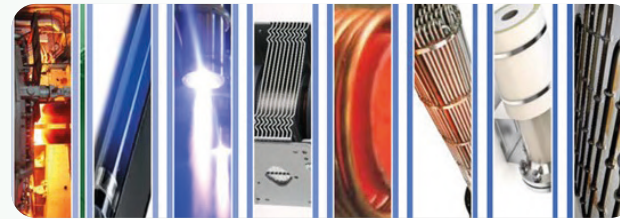
■ Various sets of **electrical heating elements** such as for instance pure Molybdenum heating elements for operation in glass smelting furnaces of AGC have also been subjected to **in-depth microscopic analysis**. Various resistive elements are being compared, along with the reactivity of the elements in molten glass. In atmospheric heating, elements consist of intermetallic phases of Mo and Si. The stability of these phases is determined by a combination of factors, including oxidation resistance, microstructure evolution rate, and nominal temperatures. While they are not brittle at high temperatures, they become very fragile when handled at room temperature.



■ When (partially) electrifying a process, ensuring temperature homogeneity is crucial. Induction heating in a float glass furnace, as envisaged by AGC, may induce thermal heterogeneities that impact product quality and facilities lifespan. It's therefore vital to consider all these inputs when designing such a furnace. To this aim, CRM Group is developing a **vision**

**system to monitor the glass bath temperature distribution and the refractory condition.** Material samples (glass and various refractories) have been studied to determine emissivity at different temperatures, compared to the theoretical black body values. These measurements allow defining strategic wavelength(s) for observing molten glass, and aid in temperature calibration of the vision system.

■ CRM Group is also working in collaboration with **JohnCockerill Environment to electrify its multi-stage furnace technology** (also known as MHF or multi-hearth furnaces), used in many thermal processes. The project was started with a review of the different electrical technologies that can be applied.



Several technologies have been selected for further studies and the more conventional one has first been selected for testing on CRM Group pilot plants: radiating resistive elements. The BATCH18 **pilot furnace** at CRM Group has first **been transformed to accommodate a vaulted radiant panel**, while maintaining the possibility to heat with a gas burner for more conventional tests.

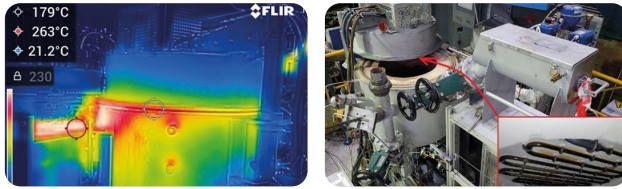
Initial tests have been carried out on the two most relevant industrial processes selected by JohnCockerill for such electrical conversion. These tests show that

Understanding behavior & performance of heating elements by in-depth characterization

Different electrical heating systems that can potentially be applied to MHF and have been reviewed: resistive elements, induction, micro-waves, plasma torches, etc



Radiative heating elements installed in the cover of the BATCH18 furnace



the quality of the product is maintained while reducing the energy consumed by more than 60%.

The data obtained will also allow designing the power and temperature patterns for **scaling-up the electrified process to the continuous MHF36 pilot plant.** The engineering of the electrification of this MHF36 has started, in collaboration with JohnCockerill. It is worthy to note that a local customer of JohnCockerill has already shown strong interest in the electrification of its industrial furnaces.

### ALTERNATIVE FOSSIL FUELS AND REDUCTANTS FOR IRON-ORE IN STEEL PRODUCTION

To reach the ambitious targets of reducing greenhouse gas emission by 50% by 2030 and achieving carbon-neutrality by 2050, the steel industry must explore different pathways.

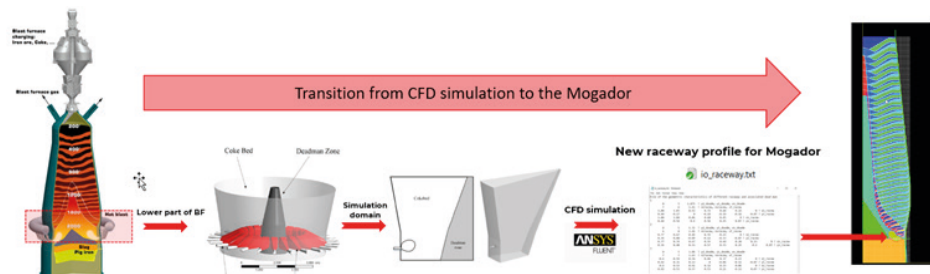
One of this pathways involves the **use of hydrogen or hydrogen-rich injectants in the blast furnace to reduce its CO<sub>2</sub>-emissions.** This practice will, more than at any time in recent decades, dramatically change the way blast furnaces are operated. To accompany this transition, CRM Group is rapidly updating its modelling & simulation tools to accommodate the new opera-

ting points of high percentage of H<sub>2</sub> in the reducing gas. CRM Group's mathematical model of the Blast Furnace process, known as 'MOGADOR', is therefore being upgraded. Since injecting high H<sub>2</sub>- levels at tuyere level affects the raceway properties (size, temperature and gas composition) and its form, a new tool based on CFD has been developed to define the size and gas composition at raceway boundaries, providing input for Mogador. The model is being utilized amongst others in the H<sub>2</sub>TRANSBF RFCS funded project aiming at 30-35% CO<sub>2</sub> mitigation by the combination of H<sub>2</sub> injection and DRI/HBI charging.

Another path for decarbonizing steelmaking involves replacing the existing Blast Furnaces by **Direct Reduction shafts.** For some years CRM Group has been upgrading its Blast furnace-related facilities to accommodate with Direct Reduction process as well. Amongst this upgrades, the lab scale furnace (500g samples) and the HUGE reactor (50 kg samples) can simulate operating conditions representative to the Direct Reduction process in a shaft (Midrex or HYL).

New facilities are also under development, including the recently commissioned plasma furnace/EAF pilot and a new direct reduction shaft simulator for faster DRI production compared to the HUGE reactor.

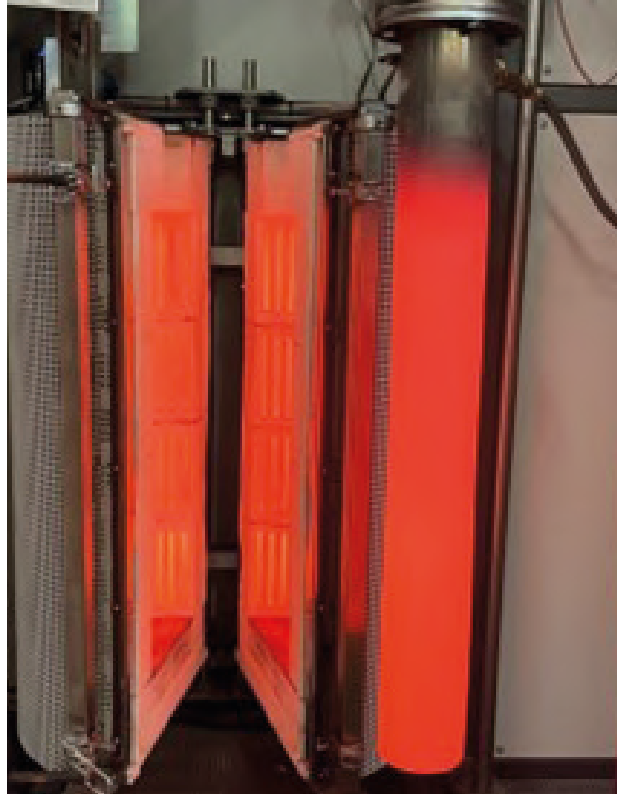
CFD simulation to predict the impact of H<sub>2</sub>-Injection on raceway and the integration of these results in the CRM Group MOGADOR Model



Lab Reduction furnace  
for BF and DR burden  
characterisation.



Lab reduction furnace  
details



Those facilities provide a significant added value for direct collaboration with industrial partners, as well as in RFCS-funded projects linked to direct reduction and regrouping the main European stakeholders: a.o. Steelproducers (ArcelorMittal, Tata Steel, Voestalpine, ADI, Dillinger, HKM. ....), technology providers (Primetals, Köppern, Danieli) and RTO's.

In the steelmaking process, reductants are essential for converting iron ore into hot metal. Traditionally, fossil carbon-containing reductants like coal have been utilized. In the SMART Life project we study the substitution of these fossil carbon-based reductants with circular waste-based reductants, such as end-of-life plastics. Through trials on our laboratory and pilot simulators we support ArcelorMittal Belgium in preparing the next phase of the recently commissioned Torero plant. Currently the Torero plant prepares bio-coal from waste wood, in the near **future alternative reductants** from waste plastics & textiles will also be produced.

The use of alternative carbon sources to **replace fossil fuel** has also been demonstrated for the sinter plant. In the RFCS-funded project 'Towards A zero CO<sup>2</sup> Sintering – TACOS' we succeeded in producing sinter at sinter pot scale without any fossil fuel. This could be achieved by a combination of alternative carbon sources for replacement of 65% of the solid fuel into the raw mix and the VeLoSint process by producing

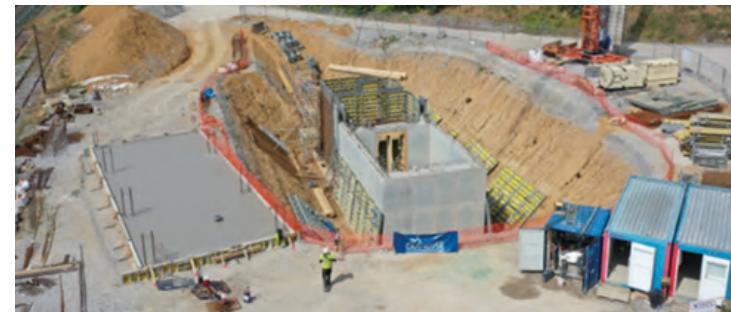
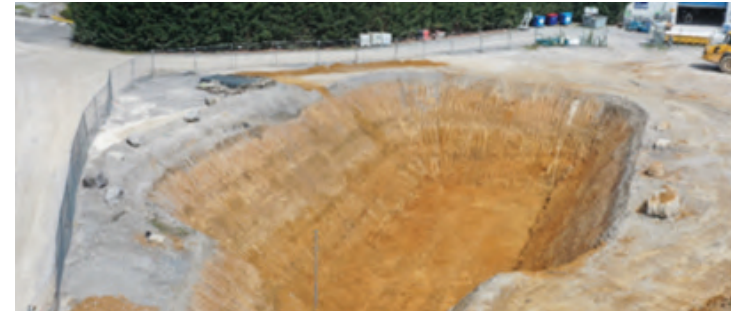


hot fumes in an external combustion chamber to compensate the other 35% of the solid fuel. In addition to complete suppression of the need for fossil fuel, the productivity could be improved (+18%) and the NO<sub>x</sub>-SO<sub>x</sub> emission could be drastically reduced.

A new project 'TRANSINTER Sintering decarbonisation low capex solutions & sinter process roll in the transition to DR route' within the RFCS funded program has been launched to further investigate solutions for clean sinter plants and to identify the path for valorization and transition of the sinter plants in the shift from iron & steelmaking from blast furnace to the direct reduction route.

### PROCESS ADAPTATIONS & CCUS

Finally, the **capture of the 'unavoidable' process CO<sub>2</sub>** related to the chemical reactions in so called CCUS Carbon Capture Utilization and Storage is an important domain of activities at CRM Group. The first important step related to CCUS is the **conversion of the process** in order to render it compatible with CCUS techniques. CRM Group and Carmeuse are joining forces for the groundbreaking "Butterfly" project, **a futuristic CO<sub>2</sub> concentration system in lime production**. The first-of-a-kind industrial demonstrator kiln concentrating the CO<sub>2</sub> liberated during the lime production is under construction in Carmeuse Seilles and will be operated by CRM Group. The project is part of the HECO<sub>2</sub>-project portfolio targeting the decarbonization of energy intensive industries and is supported by the Walloon Government and EU in the frame of Walloon Re-launch & Resilience Plan.







Another example, supported in the same HECO<sup>2</sup> project portfolio, concerns the characterization of all CO<sub>2</sub>-emission points of the production sites of the industrial partners (AGC, Carmeuse, Aperam and Prayon) and the investigation of the technical and economic feasibility of end-of-pipe CO<sub>2</sub> capture. Given the highly variable and diluted concentrations of CO<sub>2</sub> in the fumes from several of the industrial emission points such as the AOD convertor or the reheating furnaces at Aperam-Châtellet, our teams had to compare different potential solutions. **Temporary buffering**, which allows storing and concentrating the fumes seems to be the most appropriate approach to capture CO<sub>2</sub> in an economically viable way on highly variable off-gas streams.

**HYDROGEN AS AN  
IMPORTANT PIECE OF  
THE PUZZLE**

Aligned with the Belgian Hydrogen strategy and in the context of the Walloon intelligent specialization strategy related to 'Energy systems and sustainable habitats aims at developing new solutions for the green energy transition and the habitat of the future', CRM Group, UCLouvain and the cluster Tweed have given rise to the "IIS

**e-WallonHY"**, which aims at developing the green hydrogen value chain in Wallonia by bringing together the community of industrial players, research and training bodies and regional players to put in place a portfolio of innovative and coherent projects. This will enable all the IIS partners to develop their skills and to put in place the conditions necessary for the production of green hydrogen, in particular obtained from electricity of renewable origin, the transport and storage of hydrogen in different forms (solid, liquid and gaseous) and the development of applications for mobility, residential and industrial uses.

In this context, structuring projects have been launched in CRM Group within the Federal Energy Transition Fund and with the Walloon Region support:

- Unlike gas transport, where hydrogen-metal interactions are not a concern, the transportation of hydrogen poses the potential risk of hydrogen embrittlement. The development of new infrastructure or the repurpose / retrofitting of the existing gas transport network towards **the transport of pressurized hydrogen** requires an assessment of pipeline materials in terms of longevity in relation to exposure to hydrogen. To accompany the national

grid operators in upgrading the existing facilities and developing new infrastructure for transporting and storing hydrogen-containing gases, the READHY project aims to develop **innovative test methods**. The project, funded by the Federal Energy Transition Fund and conducted in collaboration with UCLouvain and UGhent will introduce new mechanical test enabling to study the crack-propagation in industrial tubes and different zones of their welds in hydrogen-containing pressurized gases.

■ The test capacity for **testing materials under cryogenic liquefied & gaseous hydrogen** will be further extended in 2024 with the development of a new platform in the MaterHYum project. This platform, with in particular tools for **quantifying the tensile and fatigue properties of materials exposed to hydrogen as well as their permeability to hydrogen gas** which will be based in the Walloon Region, and will be at the disposal of companies and research players to help them deploying the green hydrogen value chain, with the support of the SPW's S3 unit (Wallonia Smart Specialization Strategy) and the IIS e-WallonHY.

CRM Group also developed in the frame of HECO<sub>2</sub> project a **wide range of tools and procedures to evaluate the performance of electrolysis cell components** as well as the degradation of materials during their use, as a result of chemical, electrochemical or mechanical phenomena taking place in the electrolyzers.

## RENEWABLE ENERGY

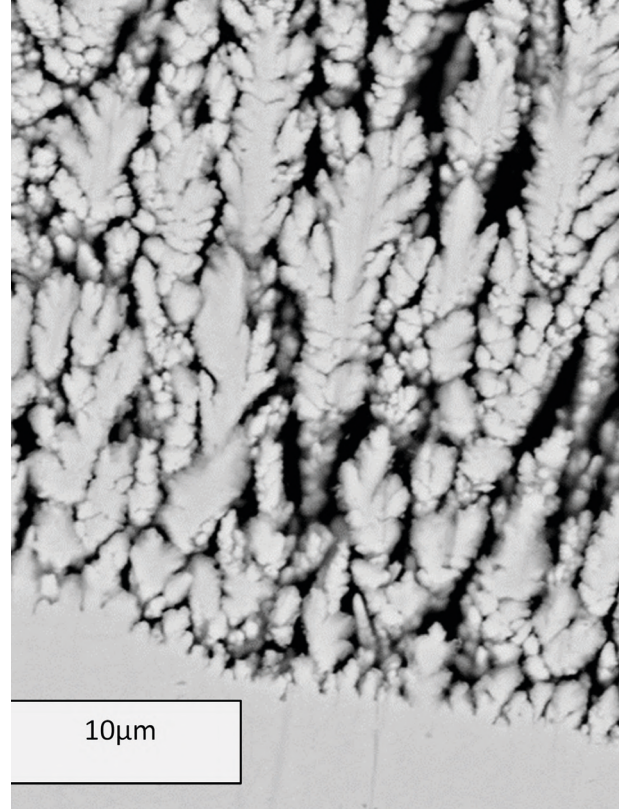
With the growing popularity of Electric Vehicles (EVs), there arises a pressing demand for the next generation of **batteries** - the solid-state Li Battery – aiming at enhancing safety, charging time and autonomy. The Horizon Europe project SEATBELT has the ambition to generate a local EU industry that revolves around **a cost-effective, robust all-solid state Li battery** by 2026. The affordable SEATBELT cells are produced by low-cost solvent-free extrusion process comprising a combination of innovative materials: thin Li metal, hybrid electrolyte, a safe cathode active material without critical materials (LFMP) and very thin Al current collector. The cell design being optimized by interface (operando and atomistic modelling) and process (machine learning) methodologies. The CRM Group plays a vital role in the development of battery materials, focusing on the **thin Li anode and the interlayer** between solid electrolyte and Lithium as well as on a thin protected **Al current collector**. Additionally, CRM group actively contributes to the **recycling process**, particularly to the purification of recycled Li.

For battery electrodes but also for fuel cells or hydrogen production, metallic **materials with very high specific surface** are of key importance for energy applications. In the frame of HECO<sub>2</sub> project, CRM Group developed competencies in the elaboration of such materials by electrochemical methods. Metal coatings with specific surfaces exceeding 1000 cm<sup>2</sup>/apparent cm<sup>2</sup> can be grown using simple and robust manufacturing routes.

The Batfactory project, awarded in the frame of the European Regional Development Fund (ERDF) program with the support of the European Union and the Walloon region, is dedicated to the production of **batteries and battery components** for stationary electrical energy storage and collective applications. The project involves **scaling up developments**, CRM Group is involved in transferring the manufacturing of roll-to-roll current collectors and electrodes to the pilot step.

Fully aligned with its Sustainable Development Goals, CRM Group is involved in the Walloon project 'SOC-CER', which seeks to establish **social inclusive renewable energy communities**. This initiative is centered around a living laboratory, aimed at developing a guide for good civic practices and pinpointing key success factors for the stakeholders (citizen authorities, public, businesses, associations and non-profit sector) to implement Renewable Energy Communities (RECs) including low revenues public.

Environmental impact assessments have been conduc-



Nickel-based coating with high specific surface and dendritic morphology prepared by electroplating for application in battery electrodes, fuel cells or hydrogen production



ted to evaluate the extent to which shared solar installations and electric mobility are contributing to EU objectives of decreasing GHG emissions ('Fit for 55' package). These evaluations have demonstrated that while these initiatives are essential to reach 2030 and 2050 targets, they alone are not sufficient. For the 2030 target, additional measures such as energy efficiency actions must also be implemented. For the 2050 target, carsharing emerges as a crucial element for achieving a significant impact at the community level. In 2024, efforts will be dedicated to validate these findings through real-life implementation of these measures, taking into account the societal response.

# CIRCULAR ECONOMY

Making the industry more circular is one of our major challenges to limit the use of raw materials and to decrease Europe's dependency on critical elements imports for which the demand is rising sharply due to new solutions as part of the energy transition.

## A CUTTING-EDGE PILOT FACILITY FOR PYROMETALLURGICAL PROCESSES

**Pyrometallurgy** offers the potential to facilitate direct recycling of metals via the metal, the slag or the fumes. With the support of the Walloon region, CRM Group is successfully starting up its highly versatile **pilot plasma/EAF furnace** at Hydrometal's industrial site (Engis). The primary aim of the furnace is to **recover critical raw materials** through various processes including melting, smelting and fuming in collaboration with Hydrometal.



*"Challenges are related to complexity of the materials so new activities new recipes, process are to be developed to bring back to the market the valuable critical elements. The plasma furnace, based on pyrometallurgy, has the ability to promote a quite direct recycling of complex material, generating either metal, either slag, or fumes, where you can collect the valuable metal, make separation, and so on.*

*"I'm pretty sure that in this recycling route, with the CO<sub>2</sub> problems, with the challenges on the raw material, on the critical metals, CRM Group has another 75 years for finding new solutions, new processes, and I'm pretty sure that the team will contribute to the challenge in the recycling.."*

*Philippe Henry, Board Member Jean Goldschmidt Intl/Hydrometal*

Steel melt in the pilot plasma furnace



Additionally, the pilot plant also supports the development of the **emerging steelmaking routes** (hydrogen-reduced DRI melted in electric arc furnace, smelting furnace...). Initial trials have focused on ferrous scrap melting, the furnace **representing a realistic Electric Arc Furnace pilot**, and an industrial **slag remelting** as preliminary step to the granulation process for **slag valorization**.

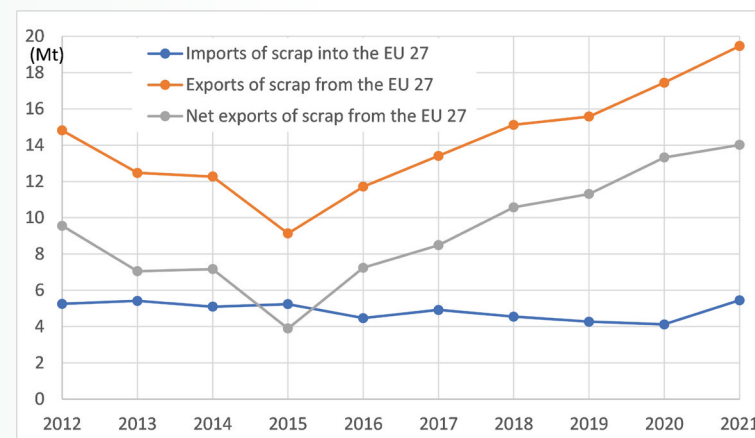
The upcoming trials will be fuming tests, utilizing self-reducing briquettes produced at CRM Group's facilities composed of oxidized low boiling point metal with carbon source. In that case, the product will be recovered in the fumes instead of in the metal or mineral phase.

## ENHANCING FERROUS SCRAP RECYCLING

**Steel scrap recycling** is at the core of the shift towards greater circularity in the steel sector. Adopting innovation in scrap **collection, sorting and pre-treatment** will enable the use of scrap as input for high quality steels. These challenges are tackled in the Horizon Europe funded project 'CAESAR' by

- identifying new opportunities to use and reuse lower-quality scrap through a better comprehension of the scrap market and the opportunities provided by advanced characterization, sorting and cleaning technologies;
- supporting the production of high-quality steel products in the EAF and the increase of scrap rate at the converter and
- developing and implementing an industrial demonstrator of scrap sorting/cleaning based on innovative combination of best available technologies.

At this stage, **an extensive mapping of the European scrap market** with emphasis of export out of EU has been provided, based on the analysis of scrap data from relevant European, national and regional reports. Several large size low-quality scrap samples (E1, E3, E40, HMS, WEEEs) have been bought on the market by the industrial partners. Some melting trials have been performed directly in ArcelorMittal Sestao and Dunkerque plants. Simultaneously, smaller-sized samples have been sent for characterization through melting trials at CRM Group premises. This approach allows for a representative estimation of the quality of the exported low-quality scrap grade.



Imports and export of scrap in the EU 27 (CAESAR project)

Furthermore, advanced cleaning technologies (Aspartel technology and BHS rotorshredder) are tested at intermediate size and, here again, the benefits are assessed by characterization melting trials.

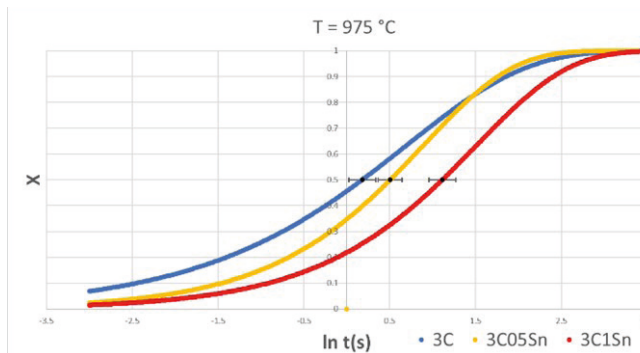
Another innovative technology investigated at CRM Group aims to enable the **recycling of galvanized and coated scrap** in both classical and electrical routes, while also recovering a high purity zinc. This involves the **dezincing** of scrap under vacuum conditions at high temperature. To thoroughly test the process, CRM Group's pre-conditioning furnace has been equipped with a condenser to liquefy the zinc vapors, a tank for recovering the liquid metal, an upgraded pumping system and a monitoring and data acquisition system for trials supervision and results exploitation. Next year, the installation of a dedicated insulated lid will allow for connection with an existing post-combustion unit, enabling atmospheric pyrolysis of any remaining organic pollutants.

In parallel, high-temperature vacuum trials with small samples have already led to zinc recovery rates beyond 95% and zinc purity above 99.99%.

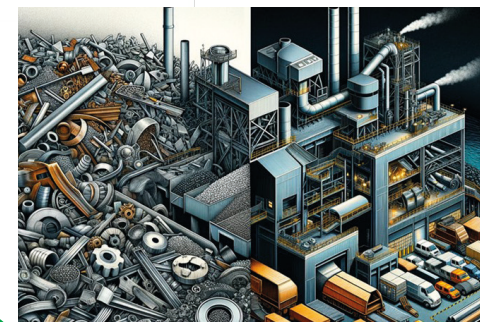
The acceleration of zero carbon steelmaking processes necessitates a thorough understanding of the metallurgical consequences that such a major shift will provoke. The introduction of more complex input flows, driven by circularity requirements, influence alloying conditions that are optimized for corresponding applications. This highlights the need to effectively manage the interaction between



Vacuum pre-conditioning furnace for scrap de-zincing and de-coating



Impact of residuals on metallurgical phenomena and product properties: impact of Sn on fractional softening (X): addition of Sn delays recrystallization (t50)



From scrap to high quality steel

## ENHANCED RECYCLING THROUGH WASTE PROCESSING

Efficient recycling often requires a preparatory stage such as drying, granulation, pelletizing or compaction. In conjunction with the new plasma furnace/EAF pilot, a dedicated **material preparation room** was implemented for the pre-treatment of the various loads. **Scaling up** processes from laboratory to industrial scale is a key competence of CRM Group and this applies equally for the waste processing. The integration of four vertical intensive mixers of varying sizes, ranging from 3 liters to 400 liters, demonstrates this capability effectively.

By-products are inevitably generated throughout the steel production chain. Their recycling, with associated economic and environmental benefits, currently mostly occurs in the sintering process. To counteract the degradation of process KPI's, such as productivity decrease and increase in pollutant emissions when **introducing by-products in the sinter mix**, a study was completed at CRM Group to assess **selective preparation strategies on their ability to counterbalance the impact on productivity and emissions**. The conclusions of the SinByOSe (SINtering with high BY-products recycling rate and environmental Optimization by SElective preparation) RFCS-funded project are summarized in a decision tree. This decision tree considers factors such as type of by-products to be pre-processed, the binder used, and the position of the selection preparation. The goal is effective recycling of the by-products without hampering the productivity while reducing emissions such as CO, CO<sub>2</sub>, SO<sub>2</sub>, NO<sub>x</sub> and VOC's.

Vertical intensive mixers in different sizes to support the upscaling to industrial applications.



Waste material preparation room

intentionally added alloying elements and residual elements. Current state-of-the-art steel grades have been developed through meticulous control of fundamental phenomena, including solid solution strengthening, precipitation, segregation and recrystallisation. However, altering compositions will inevitably impact microstructure, process conditions and final properties. These challenges are addressed at CRM Group, in collaboration with ArcelorMittal and Tata Steel, in a fundamental manner to ensure **future-proof and value-added low carbon footprint steel production**. By creating a global understanding of the **interaction between alloying elements and residuals, beyond empirical laws, the impact on product properties** can be efficiently mastered.



## PRODUCTION OF DRI OUT OF IRON AND ZINC BEARING BY-PRODUCTS

The steel industry currently recycles the majority of its by-products by internal recycling or external use. Nevertheless, substantial amounts of carbon and iron units in some sludge or dust can't be recycled yet due to a too high zinc content, but too low for external sales to zinc smelters. With the implementation of new decarbonized steel production flow sheets, other by-products will be generated, but still with the same circularity concern. The overarching objective of both European projects **ZincVal** (funded under RFCS) and **ZHYRON** (funded under Horizon Europe) is to develop technologies enabling **the reuse of low-zinc residues** (containing less than 20% Zinc) from the current and future steelmaking processes. These residues will **be transformed into direct reduced iron (DRI) and highly concentrated zinc oxide dust**, ensuring efficient utilization and minimizing waste in the steel production chain.

■ In the frame of the ZincVal project, CRM Group will study innovative ways to enhance **existing carbothermic** processes, such as Rotary Kiln and Rotary Hearth Furnace, to achieve a high degree of zinc enrichment in the generated dust while minimizing energy consumption. Various pre-treatments, such as agglomeration or addition of additives enhancing reduction or evaporation kinetics of zinc, will be explored to reduce treatment temperature and shorten processing time. A specific emphasis will be given to the quality, which will be monitoring in-line using the counting-sizing techniques developed in former ironmaking projects, along with a dedicated sampling and analysis set-up.

■ The ZHYRON project which will start in 2024 shares a similar objective. However it aims to replace the carbothermic reduction by a **new hydrogen based** one. By doing so complete decarbonization will be achieved, not only related to the steel production itself, but also for all associated recycling processes.



←  
Lab-scale weighing  
furnace



## BOOSTING CIRCULAR ECO-SYSTEMS

As part of the European Relaunch and resilience plan, the Walloon region is supporting projects under the portfolio 'Reverse Metallurgy +' (RM+) with the aim to strengthen the recycling and the circular economy in Wallonia.

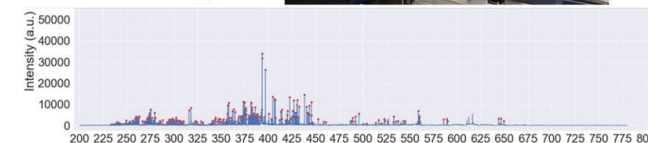
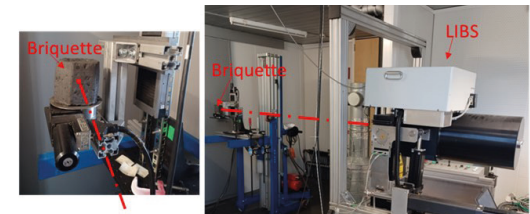
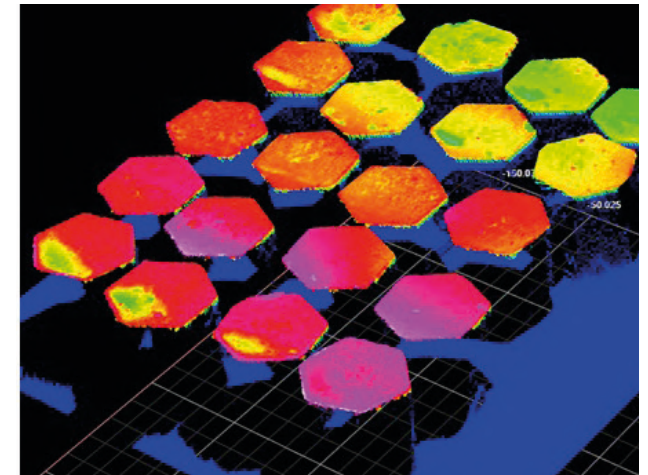
■ The Cistemec project tackles the challenge of **recycling the new end-of-life products** associated to the electric mobility such as electric cars, bikes and scooters. The objective is to recover all metals and rare earth elements from the batteries and magnets of the electric motors. In this frame, CRM Group has started studying at lab scale how to pyrolyze battery cells to allow their further processing in hydrometallurgical processing steps. Safety aspects have been thoroughly assessed (a.o. avoidance of fire risk and hazardous dust dispersion), in order to adapt accordingly the available pilot scale facilities at CRM-ETP before further upscaling.

■ CRM Group contributes through LIBS-based remote analysis to ECWALI, another RM+ project seeking to advance the selective sorting & separation of various aluminum and stainless steel grades through intelligent sensor based analysis combined with robotic sorting.

Battery recycling: battery cells after pyrolysis (top) and dismantled batteries to observe and analyze the condition of the components



LIBS measurements to be integrated in the on-line multi-sensor analyzer for characterization of chemical composition of briquettes



■ In the scope of PyroTeCnIC project, CRM Group aims to valorize the Walloon know-how in pyrometallurgy. For that, briquetted products of residues rich in alloying elements are developed to serve as secondary raw materials. To ensure high performance despite the greater intrinsic variability CRM Group is designing a specific on-line instrumentation for briquet quality control at Revatech. Quality control means mastering the morphology and mechanical properties of the product but especially **the quantification of the chemical composition of briquettes**. To achieve this objective, an **on-line multi-sensors analyzer prototype** is being developed at CRM Group. Using the LIBS technique, laser measurement equipment and other characterization technologies, the analyzer is being designed to certify the quality of the recycled product as a valuable secondary raw material for the pyrometallurgical industry.



**The Walloon Initiative for Circular Materials** “WIN4C”, led by CRM Group, gathers more than 80 private and public actors, from metallic, mineral and polymeric value chains, with the ambition to turn Wallonia into the European Circular Valley for technological materials, and to implement a strong circular economy. This ambition, supported by a global action plan defined for the next 3 years, will be reached by strengthening connections between actors from different value chains, by developing remarkable collaborative platforms, and place Walloon innovation actors at the heart of European partnerships. (logo Win4C). Win4C has co-organized with the innovation cluster ‘Pôle Mecatech’ an international event around the battery circular value chain. More than 150 participants were inspired by prestigious speakers all over Europe, by workshops and networking during this 2-days event.

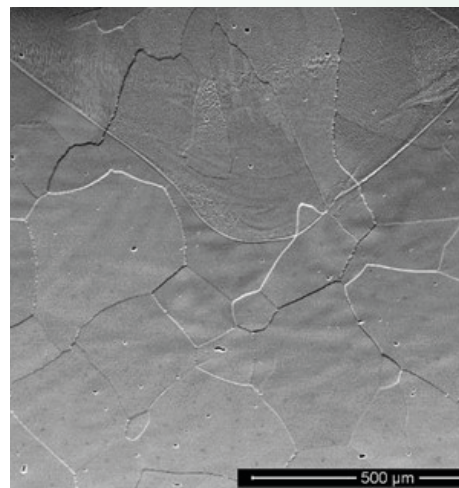
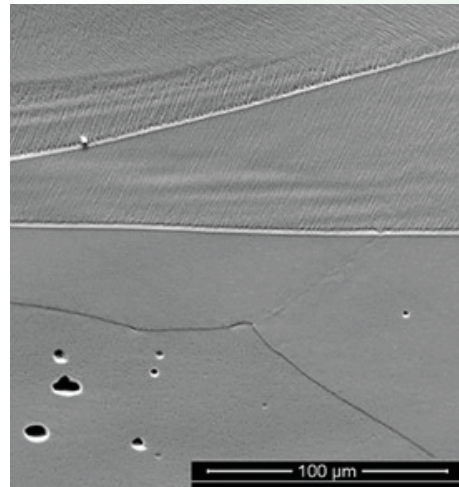
# ADVANCED MANUFACTURING

Advanced manufacturing at CRM Group covers the entire value chain, starting from the design and development of new alloys, progressing through metal deposition, including multi-material aspects, surface finishing, and joining, and extending to repair, re-use, and recycling processes.

## INNOVATIVE ALLOY DEVELOPMENT

To fully unlock the potential of the additive manufacturing technology, there's a need to develop new alloys tailored specifically for additive manufacturing. CRM Group is addressing this challenge of designing novel alloys (Ti,Al, ...) for additive manufacturing in different partnerships:

■ CRM Group is leading the Belgian-Italian partnership 'Ti4AM' in the framework of the ESA GSTP (European Space Agency General Support Technology Program) to develop novel beta-metastable titanium alloys with among others Anyshape, Politecnico Milano and UCL. These alloys are specially developed to exhibit a greater tolerance towards the presence of defects and rough surface states compared to the conventional Ti6Al4V alloy. Besides the coordination, CRM Group is actively engaged in conducting functional testing on the alloys. This includes tasks such as solidification simulation via electron beam melting, alpha-case growth and measurement of the Coefficient of Thermal Expansion (CTE).



Development of new Ti-alloys:  
SEM observations of rapidly solidified molten pools in novel Ti metastable alloy



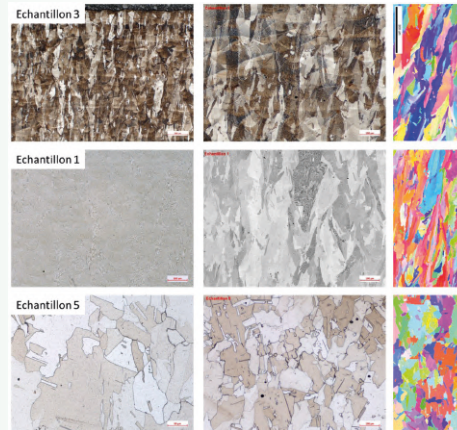
"We are working on R&D and innovation with CRM Group on servicing the powerplants for maintenance, repair and replacement and in that frame we are working on advanced repair techniques using additive manufacturing and cold spray. CRM Group integrates a lot of different aspects of their core competencies and skills. But they are also integrating digitalization into all types of processes, and they can provide services along the value chain. They are a key partner for us as a window on the R&D world, on the academic world, and as an integrated services provider that can enable us to accelerate our innovation."

Xavier Pitoiset, Chief Engineer  
Westinghouse

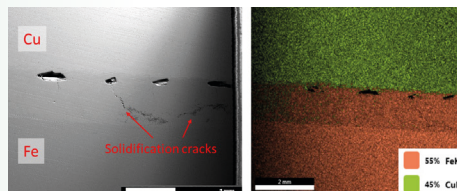
Corrosion test on newly developed Al-Zn-Mg alloys for Direct Energy deposition specially developed for aeronautical applications."



Supporting the 'first-time-right' 3D-printing and modelling by deep characterization (EBDS) of newly developed Scalmalloy® and Ni-alloys



Multi-metal additive manufacturing: Electron beam melting of Cu to Fe showing the formation of composition-driven solidification cracks



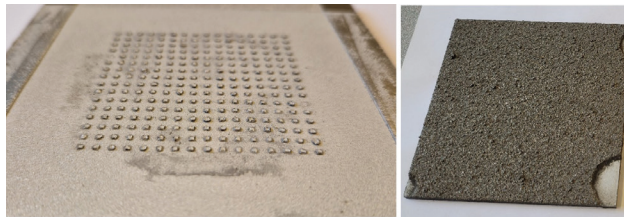
In the framework of another ESA project 'AI4DED', CRM Group refines the composition of previously studied **Al-Zn-Mg alloys to make them more compatible to Direct Energy Deposition (DED) additive manufacturing**. With requirements dictated by our **aerospace** partners, the alloy should not only be strong but also ensure a high stress corrosion resistance, good ductility and fully compatibility with anodization techniques. To tackle these goals, CRM Group also develops fast testing routes and novel stress corrosion cracking testing devices.

To further promote and improve additive manufacturing processes, achieving **'first-time-right' production** is imperative for a widespread adoption of the technology. The modelling work undertaken within the DIAMANTS project, supported by the Walloon region, will play a significant role in advancing this objective, particularly for the **high-value materials** such as Scalmalloy® or nickel based alloys. CRM Group supports the modeling of Cenaero and GDTech and the development of **new material laws** with tensile testing up to 900°C, with specific thermal treatment and conductivity, metallographic and EBSD analysis.

## MULTI-MATERIAL ADDITIVE MANUFACTURING

When printing **multi-metal components**, process conditions have to be carefully selected to obtain sound interfaces to enhance the mechanical and physical performance of the multi-metal printed component. In collaboration with ULC and Aerosint and with the support of the Walloon region, CRM Group is conducting research into the metallurgical aspects of dissimilar material combinations such as Al-Cu and Fe-Cu. Various tools, including thermal spray and electron beam melting, are used to physically simulate the interactions between these materials and the type of microstructure formed at the interface.

■ In collaboration with SIRRIS and supported by Wallonia in the Win4Collective program, the research project 'LIGHTFUNC', is focused on the manufacturing of **polymer-metal multi-material 3D components**. These components offer both design freedom, thanks to polymer 3D printing technologies, and weight savings, particularly advantageous for the transport and aeronautic sectors. Specifically, CRM Group is in charge of **designing appropriate interfaces to ensure a strong adhesion** of the polymeric material to the metal through mechanical anchoring. Various technologies are under investigation, including thermal spray, direct energy deposition and metal forming all aimed at creating geometric patterns on 3D metal parts surfaces. The thermal spray process is initially used to explore different types of surface morphologies: level of roughness, pattern geometry and surface density, type of pattern material, ... The effectiveness of each pattern is assessed by printing polymeric test pieces and subjecting them to tensile tests.

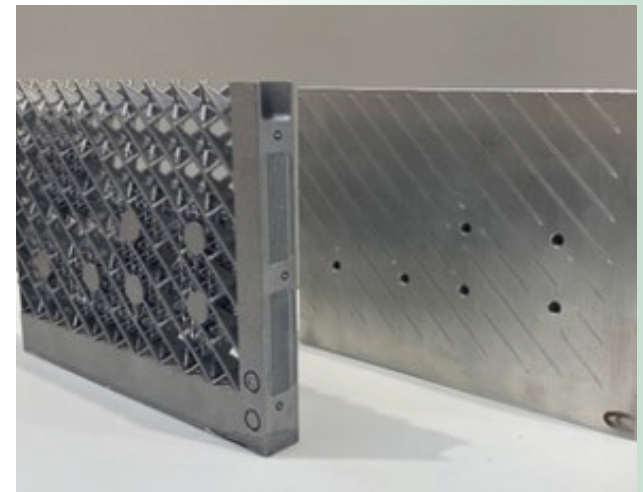


Multi-material 3D printing: Design of interface for strong adhesion between polymer & metal.



■ Additive Manufacturing and joining combines the design freedom of additive manufacturing with the flexibility and scalability offered by welding. The current understanding of the **impact of the joining process of additive manufacturing components in the context of spaceflight applications** however remains limited and is tackled in the JAMP-project (Joining of Additive Manufactured Parts) studying the joining of additive manufactured parts of two metals, aluminium and titanium, under ESA GSTP contract. Two spaceflight use cases were selected by the consortium (Redwire Space, Raytech, Sirris and CRM) for the study. A comparative study of different welding processes on flat samples supported the selection of the appropriate technologies and manufacturing concepts for the use cases.

Use cases of joining additive manufactured parts



## ADVANCED MANUFACTURING FOR A CIRCULAR ECONOMY

The advanced manufacturing platform at CRM Group is **highly connected to the circular economy** by repairing parts, the production of powders from waste materials and the functionalization of surfaces to improve longevity of parts.

In the frame of the European Relaunch and resilience plan and the Walloon Relaunch plan, the Walloon region supports projects aiming at reinforcing the recycling and the circular economy in Wallonia. The REMADE-project as part of the Reverse Metallurgy + (RM+) portfolio develops cheap metallic powders with reduced environmental impacts for various innovative manufacturing technologies (3D manufacturing, thermal spray, direct metal deposition,...). 15 partners including 11 industries follow this objective. CRM Group activities in 2023 focused on:

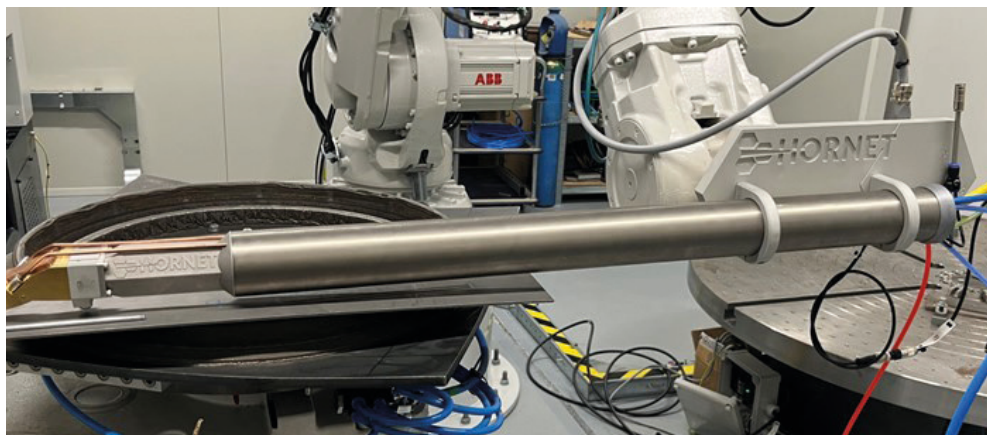
- The preparation of the stainless steel **scrap to produce electrodes** to feed the future atomization tower.

- Developing **repair strategies for the nuclear sector** with the determination of the process window for the reparation of defects on stainless steel parts with laser cladding including the automation of this process with robots and integration of **special nozzles for the internal repair of pipes with diameter larger than 70 mm.**

- The **robotized cold spray**, dedicated to repair or coating of multi-material parts, has also been delivered end of December and will be commissioned on March 2024.

- New coatings in which we have introduced diamonds to improve the coating durability of cutting tools.

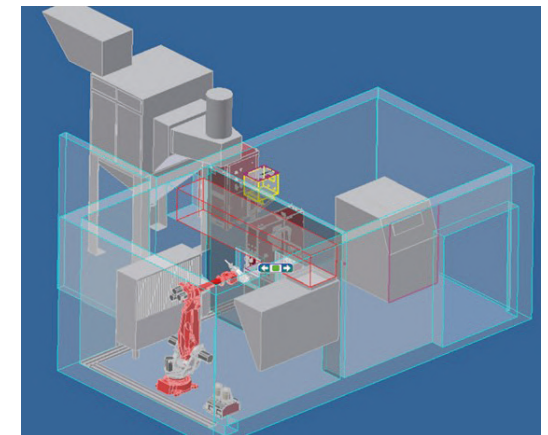
The aim of the European Varetit project was to demonstrate the feasibility of **upgrading Ti-6Al-4V titanium scrap** into high added value material by means of **simple processing steps and without melting process.** Within the project, **titanium machining chips were successfully transformed into powder that can be used in additive manufacturing processes.** Several steps were needed: cleaning, hydrogenation-dehydrogenation (HDH) process and grinding have been used. The produced powder has been characterized via morphological, flowability, size and chemical analysis in comparison with commercial titanium TA6V powder. Preliminary additive manufacturing tests were then carried out using powder bed fusion (SLM) and laser metal deposition (DED) techniques. Material health has been assessed with very promising results. It can be concluded that many difficulties were tackled to successfully produce the titanium powder from machining chips and that all the produced powder has been used: fractions < 70µm for powder bed fusion, fractions between 70 µm and 140 µm for DED applications and powder > 140µm for steel making.



Metal Deposition nozzle for the repair of internal pipes of 70mm+



Schematic view of the cold spray equipment



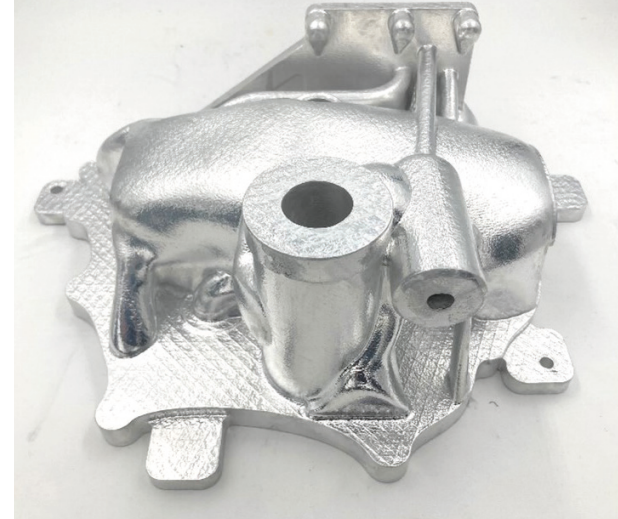
## SURFACE FINISHING

Improving the efficiency and performance of **finishing operations for additively manufactured components** is the primary objective of the FiSSel project, which is funded by the Walloon Region in the Win-4Collective framework. CRM Group has designed and implemented a **demonstration pilot line dedicated to chemical and electrochemical surface treatments**. This pilot line facilitates the assessment of finishing procedures on use-cases provided by the industrial user committee. The design of the line mirrors the configuration of a classical industrial surface treatment line but at smaller scale. It comprises six tanks, each with a capacity of 20 liters, enabling screening and validation studies. Parts with size up to 75x75x150mm<sup>3</sup> can be treated.



Pilot line for chemical and electrochemical surface treatments on additive manufactured parts installed at CRM Group in the frame of FiSSel project

CRM Group's expertise in surface finishing of additive parts was also put at the service of the European Space Agency in the frame of GSTP FITFAME project, coordinated by SABCA. This project is focused on **the finishing of complex parts, featuring inner channels and poorly accessible surfaces**. The results of



LPBF-printed hydraulic manifold printed by APworks and electropolished by Chimiderouil using a CRM Group developed electropolishing process.

the tests are more than conclusive and confirm the added value of the treatment protocol developed by CRM Group and implemented by Chimiderouil.

## DEMONSTRATOR

Within the scope of the IAWATHA VAMETAM EFRD project, CRM group has been actively involved in the development of the HYMAX equipment (Hybrid and Manufacturing XL) which incorporates the use of the Direct Energy Deposition 3D printing technology for the creation of a demonstrator. This highly flexible equipment with a 6-axis robot, 3 DED (Direct Energy Deposition) technologies and 3 external manipulators provides a multitude of possibilities. However, such flexibility also introduces complexity. To address this challenge, a demonstrator proposed by SONACA was selected. The focus was on the programming with NX Siemens and generating complex trajectories of 3D printing. Through this development effort, numerous challenges have been addressed, leading to the partial production of the demonstrator.

# DIGITALIZATION

Digitalization is the enabler for the circular economy, the energy transition and advanced manufacturing and the accelerator for the development of industrial processes and solutions.

## 3D additive functional coatings based on printed electronic

The evolution from printed electronics to **3D additive electronics** represents a major leap forward in the integration of sensors in three-dimensional objects. This technology holds the potential for innovative solutions and applications across various sectors: automotive, aeronautical, steel production, smart building industries, defense and, more recently, the space industry. By integrating sensors into 3D surfaces manufactured for these sectors, it becomes feasible to monitor critical parameters such as temperature, stress, vibration, corrosive environment, etc. This capability facilitates condition monitoring and extends the operation lifetime of the components.

## 3D CONFORMABLE HEATER ELEMENTS

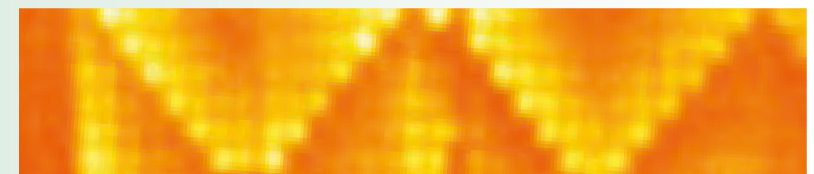
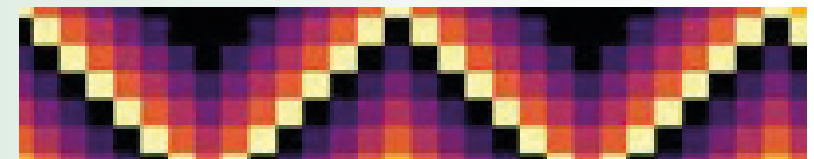
As part of the Wings (Walloonia Innovations for Green Skies) and VIRGA projects, we have developed two solutions for **heating devices using Printed Electronics, tailored to 3D objects**. The first solution, a collaboration with Sonaca, focuses on **Ice Protection Systems for aircraft leading edges**. In this application, a heating material is directly deposited on the 3D composite surface using a thermal spray wire arc process. The second solution, developed in partnership with John Cockerill, involves creating **smart stealth solutions in the Thermal Infrared (IR) band for the defense sector. This involves designing activatable heating patterns** to mimic the IR thermal signature of an object, produced using printed electronics technology. The feasibility of both technologies has been demonstrated, with performance validated by InfraRed (IR) camera testing, confirming

User interface with applied image and result on the infrared camera

*“We work together with CRM Group to develop new sensors that do not exist yet on the market. The latest projects I have in mind with CRM Group are the strip cleanliness measurement at the entry of the furnace. We are also working on a sensor that is able to measure the residual austenite in the steel. Additionally, we work on projects concerning digitalization: CRM Group has developed for us some low-cost IoT sensors. They have also developed a specific positioning system for confined spaces like the cellar of the line. Furthermore, they have developed a prototype of enhanced reality that uses connected glasses to guide the operators through the procedures.”*

*Bertrand Lejeune, General Manager Tata Steel – Segal*

Small demonstrator with a 120 x 440mm screen (8x32 pixels)





their ability to requisite temperature ranges. Right now, CRM Group is collaborating with both partners to scale up these solutions to representative sizes and is in the process of constructing two prototypes for further evaluation. The demonstrator included algorithms to control the solution. These algorithms range from simple predetermined pattern applications to full machine learning pattern relying on environment recognition.

## RFID ANTENNA ON METAL FOR STEEL PRODUCTS

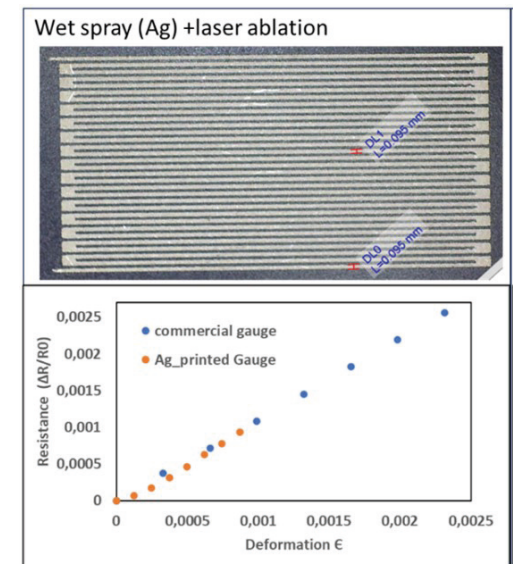
Investigations for integrating intelligent functions into steel products for construction and transport markets aim to promote circular economy objectives, innovation, and product tracking. A case study of the **e-identity product card for circular economy** concerned the sheet pile production in collaboration with ArcelorMittal. The objective was to propose a reliable **traceability solution with RFID tags**. This solution ensures an end-to-end tracking from the storage at the mills until the delivery, installation at the construction site, and ultimately end-of-life processes such as deconstruction for reuse and restocking. Initial test campaigns **at production site stock yard** identified RFID tags (flexible and thin tags, volumetric tags) compatible with sheet pile use. Operational tests for the introduction of the solution at an industrial level have started. **On-site tests with real application** of various RFID systems suitable for sheet piles ex-

plored aspects such as the fixing system and the operational challenges throughout the life cycle. RFID-tags positioned on the top part of the sheet piles (always outside soil) demonstrated resistance to the vibratory and impact hammer during pile driving and removal operation, maintaining readability and integrity. Ongoing tests and developments throughout 2024 aim to further enhance and optimize the solution.

## STRAIN SENSOR BY PRINTED ELECTRONIC

A printed strain sensor detects strain through resistance change when the object experiences strain in a certain direction. Typically printed with metallic inks in a serpentine shape, we recently investigated various ink materials such as silver (Ag), carbon (C), PEDOT: PSS as well as a variety of bulk material such as NiCr, NiAl, Cu and ZnAl using **thermal projection processes**. In addition to traditional R2R printed electronics, new deposition processes like wet electrostatic spray, pneumatic spray or thermal spray (plasma, electrical arc and cold spray) have been developed to apply functional coatings on complex surfaces of 3D objects. The advantage of the plasma spray processed sensor (ceramic and bulk metallic material) is its **resistance to elevated temperatures and corrosive environments**. In addition, **laser ablation (scribing)** is investigated on the coated layer to create a high-resolution strain sensor pattern. Serpentine path down to 80  $\mu\text{m}$  track width can be easily obtained.

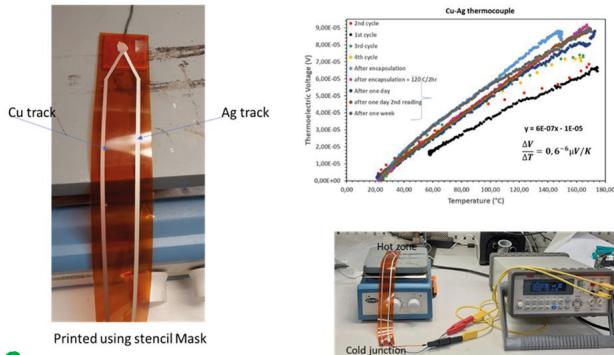
Serpentine style strain sensor pattern printed for Silver based strain sensor and change in resistance with respect to the applied deformation.



## THERMOCOUPLE SENSOR BASED ON 3D ADDITIVE ELECTRONIC

In the ACES Win4Collective project supported by the Walloon region and led by CRM Group in collaboration with Sirris and Multitel, **a thermocouple was printed on a flexible Kapton device as a step towards 3D objects.** Cu-Ag thermocouple material tracks of 25 cm length, 0.2 cm width were printed. The measuring hot junction is formed by the overlap of Cu and Ag tracks and through electrical terminal connectors at reference point (cold junction). The thermoelectric voltage generated by the temperature difference between hot and cold junction is linear and stable to the temperature over the temperature range 25 – 170°C and in time. In the current study, a combination of stencil masking and wet spray process was used to manufacture this sensor, making it compatible with 3D objects.

Cu-Ag printed thermocouple study (ACES)



Printed Cu-Ag thermocouple (2D planar flexible substrate) fabricated by wet electrostatic spray method, its measurement setup and thermoelectric voltage with respect to temperature variation

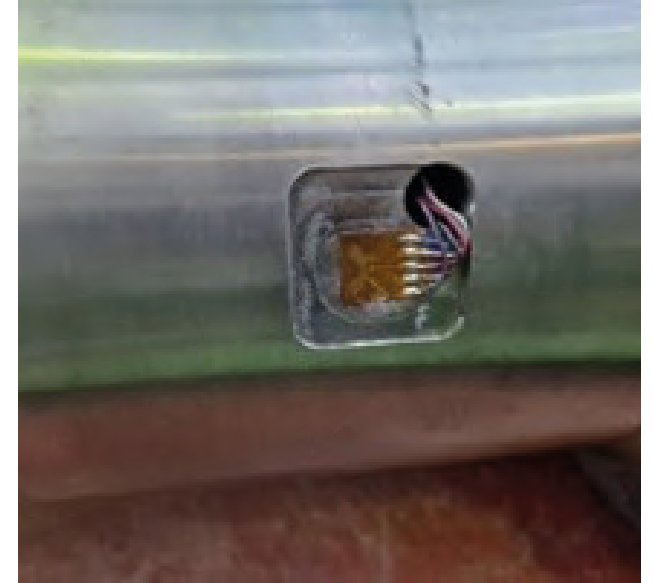
## INDUSTRY4.0

Smart reliable sensors in combination with sophisticated data analysis and treatment are the drivers of the Industry4.0.

In steel industry mastering the roll performance is of major importance for product quality, productivity & production cost.

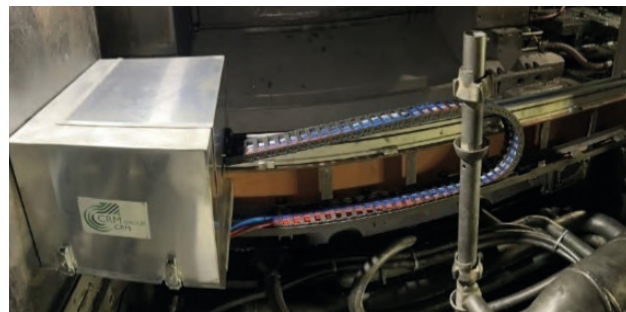
■ A collaborative regional initiative involving Marichal Ketin, Pepps, CRM Group and Taipro engineering aims to develop and validate at pilot line a **connected work roll for hot rolling.** This innovative approach facilitates the creation of a **digital twin for the work rolls**, enabling closer monitoring and analysis of their life cycle. This integrated system enables the prediction and detection of internal roll faults, incidents, thereby enhancing product quality through online profile and friction calculations. CRM Group has enhanced laboratory cylinders by integrating multiple sensors to create a prototype for a connected work roll. These sensors, including temperature, torque, and acceleration measurements, will transmit real-time data to a cloud platform.

■ In the field of cold rolling, CRM Group is participating in the RFCS funded BURWear research project, which aims to master the wear behaviour of back-up rolls in cold rolling mills. To achieve this objective, the BURWear consortium is developing a wear evolution model requiring an **on-line profile sensor** for vali-



Instrumentation of the connected work rolls

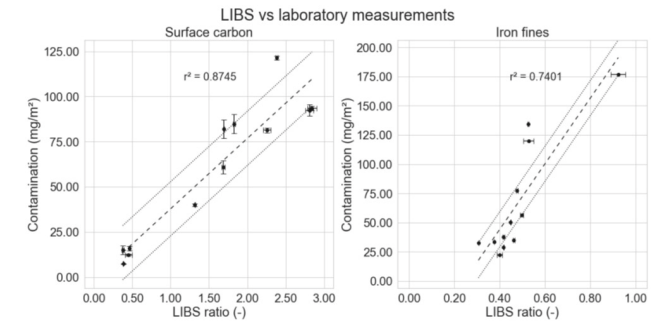
dition. This sensor system designed by CRM Group **measures the profile of a back-up roll in-line** during mill stoppages, i.e. when the roll is stopped. Considering the environment and the geometry of the roll, this sensor is capable of withstanding in-line stresses and making accurate measurements ( $<10\mu\text{m}$ ) over a length of almost 2 meters. The sensor is installed at Tata Steel Ijmuiden 6-high cold rolling mill and will be in operation for several months of measurement campaign during 2024. The results will be available next year.



In-line sensor for measuring with high precision the Back-Up Roll (BUR) wear in a 6 high cold rolling mill

■ The demand for high coating quality, particularly for exposed components, continues to rise. To meet these standards at the end of the galvanizing process, it is imperative to maintain high substrate surface cleanliness after cleaning at the entry of the galvanizing line, ensuring minimal carbon pollution and iron fines. The LIBS-based (Laser Induced Breakdown Spectroscopy) CleanEx sensor, developed in collaboration with ArcelorMittal and Tata Steel, is a **high-sensitive on-line device evaluating surface pollution level at the exit of the cleaning section before galvanizing**. After a first test on our pilot line and industrial trials in SEGAL, the sensor prototype has been fitted to ArcelorMittal EUROGAL galvanizing line to further validate the method industrially. The method can differentiate surface carbon from iron fines pollutions without any contact with the product (working distance is approximately 300mm). Sarclad has been selected by CRM Group as the partner for the commercialization of the sensor.

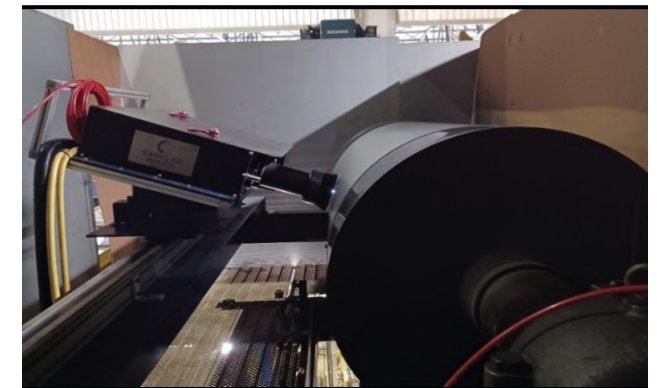
■ During skin pass after galvanizing, two types of defects have been identified on the skin-pass rolls, particularly in dry skin-pass stands: zinc fouling, which involves the accumulation of zinc particles inside the roll's rough surface, leading to poor roughness transfer, and zinc staining, characterized by large zinc agglomerations on the roll causing periodic impacts on the strip. To prevent these defects, most skin-pass stands are now equipped with water-based cleaning systems, which consume significant energy and generate wastewater. This project aims to develop a dry skin-pass cleaning system utilizing laser technology for zinc removal, coupled with online defect detection, quantification, and localization. CRM Group will develop the **roll**



On-line measurement of surface carbon and Fe-fines at the entry of the galvanizing line: Correlations between LIBS industrial measurements and laboratory analytical measurements



Cleanex: installed at ArcelorMittal Eurogal line.

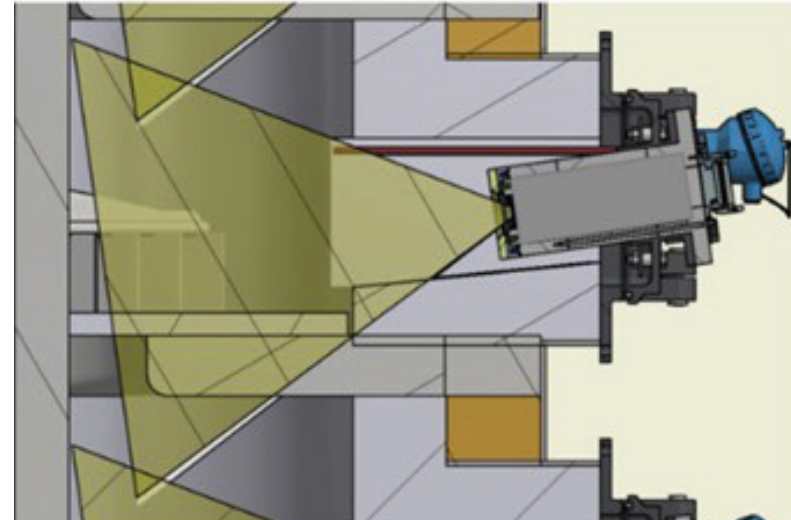


**monitoring system using its On-Line Microscope (OLM sensor).** First preliminary trials have **proven the aptitude of the OLM in combination with artificial intelligence applied on the images to detect both Zn-fouling as well as Zn-stains.** The ultimate goal of the OLACSKIN project is to demonstrate a pilot system that integrates roll inspection using OLM and laser cleaning and will be achieved, in collaboration with Tata Steel and P-Laser in the frame of a newly funded RFCS-project.

In collaboration with John-Cockerill, CRM Group is also engaged in the **digitalization of the Multiple Hearth Furnaces (MHF)** alongside the electrification efforts. An **endoscope-based inspection system** is under development, designed to be installed on each furnace floor structure to enable comprehensive observation of the entire calcination process. Currently, pressure inside the furnace is controlled by a conventional system, steered by a PID regulation unit that adjusts the speed of an extraction blower. The potential of enhancing this control through **da-**

**ta-driven modelling** is being assessed. At present, process data has been collected and used to perform initial analyses, including Principal Component Analysis (PCA). The key process parameters and actuators are defined for future inputs for a machine learning model. The objective of this model is to anticipate pressure variations in the furnace, with the aim of subsequently implementing a closed-loop control of the blower speed.

In 2023, CRM Group has been awarded a Horizon Europe project **‘DILAPRO Digital LAsEr PROduction’** that will allow ensuring that the complex products made with laser technology such as additive manufacturing meet all industrial needs in terms of design, quality, cost and sustainability. A digital twin software will be developed in order to qualify and certify the properties of the parts. CRM Group will support the development of the **digital twin by integrating sensors** on the direct energy deposition equipment HYMAX and demonstrators will be manufactured.



Digitalization of MHF:  
Illustration of the  
inspection system placed  
at each hearth and desired  
fields of view



# INDUSTRIAL PROCESSES, SOLUTIONS AND SERVICES

CRM Group has been known for decades for its ability to scale up innovations to industrial processes and solutions. This is possible thanks to our thorough knowledge of industrial processes, our pilot lines and the cooperation with industrial partners.

## IMPROVED PROCESS CONTROL IN STEEL HOT ROLLING MILL BY OPTIMIZATION OF COOLANT APPLICATION

Within the EU RFCS funded project **SMARTCOOL**, an advanced transfer bar cooling system is developed to correct transfer bar temperature distortions based on real time measurements captured just before the transfer bar cooling. A homogeneous temperature profile over the width and length will, besides more accurate product properties, improve the strip steering in finishing mill and reduce rolling incidents as cobbles. The project follows a phased approach, beginning with the validation of the concept on a full scale at laboratory level before progressing to industrial implementation. Together with the project

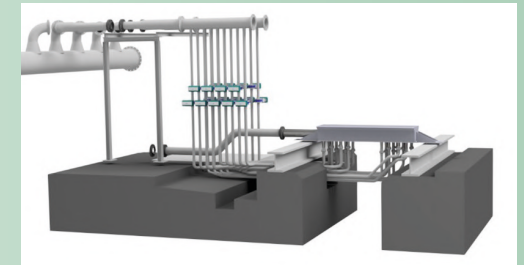
partners, ArcelorMittal, Tata Steel and University of Technology Brno, a detailed evaluation after long-term industrial trials will be performed to define the benefits and to study the roll out to other mills and applications.

## ON-LINE & REAL TIME PROFILE MEASUREMENT IN STEEL HOT ROLLING MILL

Controlling the wear of the pinch roll situated ahead of the down coiler in a hot strip mill is imperative for effectively addressing strip flatness concerns and minimizing coiling defects. To enable real-time monitoring of this pinch roll wear, CRM Group implemented a Roll Profiler as part of the RFCS funded 'RollRprof' project. The primary concern regarding the sensor development centered around the challenging working environment characterized by high temperatures, water exposure, the presence of abrasive particles, and significant mechanical stresses. Extensive testing of the system was conducted on a hot strip mill coiler roll, demonstrating its robustness and accuracy. Various data treatment algorithms were employed to mitigate signal noise stemming from vibrations, sensor temperature fluctuations, heat-induced deformations, and mechanical variations across different operational

*CRM Group is very critical to ArcelorMittal. Their expertise in developing innovative technology and pilot plants that eventually move into industrial applications is certainly a very unique skill and expertise that they have displayed over many decades. So, again, I only want to say that it is really very important for us to have the expertise and the innovativeness of the CRM Group team."*

*Pinakin Chaubal, CTO  
of ArcelorMittal*



Principle of the advanced transfer bar cooling system developed in the SMARTCOOL project



Full scale smart transfer bar cooling header for full characterisation at CRM Group

campaigns. The wear measurement, model prediction (developed by ArcelorMittal), and final offline roll measurements closely aligned, affirming the system's effectiveness. Moving forward, the Roll Profiler will be utilized alongside the wear model to optimize pinch roll wear and tailor the model for new steel grades expected in future production at ArcelorMittal Dunkirk.

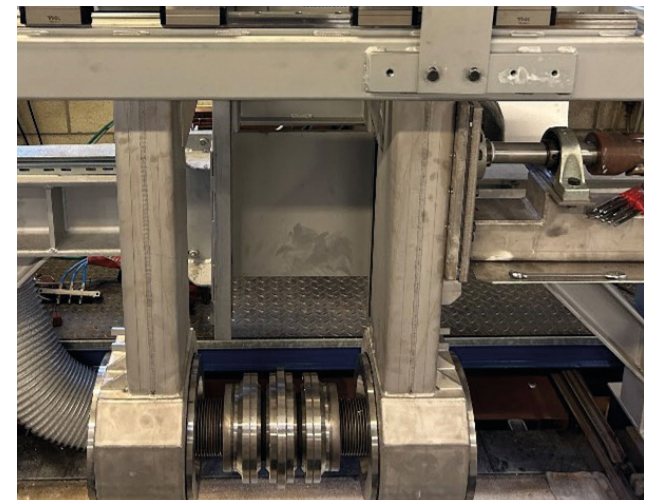
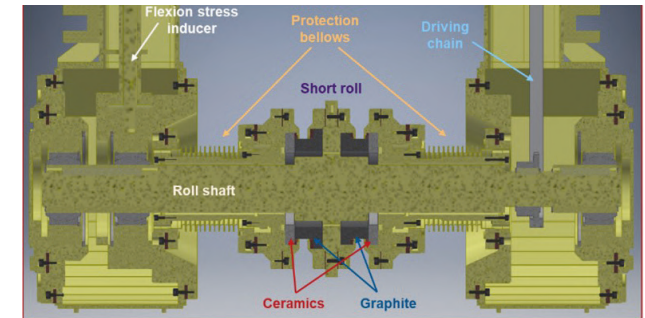
## INNOVATIVE TECHNOLOGIES FOR ZN-COATING

In coating technology, enhancing the speed of **hot dip galvanizing lines** poses technical hurdles, necessitating **improvements in submerged equipment** and strip stabilization mechanisms. Wear-induced vibrations from bearing deterioration in submerged rolls contribute to defects in coated strips, downgrading products and frequent hardware replacements, hampering line productivity. A solution devised by CRM Group involves removing rotation devices (bearings) from corrosive zinc melt using a specialized sealing system to mitigate vibration occurrences. A prototype tested earlier exhibited exceptional corrosion resistance and sealing capabilities but lacked assessment under varying process parameters (strip tension, line speed, ...) nor any risky zinc flow around the device. Consequently, **a new prototype** was developed in 2023 to **eva-**

**luate bearing behavior under diverse conditions such as loading, misalignment, shaft flexion, and process changes.** The improved prototype includes one leg for driving the roll and the other for stress generation and misalignment simulation. Tightness is maintained through ceramic-coated graphite parts and borided bellows, ensuring proper sealing even with minor roll and shaft displacements. Mounted on the pilot stand, the prototype is ready for rigorous testing in 2024.

**JVD (Jet Vapor Deposition) technology** has been developed by CRM Group as a new way to coat steel with Zinc vapor under vacuum. This technology has many advantages, one of them its **remarkably low carbon footprint** in comparison to conventional coating methods such as electro- and hot dip galvanizing. This development culminated in the construction of the **world's inaugural JVD** plant by ArcelorMittal with production started in 2017. In 2023, **Arcelor-Mittal forged a partnership with John Cockerill** to extend the application of CRM Group's JVD technology beyond its own operations to other steel manufacturers. CRM Group is actively engaged with the ArcelorMittal - John Cockerill consortium, providing **expertise during discussions with prospective licensees regarding technical specifications.** This licensing initiative signifies a significant milestone in the advancement of JVD technology as a groundbreaking solution in the field of metallic coatings. The technology has achieved a noteworthy level of maturity, evidenced by the production and sale of over one million tons of coated steel in 2023 since the production start.

Upscaling of the tight bearing concept for immersed rolls in galvanizing lines



## INDUSTRIALIZATION OF THE ELECTRON BEAM TECHNOLOGY ON ARCELORMITTAL CONTRISSON PAINTING LINE

The use of solvent-free Radcure paints is a significant **breakthrough in the world of coil-coating**. 20 years after the start of extensive developments and testing within the CRM Group, **Electron Beam (EB) curing technology** was implemented in 2023 for the first time in Europe on the coil-coating line 3 at ArcelorMittal Contrisson. The EB curing process is performed at room temperature and is much faster than a conventional thermal curing. Neither carbon dioxide nor VOC are produced and released with the use of this **green curing technology**. This was the motivation for ArcelorMittal to reduce its carbon footprint and to improve its energy performance and productivity.

CRM Group played a key role in **co-developing paint products** with suppliers, considering product specifications and coil coating line constraints. Additionally, CRM Group supported ArcelorMittal throughout the implementation of EB technology, **validating the process on the LERO pilot line**, defining **specifications for industrial upscaling equipment**, and assisting during engineering work, acceptance tests, commissioning, and initial trials. CRM Group also helped writing a Failure Mode and Effects Analysis (FMEA) document for quality control and supported ArcelorMittal in completing investment files to secure EU funding from the Innovation Fund for the project.

**Ready to plug-in Building-Integrated-Photovoltaic insulated panel for roofing steel envelope on the market**

In the domain of **solar energy**, the long-lasting collaboration between ArcelorMittal Construction and CRM Group has resulted in 2023 in the official launching by ArcelorMittal Construction of HELIOROOF solution; a **prefabricated insulated solar roof panel for pitched roofs**, outcome of the Helexio® Line plant funded by the EU innovation fund. This innovation is expected to reduce embodied CO<sub>2</sub> by 25% compared to standard solutions and prevent 170,000 tons of CO<sub>2</sub> emissions during the first decade of use. Joint efforts are pursued to allow ArcelorMittal Construction to recruit and deploy projects for pioneer customers as they prepare for the industrialization of Heliroof technology in Contrisson, France, by the second part of 2024.



World premiere - First steel coil with EB topcoat Contrisson in the presence of CRM Group

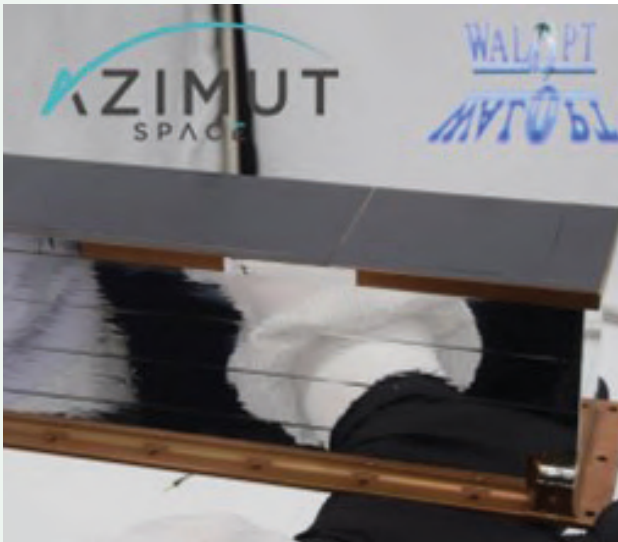
Electron beam equipment



## PHASE CHANGE MATERIALS FOR THERMAL MANAGEMENT OF ELECTRONICS IN SPACE

CRM Group developed innovative equipment for improved thermal management of electronics. These cutting-edge damping units are designed to effectively store and release thermal energy through the utilization of phase change material technology. In 2023, significant progress was made with the manufacturing and testing of multiple Phase Change Material Capacitors concluding ongoing PCM studies. Furthermore, critical properties of PCM capacitors, such as burst pressure and resistance to radiations were determined. This assessment has facilitated the increase of the Technology Readiness Level (TRL) of those units. New flight opportunities are now under evaluation.

### CRM GROUP'S CHARACTERIZATION



Phase Change Material (PCM) capacitors



### LABORATORY BRINGS ADDED VALUE TO A CASE STUDY FOR THE AERONAUTIC INDUSTRY

As part of the Walloon Initiative for Green Skies (WINGS), CRM group supported Safran Aero Boosters in solving quality issues related to the pickling of Ti low-pressure compressors. Blue stains compromising product quality have been deeply characterized at CRM Group, revealing them to likely be hydrated titanium dioxide encapsulating residues from stripping baths. Further analysis on rinse baths using techniques such as XPS and SIMS identified the optimal pH range to prevent residue precipitation. Experimentation confirmed that adjusting the rinse bath's pH effectively eliminated the stains. Finally, a control system linking pH, conductivity, and chemical species in the bath was implemented to ensure industrial scalability. With CRM group's assistance, Safran Aero Boosters **successfully resolved quality issues and reduced water consumption by a factor of four in the affected tank.**

Improved surface quality after pickling in the aeronautic industry





# DISSEMINATION, EVENTS AND PARTNERSHIPS

CRM Group teams up with industrial partners, research organization and clusters to accelerate the developments, to connect with partners and to widely disseminate its results.

## 75 YEARS OF CRM GROUP

Thursday 28th of September 2023 marked an important milestone in the history of CRM Group. We celebrated our 75th anniversary in the wonderful setting of the Abbey of Val-Saint Lambert, a landmark within the industrial valley of Liège. In the presence of more than 230 partners, stakeholders and employees from industry, universities, research partners and public organizations we seized this excellent opportunity to look back, be proud of our achievements and dream forward.

A retrospective video showcased our rich past with multiple breakthrough inventions and industrial implementations. The scene was set for an evening animated with clear-cut videos introducing three panel discussions showing the path CRM Group has chosen to increase its impact on the future of our main industries.

With the support of our founding members and many of our current partners we demonstrated how circular economy, energy shift and advanced manufacturing technologies are the keys to these societal challenges. Testimonials of Brad Davey, executive VP of Arcelor-Mittal, and Thomas Dermine, State Secretary for Economic Recovery, Strategic Investment and Science Policy, underlined the importance of creating a sustainable future through collaboration. It is with immense pride and gratitude that we look back on this event and especially want to thank our panelists Manfred Van Vlierberghe, Vincent Ritman, Philippe Renier, Fabrice Pelzer, Francois Michel, Sébastien Dossogne, François Lepot, Laurent Forget, Nicolas Vanbockstal, Greg Ludkovsky and Debashish Bhattacharjee for their valuable contribution to our celebration. With this continued support, we are confident that the future holds even greater accomplishments in the next 75 years of innovation, partnership, and success!

## PARTICIPATION IN KEY EVENTS

During the AISTECH ceremony at AISTech 2023 in Detroit, USA, in May 2023, our colleague Sebastien Flament received the 2023 AIST Hot Sheet Rolling Best Paper Award for the paper entitled "Importance of Roll Oxide to Increase Roll Life in a Hot Rolling Mill." on behalf of the authors Sebastien Flament, Hugo Uijtdebroeks, Gisele Walmag, Zafer Koont. Established in 2007, this award is presented to the author of a paper, selected by the AIST Rolling and Processing Technology Division, and judged to be the best paper submitted to the Hot Sheet Rolling Technology Committee.



 75 years of  
CRM Group

It's the 4th award in 10 years that CRM experts are receiving, confirming their profound & worldwide recognized expertise in steel rolling & work rolls.

### ESTAD-METEC 2023

Several CRM Group experts presented our cutting-edge research papers in the fields of zero CO<sub>2</sub> emission sintering, cold bonded agglomerates and back-up roll degradation in cold rolling at the European Steel Technology and Application Days, the largest iron and steel conference in Europe.

### DISSHEAT

In the frame of the RFCS-funded DISSHEAT project on the dissemination of the heating technology research results for emission minimization and process optimization, CRM Group co-organized several on-line webinars and a dedicated workshop at the ESTAD-METEC conference.

### HANNOVER MESSE:

CRM Group showcased its research and innovation expertise at the prestigious HANNOVER Messe, demonstrating our commitment to advancing technology and sustainability in manufacturing and energy industries.

### COP28

At the 2023 United Nations Climate Change Conference or Conference of the parties UNFCCC, known as COP28 in Dubai, CRM Group presented its hydrogen initiatives and underscored its dedication to global climate action, highlighting our role in addressing climate challenges through innovative solutions.

### Our Innovation Loop at Hannover Messe 2023



### Cop28



## GALVATECH 2023

Our experts made significant contributions to the Galvatech 2023 event in Seoul, sharing insights and advancements in galvanization technology, reaffirming our position as a leader in this critical sector. In collaboration with our R2R-NET partners we have co-organised the networking event Roll-to-Roll technologies-Get Ready for the future challenges in November 2023.

## INTERNATIONAL PARIS AIR SHOW 2023

AT the International Paris Air Show in June 2023 CRM Group experts presenting the latest advances related to the aerospace and aeronautic sectors developed in various frameworks such as ESA programs, WINGS, Skywin, Mecatech, ... and in collaboration with our industrial and research partners.

## THE CIRCULAR WALLONIA DAYS

In 2023, CRM Group actively participated in the second edition of Circular Wallonia Days organized by the Mecatech Cluster and Win4C, an inclusive event dedicated to advancing the circularity of the batteries value chain. This event brought together like-minded individuals, industries, and organizations passionate about sustainability. It provided an opportunity to unlock the full potential of a circular battery future through industrial partnerships with companies in the vibrant Wallonia Region and surrounding countries.

## EVENTS AT THE CRM GROUP

In parallel to attending external events, the CRM Group regularly welcomes guests to its facilities, including our laboratories, providing valuable insight into our state-of-the-art facilities and expertise. In 2023, for example, we welcomed a delegation to observe our capabilities in corrosion analysis, material characterization and failure studies, as part of a study day.

Several groups of students from different disciplines have visited CRM Group's facilities and learned how CRM group contributes to the key social and industrial challenges related to circular economy, energy shift and advanced & digital manufacturing technologies.

We also regularly host various workshops, such as the Solid4B cluster's hybrid workshop on December 12, 2023. Participants discovered how solid-state Li-metal batteries are paving the way for a more sustainable future, exploring their vast potential and the challenges they pose on the road to the circular economy. This was a must-attend event for innovators, policy-makers, researchers and industry leaders.

In 2023, CRM Group extended its team with the addition of 12 new colleagues, each bringing unique skills and perspectives to our organization. To facilitate their integration into our dynamic work environment, we host Welcome Days several times a year. These immersive events offer our new team members the chance to embark on a comprehensive tour of all 11 of our sites, where they can gain firsthand insights into our diverse operations and facilities.



The Circular Wallonia Day

Solid 4B



AS A COLLECTIVE RESEARCH CENTRE RECOGNISED BY THE BELGIAN AND REGIONAL AUTHORITIES, CRM GROUP IS MEMBER OF:



### Belgian Security and Defence Industry

<https://www.bsdi.be>



### Wal-Tech:

An association regrouping the 19 collective research centres certified by the Walloon Region. Several platforms have been created to share experience and coordinate activities.

<https://www.wal-tech.be>



### Win4C, The Walloon Initiative for Circular Materials (Win4C):

The strategic innovation initiative in Wallonia for the circular economy (metals, polymers & minerals). A partnership of 46 dynamic and innovative companies (23 GE, 23 SMEs), 9 research centres with outstanding infrastructures, 4 internationally recognised universities, as well as 24 public sector organisations and institutions.



### VLOOT (VLaamse Overkoepelende Organisatie van Technologie- & Innovatieverstrekkers).

It is a structural overall collaboration between more than 20 technological and scientific innovation actors in Flanders.

<https://www.vloot.be>



### MRC (Material Research Cluster Gent):

Is an initiative in which seven partners (OCAS, Gent University, Sirris, BIL, Clusta, CRM Group, SIM) share common laboratories with a strong focus on metals. This cluster has at its disposal state-of-the-art equipment for characterisation and testing from the nanoscale to large-scale industrial components and structures and more than 200 scientists and technicians under one same roof.

<https://www.mrcluster.be>



### Flanders Metals Valley

A climate-neutral and circular metallurgical cluster in Flanders, innovative and future-oriented, recognised as an essential, competitive pillar of the Flemish industry. Flanders Metals Valley is a catalyst for a vibrant, climate-neutral and circular metallurgical cluster in Flanders, dynamically embedded in an international industrial ecosystem.

<https://flandersmetalsvalley.be>



### Innovaders:

The new identity of the UCRC (Union of Collective Research Centres), which promotes collective research, encourages cooperation and synergies and defends our common interests.

<https://www.innovaders.be>



### A6K

Is a network of technological companies bringing together relevant players from Wallonia, Belgium and elsewhere in the fields of energy, communication and embedded systems or operational transformation towards Industry 4.0 to encourage the emergence of projects.

<https://www.a6k.be/fr>



### E-wallonHy:

The strategic innovation initiative in Wallonia on Green Hydrogen, bringing together different actors along the value chain of green hydrogen, from the production (power-to-H2), to storage and transport until its use.



### MadeInWal:

The strategic innovation initiative in Wallonia on 'Advanced Products & Manufacturing in Wallonia'. Federating innovation initiatives covering the entire "Manufacturing" value chain, with the aim of (re)developing Wallonia's industrial fabric.



### RIES,

A network of independent European steel research institutes (CRM, Rina-CSM, VdEh-BFI, Swerim and KI-Met)



### The European Steel Technology Platform (ESTEP)

brings together all the major stakeholders in the European steel industry (steel manufacturers, universities and research institutions active in steel research, major users of steel, and public bodies like the European Commission and national governments).

<https://www.estep.eu>



In the frame of EIT Raw Materials, a European Pilot Plant Network for Extractive Metallurgy and Mineral Processing

**(Metnet)** has been created, offering to customers an access to pilot plants in order to bring ideas or concepts into industrial use. Besides CRM, the current members are Swerea MEFOS (Sweden), BRGM, CEA & ERAMET (France), GTK (Finland), ELKEM (Norway), IMN (Poland) and MPI (UK).



### PROMETIA,

An international non-profit association promoting innovation in mineral processing and extractive metallurgy for mining and recycling of raw materials.

<https://prometia.eu>



Together with ULiège and over 120 other European industrial, academic and research partners, CRM is since 2015 a member of the KIC (Knowledge and Innovation Community) **“EIT Raw Materials”**, covering a wide range of themes like exploration, mining, efficient use of raw materials in process manufacturing industry, recycling and substitution of critical raw materials.

<https://eitrawmaterials.eu>



### Hybrid 3D network,

a network partner of small and medium-sized companies and research institutions from all over Germany, Belgium, Swiss and Austria active in (hybrid) additive manufacturing who want to expand their range of knowledge, share their experience with other partners, generate and implement new ideas and be upfront in the emerging field and market of hybrid additive 3D manufacturing technologies and processes.

<https://www.hybrid-3d-network.eu>

**AT THE EUROPEAN LEVEL, CRM GROUP TAKES ACTIVELY PART TO THE FOLLOWING ORGANISATIONS AND PLATFORMS:**



**ERMA** network brings together a growing number of organisations from the public and private sectors covering the entire raw materials value chain for contributing to ensure a reliable, secure and sustainable access to raw materials.

<https://erma.eu>



**A.SPIRE** is the European Association which is committed to manage and implement the Processes4Planet coprogrammed Partnership.

<https://www.aspire2050.eu>



### AFELIM is the French printed electronics

**association.** It represents the companies that do business in printed electronics principally in France.

AFELIM represents every profession in the value chain.

AFELIM - Association française de l'électronique imprimée



### **EBA250**

Is a platform for key stakeholders throughout the entire battery value chain.

<https://www.eba250.com>



### **The European Factories of the Future Research Association (EFFRA)**

is a non-for-profit, industry-driven association promoting the development of new and innovative production technologies.

<https://www.effra.eu/>



**Hydrogen Europe Research** is an international, non-profit association composed of more than 150 Universities and Research & Technology Organisations (RTO) from 29 countries all over Europe and beyond. Our members are active within the European hydrogen and fuel cells sector:

<https://hydrogeneuroperesearch.eu/>

## **LET US MENTION THAT CRM IS ALSO MEMBER OF :**



**WorldSteel:** the International Institute of the Steel Industry



**EUROFER:** the European Federation of the Steel Industry,



**UWE:** Union of the Walloon Enterprises

# PUBLICATIONS & CONFERENCES 2023

## AWARD

The 2023 AIST Hot Sheet Rolling Best Paper Award for the paper entitled "Importance of Roll Oxide to Increase Roll Life in a Hot Rolling Mill." Sebastien Flament, Hugo Uijtdebroeks, Gisele Walmag, Zafer Koont. Established in 2007, this award is presented to the author of a paper, selected by the AIST Rolling and Processing Technology Division, and judged to be the best paper submitted to the Hot Sheet Rolling Technology Committee.



2023 AISTEC Hot Sheet Rolling Best Paper AWARD

## CARBON NEUTRAL METAL PRODUCTION, RECYCLING & ENERGY SHIFT

**Rassili, Ahmed**

Clean Steel Partnership Project - CAESAR

ESTEP Spring Dissemination Event, March 29-30, 2023, Pisa

**J. Neutjens**

Walloon Innovation for Circular Materials

Win4C-event, June 1, 2023, Liège, Belgium

**Van Loo, Frédéric ; Fraikin, Laurent ;**

**Garcia Cimadevilla, José Luis ;**

**Froehling, Beate ; Vega, Noelia ;**

**Lorenzo, Jose Barros ;**

**Martin, Ciaran ; Xiao, Yanping**

COACH - Cold-bonded agglomerates for the blast furnace with chemically engineered binders

Metec & 6th ESTAD 2023, June 12-16, 2023, Düsseldorf

**Fouarge, Hubert ;**

**Van Loo, Frédéric ; Wiencke, Jan ;**

**Martinez-Pacheco, Maria ;**

**Di Sante, Loredana**

TACOS - Towards a zero CO<sub>2</sub>

sintering

Metec & 6th ESTAD 2023, June 12-16, 2023, Düsseldorf

**Dornelas, Bárbara ;**

**Polato, Clément ; Martinez Pacheco, Maria ; Fraikin, Laurent**

Sintering with high by-products recycling rate and environmental optimization by selective preparation

Metec & 6th ESTAD 2023, June 12-16, 2023, Düsseldorf

**T. Hauck; T. Kempken; J. Borlée**

Decarbonisation scenarios for the European steel industry and their dependence on framework conditions

Metec & 6th ESTAD 2023, June 2023, Dusseldorf

**Pierret, Jean-Christophe**

Circularity Enhancements by low quality Scrap Analysis and Refinement (CAESAR HEU project)

ESTEP Annual Event 2023 - A Circular Economy driven by the European Steel, October 3-5, 2023, Barcelona

**Neutjens**

Vers une décarbonisation de l'industrie : défis et solutions,

**J. Neutjens**

Conférence Hydrogène et Transition énergétique, October 18, 2023, Tanger, Maroc

**B. Vanderheyden**

New CRM's pilot scale plasma furnace at the service of circular economy and

energy transition

PROMETIA's 10th Scientific Seminar, November 28-30, 2023, Lisboa

**Pierret, Jean-Christophe**

Circularity Enhancements by low quality Scrap Analysis and Refinement (CAESAR HEU project)

Clean Steel Partnership Infoday organized by NCP4Industry, December 13, 2023, on-line

**J. Neutjens**

From Hydrogen to Carbon Neutrality: Technological solutions at Global and Regional level

COP28, Dubai, December 2023

## SMART & SUSTAINABLE PROCESSES & PRODUCT METALLURGY

**S. Flament, G. Walmag, H. Bolt**

Strong step forward in the understanding of back-up rolls degradation in various cold and temper rolling mills

Metec & 6th ESTAD 2023, June 2023, Dusseldorf

**Th. Gossuin, G. Moreas, W. Smailes,**

**D. Egner, M. Roiseux,**

**J. Di Girolamo**

On-line cleanliness monitoring with LIBS-based sensor

Galvatech 2023 (<http://www.galvatech2023.org/>), Seoul (KR), October 2023

## FINISHING & COATING

**Michel Boyer, Lionel Goiset, Nauwfel Amimi, Sergio Pace, Eric Silberberg**  
Jet vapor deposition: A technical economic alternative for ZN coatings of future steels potential worldwide market

*METEC/ESTAD 2023, Düsseldorf from June 12 - 16, 2023*

**O. Brégrand**

Towards High Speed Galvanizing – Mastering Wiping Conditions Using Hydrodynamic Pads Strip Stabilization.

*Galvatech 2023 (http://www.galvatech2023.org/), Seoul (KR), du dimanche 15 au jeudi 19 Octobre 2023*

**M. Mandy, M. Larnicol, L. Bordignon, A. Aouafi, M. Teaca, T. Sturel**

Hydrogen aging During Hole expanding Tests Of Galvanized High Strength Steels Investigated Using a Novel Thermal Desorption Analyzer For Small Samples

*Galvatech 2023 (http://www.galvatech2023.org/), Seoul (KR), du dimanche 15 au jeudi 19 Octobre 2023*

**M. Mandy, F.-D. Duminica, X. Vanden Eynde, M. Larnicol, M. Krid, T. Sturel, R. Grigorieva, P. Drillet**

Oxidation potential and barrier effects of Cr-based coatings on aluminized press hardened steel

*Poster in IHC 2023 - Park City Utah*

**M. Krid, P. Jacques, M. Mandy, T. Sturel, R. Grigorieva, P. Drillet**

Effect of cut bare edges and coating phases on deuterium thermal desorption profiles of aluminized PHS

*Poster in IHC 2023 - Park City Utah*

**M. Krid, M. Mandy, T. Sturel, R. Grigorieva, P. Drillet, P.J. Jacques**

A better understanding of hydrogen trapping and diffusion in aluminized press-hardenable steels

*Journal of Materials Research and Technology 28 (2024) 1514–1522*

**M. Mandy**

Interaction des métaux avec l'hydrogène

*Vers l'avenir de la métallurgie en Wallonie, April 25th, Charleroi, Belgium*

**M. Zia Hoseinpoor, T. Prošek, J. Mal-légol, D. Verchère**

Performance of coil-coated materials in deformed and overlap areas

*5th International Symposium Corrosion of Prepainted Materials, 31/05/2023, Stockholm, Sweden.*

**M. Zia Hoseinpoor, T. Prošek, J. Mallégol,**

“Mechanism of blistering of deformed coil coated sheets in marine climate”, *Corrosion Science, 212 (2023) 110962.*

**M. Zia Hoseinpoor, T. Prošek, D. Verchère**

Performance of coil-coated materials in deformed and overlap areas

*57th ECCA Autumn Congress, 20-21 November 2023, Brussels, Belgium.*

**M. Zia Hoseinpoor, T. Prošek, J. Mal-légol, D. Verchère**

Understanding into properties of prepainted steel sheets controlling their durability

*19th Asian Pacific Corrosion Control Conference (APCCC 2023), November 16-18, 2023, Guangzhou, China.*

**Peter Scholz, Dieter Weise,**

**Linda Schmidt, Martin Dembski, Alexander Stahr, Martin Dix, Florin Duminica, Sébastien Le Craz, and Jiri Koziorek.**

"Sheet Metal Design Approach for 3D Shaped Facade Elements with Integrated Solar Thermal Functionality"

*Solar, 3 (2023) 213-228. https://doi.org/10.3390/solar3020014*

**Antoine Merlo, Florin Duminica, Alain Daniel, and Grégoire Léonard. 2023.**

"Techno-Economic Analysis and Life Cycle Assessment of High-Velocity Oxy-Fuel Technology Compared to Chromium Electrodeposition"

*Materials 16, no. 10 (2023) 3678. https://doi.org/10.3390/ma16103678Scholz,*

**Florin Duminica, Muthu Karuppasamy, Philippe Guaino**

Printed Thermal Sensors for Harsh Environment by Plasma Spray."

*Proceedings from the International Thermal Spray Conference May 22–25, 2023, Québec City, Canada. (pp. pp. 316-322). https://doi.org/10.31399/asm.cp.itsc2023p0316*

## MATERIAL SCIENCE & HYBRIDE & ADDITIVE MANUFACTURING

**Norbeto Jimenez Mena**

"Development of new titanium alloy for additive manufacturing."

*3rd ESA workshop on Advanced Manufacturing, March 14-15th 2023, Noordwijk, The Netherlands.*

**Cédric Georges**

**Poudres issues de métaux recyclés**

*Vers l'avenir de la métallurgie en Wallonie, April 25th, Charleroi, Belgium*

**Jean-François Vanhumbeeck**

"Surface finishing of additively manufactured hydraulic manifold: a case study."

*Metal Additive Manufacturing Conference (MAMC2023), October 17-19th 2023, Vienna, Austria.*

**Nicolas Nutal, Romain Peyrou-Lauga & Jean-Paul Collette**

Qualification and Applications of Phase Change Material (PCM) Heat Capacitors for Space Missions European Space Thermal Engineering Workshop (ESTEWS 2023), October 10-12th, Noordwijk, The Netherlands

**Cédric Georges**

Vers l'industrialisation des technologies innovantes de manufacturing en Wallonie

*MadeinWal Workshop, December 6th, Charleroi, Belgium*

**Frédéric Novello, Murilo Masalskas Borges, Sarata Cissé, Emilie Robin, Sandra Le manchet**

"High temperature corrosion resistance of heat resistant stainless steels in simulated waste incinerator conditions."

*The annual congress of the European federation of corrosion (Eurocorr), August 27-31th 2023, Brussels, Belgium.*

**Frédéric Novello, Ridha Harzallah, Murilo Borges Masalskas**

"Impact of various salt ageing conditions on solar salt chemistry and instantaneous corrosion rate measurements."

*The annual congress of the European federation of corrosion (Eurocorr), August 27-31th 2023, Brussels, Belgium.*



# COMPANY MEMBERS

ON APRIL 17, 2024

## Active Members of CRM

ARCELORMITTAL S.A ..... G.D. Luxembourg  
TATA STEEL Nederland BV ..... The Netherlands

*An updated list of the subsidiaries considered as Active Members  
is available on the internet site of CRM.*

## THE MAIN AFFILIATED COMPANIES ARE :

### ARCELORMITTAL Group :

ARCELORMITTAL BELGIUM N.V ..... Belgium  
ARCELORMITTAL CONSTRUCTION FRANCE S.A ..... France  
ARCELORMITTAL FRANCE S.A ..... France  
ARCELORMITTAL LUXEMBOURG S.A ..... G.D. Luxembourg  
INDUSTEEL BELGIUM S.A ..... Belgium

### TATA STEEL :

TATA STEEL IJMUIDEN BV ..... The Netherlands  
TATA STEEL NEDERLAND TECHNOLOGY BV ..... The Netherlands

## Associated Members of CRM

|  |                 |  |                 |
|--|-----------------|--|-----------------|
| AGC Glass Europe .....                       | Belgium         |  |                 |
| AIR LIQUIDE INDUSTRIES BELGIUM S.A. ....     | Belgium         |  |                 |
| AMEPA GmbH .....                             | Germany         |  |                 |
| APERAM Stainless France S.A.S. ....          | France          |  |                 |
| AURUBIS OLEN .....                           | Belgium         |  |                 |
| BEKAERT N.V./ S.A. ....                      | Belgium         |  |                 |
| BIOCARBON INDUSTRIES Sàrl .....              | G.D. Luxembourg | LHOIST Recherche & Développement S.A. .... | Belgium         |
| CBR S.A. ....                                | Belgium         | MAGOTTEAUX INTERNATIONAL S.A. ....         | Belgium         |
| COMET TRAITEMENTS S.A. ....                  | Belgium         | MATÉRIAUX CÉRAMIQUES S.A. (FIVEN) .....    | Belgium         |
| DE LEUZE S.A. ....                           | Belgium         | NLMK CLABECQ S.A. – Plates .....           | Belgium         |
| DREVER INTERNATIONAL S.A. ....               | Belgium         | NLMK LA LOUVIÈRE S.A. – Strips .....       | Belgium         |
| DUFERCO S.A. ....                            | Switzerland     | ORBIX SOLUTIONS S.P.R.L. ....              | Belgium         |
| EMG Automation GmbH .....                    | Germany         | PAUL WURTH S.A. ....                       | G.D. Luxembourg |
| EQUANS .....                                 | Belgium         | PHARMA TECHNOLOGY S.A. ....                | Belgium         |
| E.S.W.A.G. ....                              | Austria         | PRAYON S.A. ....                           | Belgium         |
| FONDERIES MARICHAL, KETIN & Cie S.A. ....    | Belgium         | PRIMETALS TECHNOLOGIES AUSTRIA GmbH .....  | Austria         |
| HERAEUS ELECTRO-NITE INTERNATIONAL N.V. .... | Belgium         | RECYDEL S.A. ....                          | Belgium         |
| HERSTAL S.A. ....                            | Belgium         | RESA S.A. ....                             | Belgium         |
| HYDROMETAL .....                             | Belgium         | SAFRAN AERO BOOSTERS S.A. ....             | Belgium         |
| INDUCTOTHERM S.A. ....                       | Belgium         | SARCLAD Ltd .....                          | United Kingdom  |
| INSTITUT BELGE DE LA SOUDURE asbl .....      | Belgium         | SIMAFORM S.A. ....                         | G.D. Luxembourg |
| INTERNATIONAL MANGANESE INSTITUTE .....      | France          | SONACA .....                               | Belgium         |
| JOHN COCKERILL S.A. ....                     | Belgium         | SUEZ .....                                 | France          |
| LABORELEC S.A. ....                          | Belgium         | TECforLime .....                           | Belgium         |
|  |                 | THY-MARCINELLE S.A. ....                   | Belgium         |
|  |                 | TI GROUP AUTOMOTIVE SYSTEMS S.A. ....      | Belgium         |
|  |                 | TMT sarl .....                             | G.D. Luxembourg |
|  |                 | WESTINGHOUSE ELECTRIC BELGIUM S.A. ....    | Belgium         |

# ORGANISATION

ON APRIL 17, 2024

## Board of directors of CRM

### PRESIDENT

Thinus VAN DEN BERG, CFO - Global Research and Development, ARCELORMITTAL

### VICE-PRESIDENTS

Vincent RITMAN, Director R&D Europe, TATA STEEL

Jean-Luc THIRION, General Manager Global Research and Development, ARCELORMITTAL

### DIRECTORS

Ivan AERTS, Adviseur, Centrale der Metaalbewerkers van België

Philippe COIGNE, Directeur Général, Groupement de la Sidérurgie (GSV)

Nicolas DE ABAJO MARTINEZ, Head of Global R&D Centres and Performance Optimization, ARCELORMITTAL

Joao FELIX DA SILVA, Executive President, Member of the John Cockerill Executive Committee, John Cockerill Industry

André FOUARGE, CTO Finishing, ARCELORMITTAL Europe - Flat Products

Leo KESTENS, Professor, Universiteit Gent

Carel KLEEMANS, Technical Director, TATA STEEL Mainland Europe

Anne MERTENS, Associate professor, ULiège

Lahoucine OURHRIBEL, Secrétaire Général, ACV-CSC METEA

Christian BOBADILLA, Long Products Research Manager, ARCELORMITTAL Global R&D

Ilja PORTEGIES ZWART, Head of Technical Packaging Steel, TATA STEEL

Pedro PRENDES, Global R&D Process Portfolio Leader, ARCELORMITTAL

Mario SINNAEVE, R&D - Quality Control Manager, S.A. des Fonderies Marichal, Ketin & Cie

Sven VANDEPUTTE, Managing Director, OCAS N.V.

Hans VAN DER WEIJDE, Director Programmes TATA STEEL Europe R&D, TATA STEEL

Manfred VAN VLIERBERGHE, CEO ARCELORMITTAL Belgium

Michael VENTURI, Secrétaire Général Adjoint, MWB-FGTB

Laurent WENKIN, Coordinateur Normalisation et Compétitivité, SPF Economie, PME, Classes moyennes et Energie

## **OBSERVERS**

Jean-François HEUSE, Inspecteur Général ff, Département de la Recherche et du développement technologique, Service Public de Wallonie

Yvon MASYN, Adviseur, Vlaams Agentschap Innoveren en Ondernemen

Joeri NEUTJENS, Directeur Général, CRM

## **AUDITOR**

Anne DORTHU

## **Iron and Steel Committee of CRM**

### **MEMBERS**

#### **ARCELORMITTAL**

Jean-Paul ALLEMAND

Marc DI FANT

Eric HESS

Thierry IUNG

Pedro PRENDES

Mayte RODRIGUEZ

Sven VANDEPUTTE

#### **TATA STEEL**

Jochem GROOT

Carel KLEEMANS

Christophe PELLETIER

Hans VAN DER WEIJDE

#### **CRM**

Joeri NEUTJENS

Griet LANNOO

Eric SILBERBERG

# QUALITY MANAGEMENT

  
**QUALITY MANAGEMENT SYSTEM CERTIFICATE**  
**ISO 9001 : 2015**  
*BQA hereby declares that the management system of CRM Group*



*Issued in accordance with the BQA Standard 21.027 - Quarter Product 1 - 1900 Liège and Rue du Bois, Saint-Luc - 4102 Ombrieux and Rue du Centre, 201 - 4000 Liège and Technologiepark 9015 - 9012 Zuwarende - Belgium for CRM ASBL - Centre for Research in Metallurgy asBL and by Atte de l'innovation, 1815 - Quarter Product 1 - 4000 Liège and Rue Nostra, 1 - 4000 Flawalle - Belgium for ACACS srl - Advanced Coatings and Coatings Solutions srl but have examined and found in conformity with the ISO 9001, edition 2015, standard for the following application field:*

**Industrial research and associated activities such as testing, calibration and expertise.**

*This certificate has been issued by BQA in accordance to its quality manual concerning the certification of systems, and after consulting the contract of certification V°CFR / CDP (MS 16.4.202) 33A / 1° which the company accepts a regular control of its management system.*

*Certificate N° 0124 / 2024-05-27*  
*Issue date: 2024-05-27*  
*Valid until: 2024-05-27*

  
**D. SIMOENS**  
 Director

  
 1179-QMS

The sole valid version of this certificate may appear in French or in Dutch. This certificate may only be delivered in its original.  
 Alleen de versie in het Nederlands of in het Frans is geldig. Dit certificaat mag enkel worden afgegeven in het origineel.


 Organisme belge d'Accréditation  
 Belgische Accreditatieinstelling  
 Belgische Akkreditierungsstelle  
 Belgian Accreditation Body  
 EA MLA Signatory

**Accreditation Certificate No. 267-CAL**

In compliance with the provisions of the Royal Decree of 31 January 2006 setting up BELAC, the Accreditation Board hereby declares to have granted accreditation conform the requirements of the standard EN ISO/IEC 17025:2017 to:

**CENTRE DE RECHERCHES METALLURGIQUES ASBL -  
 CENTRUM VOOR RESEARCH IN DE METALLURGIE vzw  
 C.R.M.  
 Rue Ravenstein 4  
 1000 Bruxelles**

The body demonstrated the competence to perform the activities in the activity sites, as described in the scope of accreditation 267-CAL which is an integral part of the present certificate.

The current version of the scope of accreditation is available at [www.belac.be](http://www.belac.be).

This certificate remains valid as long as the body continues to meet the accreditation conditions.

The Chair of the Accreditation Board BELAC,

  
 Maureen LOGGHE

Version : 10  
 Validity period : 2023-03-16 - 2027-10-27  
 Original version of this certificate is in French.

BELAC 4-3191-R0-2020


 Organisme belge d'Accréditation  
 Belgische Accreditatieinstelling  
 Belgische Akkreditierungsstelle  
 Belgian Accreditation Body  
 EA MLA Signatory

**Accreditation Certificate No. 267-TEST**

In compliance with the provisions of the Royal Decree of 31 January 2006 setting up BELAC, the Accreditation Board hereby declares to have granted accreditation conform the requirements of the standard EN ISO/IEC 17025:2017 to:

**CENTRE DE RECHERCHES METALLURGIQUES ASBL -  
 CENTRUM VOOR RESEARCH IN DE METALLURGIE vzw  
 C.R.M.  
 Rue Ravenstein 4  
 1000 Bruxelles**

The body demonstrated the competence to perform the activities in the activity sites, as described in the scope of accreditation 267-TEST which is an integral part of the present certificate.

The current version of the scope of accreditation is available at [www.belac.be](http://www.belac.be).

This certificate remains valid as long as the body continues to meet the accreditation conditions.

The Chair of the Accreditation Board BELAC,

  
 Maureen LOGGHE

Version : 9  
 Validity period : 2023-03-16 - 2027-10-27  
 Original version of this certificate is in French.

BELAC 4-3191-R0-2020

# LEADERSHIP TEAM

**Joeri NEUTJENS**  
CEO - CSO

Strategy, External Relations  
Administration & Reporting  
to ExecCom, BoD, GA

R&D Management Committee  
BD, Communication,  
IP, Legal

Facility Management, HSE  
Scientific Policy & Partnerships

**Sabine MAHY**  
CFO

Finance  
Purchasing

**Eric SILBERBERG**  
CTO

CTO Coating & Finishing  
Engineering  
& Industrial Solutions  
Capex management

**Raphael PAULUS**  
CHRO

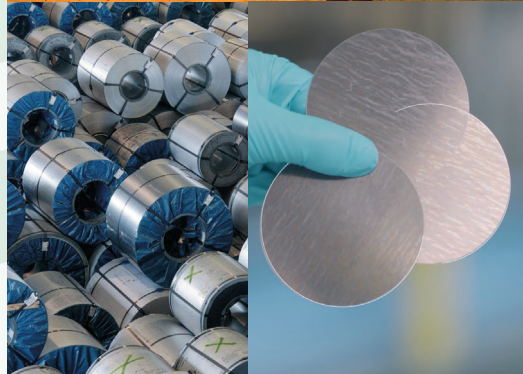
Human Resources  
Quality, IT  
Operational excellence  
Performance management

**Griet LANNOO**  
CTO - CPO

CTO Primary  
Innovation  
& Strategic Funding  
Iron & Steel Committee  
Program Coordination  
& Reporting

CEO: Chief Executive Officer  
CPO: Chef Program Officer  
CFO: Chief Financial Officer  
CSO: Chief Scientific Officer  
CHRO: Chief Human Resource Officer  
CTO: Chief Technical Officer





• **AC&CS Sart-Tilman** > Liège  
Advanced Coatings & Construction Solutions

• **AC&CS Ivoz-Ramet** > Flémalle  
Advanced Coatings & Construction Solutions

• **CEWAC** > Liège

• **CRM Gent** > Zwijnaarde  
Centrum voor Research in Metallurgie

• **CRM Sart-Tilman** > Liège  
Centre de Recherches Métallurgiques

• **EcoTechnoPôle** > Liège  
ETP

• **PiMW Sart-Tilman** > Liège  
Pôle d'Ingénierie des Matériaux de Wallonie

• **CRM Engis** > Engis

• **MBTech** > Angleur



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