INNOVATION DAY LJUBLJANA 2023

Driving e-Mobility and Clean Energy Conversion through Materials Design & Manufacturing

Jožef Stefan Institute
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DRIVING E-MOBILITY AND CLEAN ENERGY CONVERSION THROUGH MATERIALS DESIGN & MANUFACTURING

Ljubljana, Slovenia, 2023

Jožef Stefan Institute

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2nd Innovation Day Ljubljana - Driving e-Mobility and Clean Energy Conversion through Materials Design & Manufacturing aimed at both the research & innovation and industrial audience in Europe. The event is organized in collaboration between the Jožef Stefan Institute, EIT Manufacturing and SRIP FoF and is held at the Union Hotel in Ljubljana.

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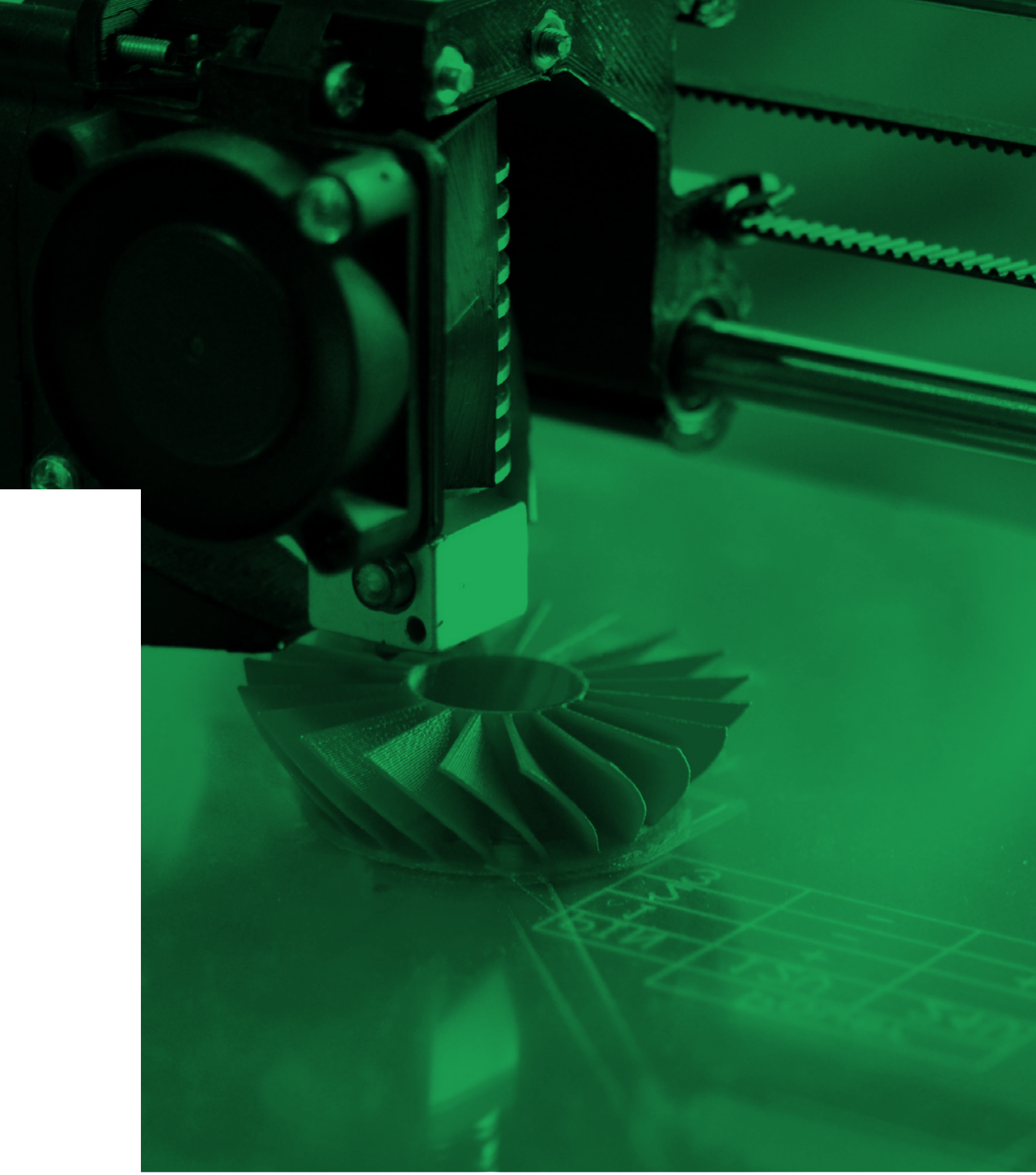

Preface

Imagine a typical morning routine in a European family: commuting in an electric car, coordinating activities over a mobile phone, and receiving weather updates informed by space technology. This routine, seemingly simple, is actually a testament to centuries of materials science research and innovation. From electric vehicles to communication devices, advanced materials have become integral to our daily existence and our understanding of the world.

In this rapidly evolving era of material science, we are witnessing a remarkable fusion of fundamental research and innovative applications. This synergy is critical for the transition to a green-energy-based economy, fostering an information-centric society, and nurturing healthier environments. Material science stands at the forefront of addressing pressing societal challenges, essential for stimulating economic growth.

The emergence of Industry 5.0, emphasising human-machine collaboration, will further revolutionise material science. This interdisciplinary field is now reshaping material fabrication by integrating machine learning with materials modelling and targeted processing. Such advancements are paving the way for more efficient and customised material designs, crucial for a sustainable future that supports a comprehensive, circular materials ecosystem.

Central to achieving a climate-neutral and circular economy by 2050 is Europe's capacity for innovation in clean energy and e-mobility. Permanent magnets, especially those used in electric vehicles and renewable energy technologies, play a pivotal role in this transformation. The magnet market, while specialised, exerts a colossal downstream impact, significantly influencing the EU's mobility sector and import dependency. The increasing demand for magnets, essential in various industrial and consumer applications, calls for a transformative approach to their production and recycling.

The systemic changes that await us require the cooperation of the research institutions with the manufacturing industry, which has seen a decline in Europe. In this landscape of change, Slovenia, though small, holds a significant position in the European magnet production sphere. It makes a significant impact through its magnet factories and the comprehensive materials value chain. Notably, Slovenia is home to two major permanent magnet manufacturers, Magneti Ljubljana and Kolektor Group. These companies are key players in the e-mobility sector and have successfully maintained a competitive edge, giving

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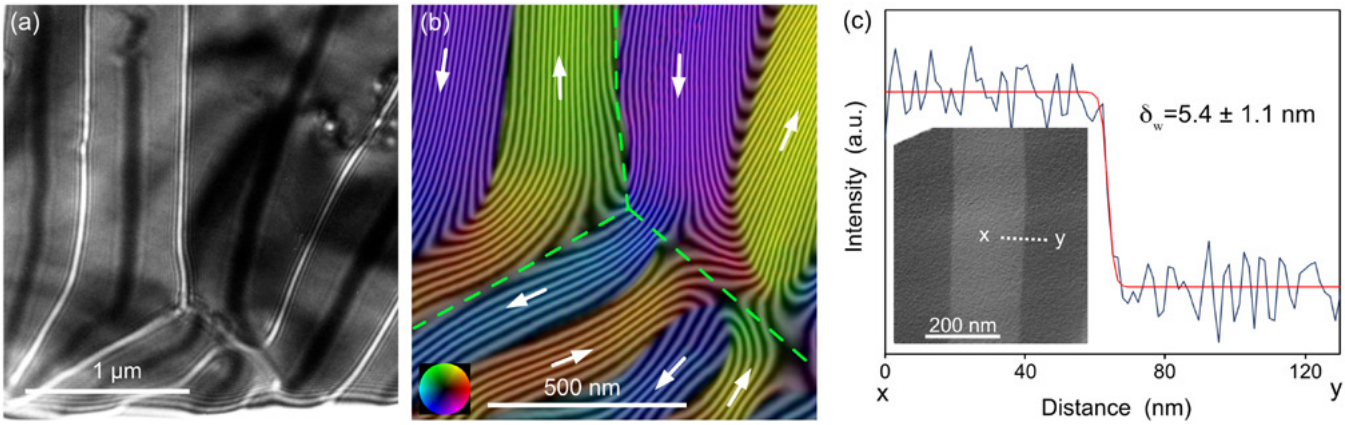

Fig 1.: Magnetic imaging studies of the grain-boundary diffusion processed Nd-Fe-B magnet

Slovenia a considerable advantage in this field. The scope of Slovenia's involvement in magnet production extends beyond manufacturing. It encompasses the entire lifecycle of materials, starting from processing primary raw materials, such as the expertise of Talum in aluminium extraction, which could bridge the gap in extracting primary rare earth materials. Furthermore, companies like Zeos and Surovina play a vital role in the collection and recycling of secondary raw materials. The value chain also includes manufacturers of electric motors like Domel and Elaphe, and producers of finished products such as Gorenje Group.

This extensive involvement positions Slovenia as a central hub for advanced materials-based technologies, encompassing research, innovation, and economic activities. To strengthen this role and contribute to the circular economy, there's a need to focus on future legislative amendments and incentives. Emphasising domestic production of metals and alloys suitable for manufacturing permanent magnets – a sector still thriving in Slovenia – is essential, highlighting Slovenia's strategic position in these rapidly expanding sectors.

For over three decades, the Department for Nanostructured Materials at the Jožef Stefan Institute has been at the forefront of permanent magnet research and innovation. We are devising solutions regarding the design and production of permanent magnets with improved magnetic properties and efficient use of material resources.

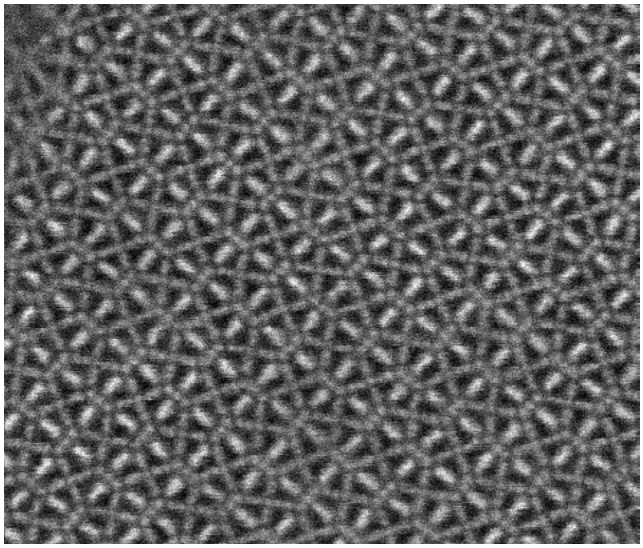

Fig. 2: Atomic resolution Z-contrast image of a $Nd_2Fe_{14}B$ crystal grain viewed in the [001] zone axis

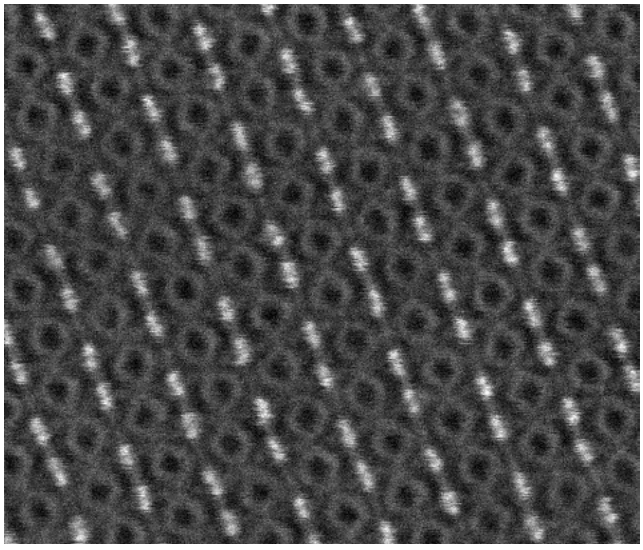

Fig. 3: Atomic resolution Z-contrast image of a $Nd_2Fe_{14}B$ crystal grain viewed in the [100] zone axis

Our goal is to develop new solutions contributing to a more sustainable and resilient Europe. Our collaborations with industry partners, both domestically and internationally, are a testament to our dedication, as seen in our numerous international patent applications and successful projects.

However, transitioning from research to industry, a phase known as the Valley of Death, calls for a close collaboration among researchers, commercial enterprises, and financial backers. Stable funding, long-term investments in innovation, and a balanced approach to technological readiness are fundamental to this endeavour. An integrated technological approach is what will empower us to meet upcoming challenges and swiftly introduce a range of technological solutions to the market, enhancing competitiveness. In this crucial transition, entities such as EIT Manufacturing play a key role, in bridging this gap, fostering cooperation between business, education, and research.

Moreover, effective implementation of materials technology in e-mobility and clean energy sectors necessitates extensive education across all levels of expertise. This includes not just academia and research institutions, but also the continuous professional development of engineers within the industry. Here, EIT Manufacturing asserts its significant influence, underpinning the educational framework within this sector. Knowledge sharing between research organisations and industry not only brings the two sides closer but also narrows the gap between knowledge across the technology readiness scale, at the forefront of the industry's technological needs.

Jožef Stefan Institute, photo: Arne Hodalič and Katja Bidovec

Jožef Stefan Institute, photo: Arne Hodalič and Katja Bidovec

The "Innovation Day Ljubljana" event encapsulates our efforts to tackle the challenges in e-mobility and clean energy conversion. By promoting knowledge exchange and collaboration across research, academia, and industry, we aim to propel the region towards a sustainable and interconnected future. Our gratitude extends to all participants and sponsors for their vital contribution to the success of this event in Ljubljana.

Prof. Sašo Šturm, Ph. D.
Head of Department for
Nanostructured Materials
Jožef Stefan Institute

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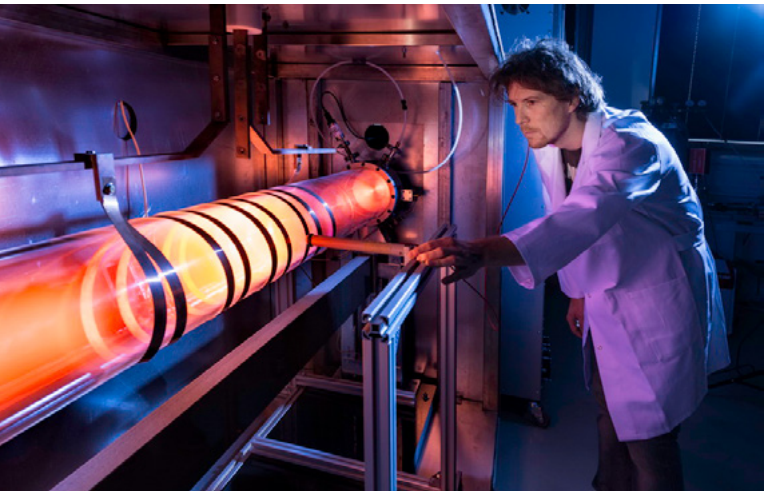
Jožef Stefan Institute, photo: Marjan Verč

Jožef Stefan Institute

The Jožef Stefan Institute is the leading Slovenian scientific research institute, covering a broad spectrum of basic and applied research. The staff of more than 850 specializes in natural sciences, life sciences and engineering.

The Jožef Stefan Institute is named after the distinguished 19th century physicist Jožef Stefan, most famous for his work on the Stefan-Bolzmann law of black-body radiation. The subjects concern production and control technologies, communication and computer technologies, knowledge technologies, biotechnologies, new materials, environmental technologies, nanotechnologies, and nuclear engineering.

The mission of the Jožef Stefan Institute is the accumulation - and dissemination - of knowledge at the frontiers of natural science and technology to the benefit of society at large through the pursuit of education, learning, research, and development of high technology at the highest international levels of excellence.



Jožef Stefan Institute, photo: Arne Hodalič and Katja Bidovec

The Institute was founded in 1949 at a time when scientific research was expanding rapidly throughout the world. Initially established as an institute for Physics within the Slovenian Academy of Sciences and Arts, it is today involved in a wide variety of fields of both scientific and economic interest. After close to 60 years of scientific achievement, the Institute has become part of the image of Slovenia. The basic goals of the Institute are to provide expert scientific and applied output in the form of processes, products and consultancy, and to produce well-trained young scientists.

The underlying philosophy is that these objectives can be achieved only if based on international-class scientific research. With this in mind, the in-house research has been reinforced by building strong links to universities, other research institutions and industry. The Institute is closely connected with Slovenian universities, where many scientists who initially developed their research

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talents at the Institute have been appointed to teaching posts, while still retaining their research positions or research teams at the Institute. Since 1985 more than 800 postgraduate students have gained their MSc. and PhD degrees at the Institute. Close contacts are also maintained with secondary schools, providing work practice on research projects in natural sciences and organising regular visits to the laboratories.

In 1995 the Nova Gorica Municipality and the Jozef Stefan Institute founded the first private postgraduate school in Slovenia, the Nova Gorica Polytechnic. This school has developed in the fourth Slovenian university, providing courses in many scientific fields. In collaboration with a group of leading Slovenian industrial organisations, in 2003 the Institute founded The Jožef Stefan international postgraduate school. As part of its support for applied research in the field of ecology, the Institute is one of the founders of ERICo Velenje, the Institute for Ecological Research.

> The Jožef Stefan Institute is the leading Slovenian research organisation. It is responsible for a broad spectrum of basic and applied research in the fields of natural sciences and technology. The staff of around 800 specialize in research in physics, chemistry and biochemistry, electronics and information science, nuclear technology, energy utilization and environmental science.

As a co-founder of the University of Nova Gorica and the Jožef Stefan International Postgraduate School the Institute is also very involved with the university education. In 2006 a long-term cooperation agreement with University of Ljubljana and University of Primorska was signed.

Close collaboration with the University Medical Centre has resulted in the development of medical equipment (tomography, electrical stimulators and appliances), the provision of isotopes for clinical research and treatment of patients, and the introduction of new research techniques and diagnostic methods into clinical medicine. The Jožef Stefan Institute and the Valdoltra Orthopaedic Hospital founded the Research Institute Valdoltra, which is now an independent institution.

Being well aware of the international nature of science, the Institute has devoted considerable efforts to international cooperation. Today it co-operates with many leading scientific research institutions worldwide.

The Institute devotes a considerable amount of effort to transfer the results of its research and knowledge to produce applications and to the market. It was in this context that some years ago, the Technology Park was established at the Jožef Stefan Institute. This was the predecessor of the Ljubljana Technology Park, whose founders are the Institute, Helios, the Institute for Biology, IskraTEL, the Chemistry Institute, LEK, SKB Banka and the Technological Development Resource Centre. The Technology Park currently includes seven private companies, whose staff derive from the Institute's research staff and elsewhere. Their products, technologies and services have been developed within research or application projects over the past few years. The Park supports the creation and growth of new enterprises based on the results of research from Slovenian universities and international institutes. The Institute actively makes use of this support for hi-tech enterprises to create an environment in which innovation, financing and production interact to accelerate the cycle of development of innovative products.

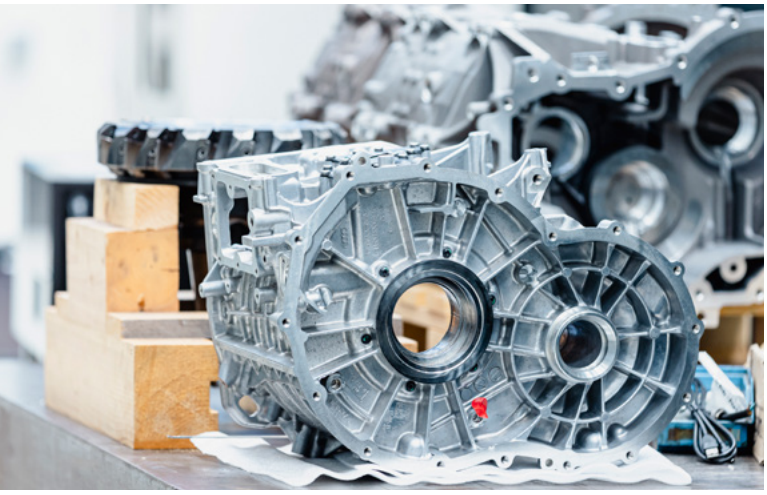
Prof. Boštjan Zalar, Ph. D.
Director
Jožef Stefan Institute

Jožef Stefan Institute
Ljubljana, Slovenia

EIT Manufacturing – the largest innovation community for manufacturing in Europe

EIT Manufacturing is one of the nine knowledge and innovation communities supported by the European Institute of Innovation and Technology (EIT), a body of the European Union. EIT Manufacturing's vision is to become the leading European innovation community for manufacturing. To reach this ambitious goal, EIT Manufacturing brings European stakeholders focused on manufacturing together in innovation ecosystems that add unique value to European products, processes and services and inspire the creation of globally competitive and sustainable manufacturing. EIT Manufacturing integrates activities in the areas of Innovation, Education and Business Creation, and connects more than 100 leading actors in the manufacturing domain across research, business and academia to drive innovation and support the development of new technologies and solutions. Additionally, the Regional Innovation Scheme (RIS) – the EIT community's outreach programme to strengthen the innovation performance of countries classified as modest or moderate innovators – offers various initiatives to foster innovation in the targeted countries.

Photo Credit © Matthias Heschl



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While EIT Manufacturing is headquartered in Paris, France, six innovation hubs across Europe directly support their partners and ecosystem stakeholders on a regional level. Their offices are located in Darmstadt, Germany (Central), Vienna, Austria (East), Gothenburg, Sweden (North), Milan, Italy (South), Athens, Greece (South East), and San Sebastian, Spain (West). In addition, EIT Manufacturing works together with local organisations that act as regional representatives in many European countries. These hubs help EIT Manufacturing to better connect to the local manufacturing ecosystems and to support stakeholders with individualised services.

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MAKING INNOVATION HAPPEN

EIT Manufacturing helps manufacturing companies in Europe to become greener, more sustainable and resilient and to find innovative solutions to their most pressing challenges: the transition towards a circular economy, digitalisation and towards the decarbonisation of industry.

Through its innovation activities, EIT Manufacturing supports European consortia to execute innovation projects that aim to solve real industry problems and fill innovation gaps and bring these new solutions to the market. In the area of Education, EIT Manufacturing offers Master and Doctoral Programmes together with its partner universities, as well as specialised training programmes for upskilling and reskilling the manufacturing workforce. As startups are an important part of every industry domain and vital for a society's economic growth, EIT Manufacturing engages with and actively supports industry startups and scaleups in Europe to help them access new markets or find business partners.

> Interested stakeholders are invited to join EIT Manufacturing's social network and open innovation platform AGORA and become part of the largest innovation network for manufacturing in Europe!

Visit our website to learn more!
www.eitmanufacturing.eu

Contact us!
east@eitmanufacturing.eu

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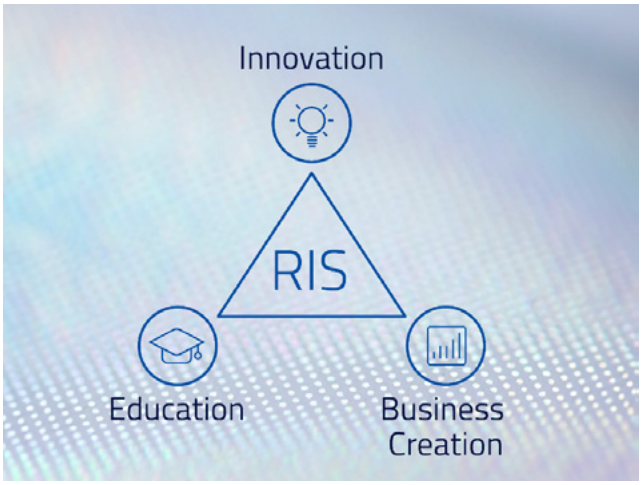
EIT Manufacturing RIS Hub Slovenia

EIT Manufacturing refers to the European Institute of Innovation and Technology (EIT) Manufacturing. The EIT promotes innovation and entrepreneurship in Europe by supporting initiatives that bring together business, education and research.

> The mission is to bring together manufacturing stakeholders across Europe to integrate innovation, education and business creation (knowledge triangle) for an entrepreneurial and sustainable Europe.

To ensure that innovation reaches the market, industry has the right talent and entrepreneurs can thrive, the EIT Manufacturing connects and integrates the entire knowledge triangle and the Regional Innovation Scheme (RIS). RIS is part of the EIT's strategy to extend its activities across Europe and reach regions that are not directly involved in the EIT's Knowledge and Innovation Communities (KICs). The RIS Hubs are regional offices dedicated to promoting innovation and collaboration in specific geographical areas.



In Slovenia, the EIT Manufacturing RIS Hub is run jointly by the Jožef Stefan Institute (JSI) and by the University of Ljubljana, Faculty of Mechanical Engineering (ULFME). The international cooperation between our Center Factories of the Future (FoF), as part of the JSI, which manages the Slovenian SRIP FoF cluster, and the EIT Manufacturing is truly outstanding. We are constantly strengthening the existing synergies to raise the level of Slovenian innovative SMEs and mid-cap companies in the entire knowledge triangle by supporting activities on both sides and involving all relevant stakeholders. The RIS Hub serves as a regional center connecting local companies, universities and research institutions with the broader EIT Manufacturing network. It aims to strengthen the innovation ecosystem in our respective regions by facilitating knowledge sharing, collaboration and the implementation of innovative solu-

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tions. One of our goals is to create a unified representation of EIT Manufacturing in the RIS countries of the EIT Regional Innovation Scheme - Eastern EU Region, raise awareness and gain the support of national authorities.

> “Manufacturing is a global foundation for prosperity and key to Europe’s economic, social and environmental sustainability. For this reason, we at the RIS Hub are particularly committed to supporting local innovators and strive for collaboration and knowledge exchange between industry professionals, academic institutions and research centers. By bringing together a variety of stakeholders, we seek to create a vibrant ecosystem where ideas thrive and transformative solutions emerge.

We organize various events, workshops for SMEs and other stakeholders focused on the green transition and digital transformation of Slovenian industry. One of the most high-profile events is »Innovation Day Ljubljana«, which has become a traditional annual event.

We consistently support our members in participating in innovation programs and sharing best practices. We actively promote engagement by facilitating expert consultations and workshops. Our engagement also extends to the organization of events such as the workshop in Ljubljana, where we improve our members’ access to the European expert community with the support of the EIT Manufacturing Network. Through the services of the EIT Manufacturing RIS Hub, we offer help and support to the manufacturing sector and the entire innovation ecosystem. We promote networking and facilitate connections to drive innovation ideas forward.

Nataša Pibernik
Project Manager
Jožef Stefan Institute

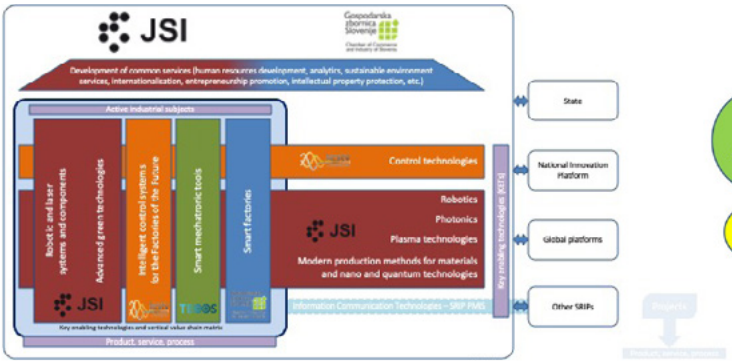
Jožef Stefan Institute
Ljubljana, Slovenia

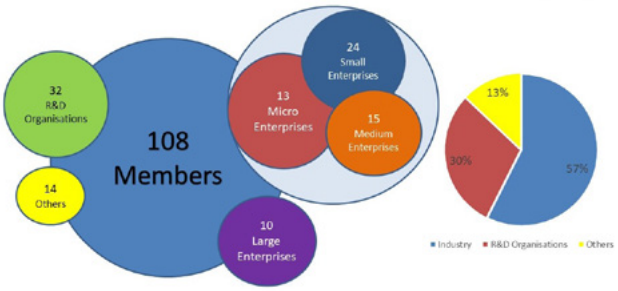
SRIP FoF - Strategic Research and Innovation Partnership
Factories of the Future

As part of the Strategic Research-Innovation Partnership Factories of the Future (SRIP FoF), the FoF's main objective is to bring together Slovenian research, industry and government. Together we are looking for breakthrough products, services and technologies for the Factories of the Future and working towards the green transition and digital transformation as key strategic goals. This will create the possibility of efficient production at home, enabling competitiveness and further development in the global economy.

We create and integrate a supportive environment with professional services for industry and research institutions that address future challenges in the field of human resources. In this way, we ensure a rapid transfer of knowledge to industry and new content for the education system.

SRIP FoF ensures openness for the participation of new members. It is open to all interested organisations that show their willingness to actively participate in a partnership that aims to work for the benefit of its members and - through horizontal networks - for the benefit of other SRIP and other users. The membership structure of the SRIP FoF is highly diverse and tailored to the Factories of the Future sector to ensure balanced management of the partnership and collaboration with all relevant stakeholders. The members of the SRIP FoF are mainly com-





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panies, followed by research organisations from all over Slovenia. Research organisations play an important role in horizontal networks and are also the holders of individual Key Enabling Technologies. In second place are associations, which are important for the dissemination of technology and science among young people.

In order to bring together the players in the respective areas, the SRIP FoF is set up in a two-dimensional matrix structure in which Key Enabling Technologies (KETs) and Vertical Value Chains (VVCs) are interlinked. The innovative potential of the SRIP FoF depends on the competencies and capacities of the vertical and horizontal key positions operating within the SRIP FoF. Therefore, there is a structure in which the key potential is represented by the KET and VVC coordinators. Together, they are connected with partners from research institutions and industry, who form the Programme Committee as the main think tank of the SRIP FoF.

In this context, the Key Enabling Technologies (KETs) are of great importance, as they represent a research and innovation potential not only for the SRIP FoF, but practically for all SRIPs in Slovenia. In the SRIP FoF, we constantly strive to appoint key players from industry in the categories of SMEs, large companies and research institutions as coordinators. This ensures a relative balance in the management of the SRIP FoF as well as the breadth and depth of its content.

It is typical of the Slovenian region that it is highly industrialised, with many niche-oriented cutting-edge products, services, systems or technologies in various fields. In this segment, the Slovenian industrial ecosystem differs from other, especially larger European countries. Therefore, SRIP FoF is very active in the implementation at national and international level. At the national level, it is primarily concerned with the positioning and role of Key Enabling Technologies. SRIP FoF is a repository of five KETs:

- control technologies,
- robotics,
- photonics,
- plasma technologies,
- advanced manufacturing technologies for materials and nano and quantum technologies.

In close cooperation with the Vertical Value Chains (VVCs) that have gained a foothold in the markets, new strategies are developed which are then transferred by the SRIP FoF to the innovative, entrepreneurial and national level. The VVCs include:

- robotic and laser systems and components,
- advanced green technologies,
- intelligent control systems for the factories of the future,
- smart mechatronic tools and
- smart factories.

Through the efficient orientation of R&D and the use of knowledge and technologies, the SRIP FoF contributes indirectly and directly through KETs to the digital transformation and the acceleration of the transition to an energy-efficient and green economy (green transition) in almost all SRIPs in Slovenia, which is the main goal of the Slovenian Sustainable Smart Specialisation Strategy (S5).

As integration into international value chains is crucial for our members, we are a member of international associations and initiatives: EIT Manufacturing, EFFRA & MIE, A.SPIRE & Process4Planet, Vanguard, WMF, Hydrogen Europe, S3CoP-SmartRegions, which have a significant positive impact on the operation of the SRIP FoF.

We kindly invite you to visit our website to learn more!
www.ctop.ijs.si

Contact us!
ctop@ijs.si

Asst. Prof. Dr. Igor Kovač
Jožef Stefan Institute

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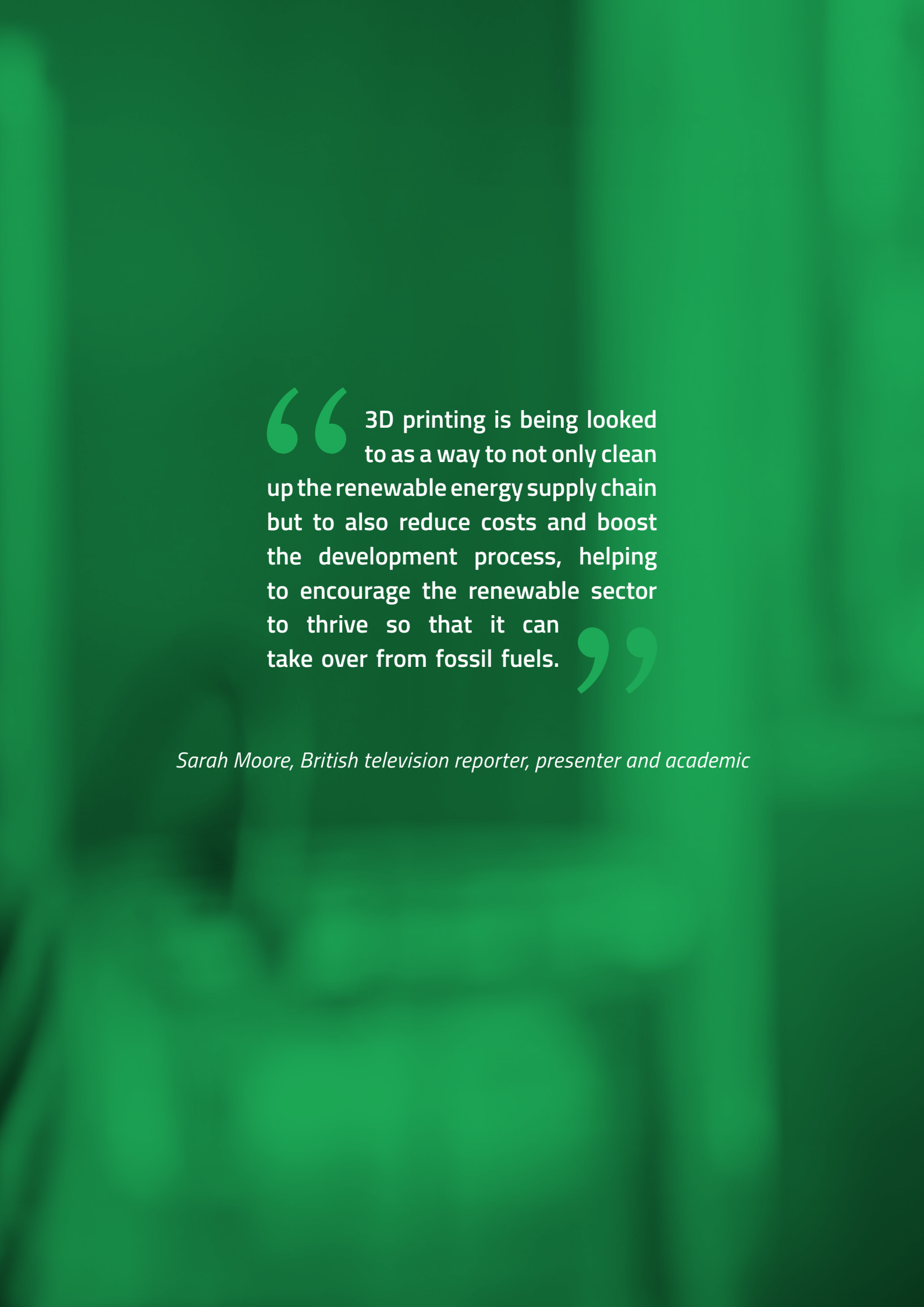
Strategic Research Innovation Partnership
FACTORIES OF THE FUTURE



> 3D printing is being looked to as a way to not only clean up the renewable energy supply chain but to also reduce costs and boost the development process, helping to encourage the renewable sector to thrive so that it can take over from fossil fuels.

Sarah Moore, British television reporter, presenter and academic

Anisotropic fast PROtotyping of MAGnetic materials (aProMag) Project

The main goal of aProMag was to prototype, validate, and bring to market technology for fast prototyping of rotors for brushless DC motors and actuators using 3D printing in a magnetic field which enables anisotropic alignment of hard magnetic material. The cutting-edge technology will reduce waste by 3D printing technology, with very low waste and material used re-usable up to 5 times (~97% material yield). The source of the feedstock powder used is a raw material obtained from end-of-life NdFeB magnets enabling the circular economy. Technology also significantly shortens the manufacturing time of final products to test design concepts up to 5 times and significantly reduces the cost of conventional injection molding tools. Partners involved cover all value chains, have strong synergies and complementary expertise encompassing materials production, manufacturing processes for filaments, and 3D printing of magnetic prototypes. The end-user to test new methods is a world-renowned manufacturer in the field.

The field of 3D printing is witnessing a remarkable innovation with the aProMag project, a groundbreaking initiative focusing on the development of polymer-bonded permanent magnets. Distinguished by its use of recycled end-of-life powder, this project is setting new standards in sustainable manufacturing and material science.

At the heart of aProMag is a commitment to environmental sustainability, by transforming recycled end-of-life powder into high-quality filaments and feedstock for 3D printing, paving the way for a circular economy

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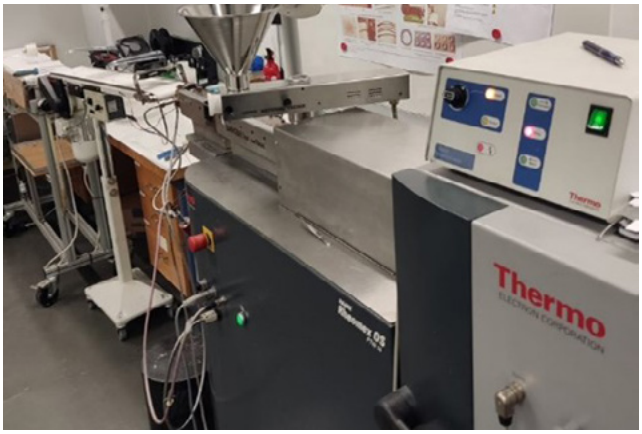
in manufacturing. This innovative approach is not only an environmental step forward, but also a cost-effective solution that reduces reliance on critical raw materials.

A key achievement of the aProMag project is the optimization of filament and feedstock production. This progress ensures that the recycled materials meet the stringent requirements of 3D printing processes. The optimized filaments exhibit consistent quality and improved performance characteristics, which are critical to producing high-quality magnetic components.

Fig 1: aProMag project logo



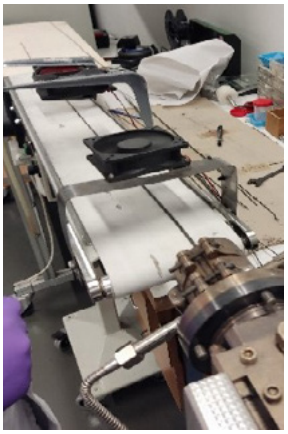


Fig 2: Filament extrusion process

In this project, Dr. Jakob Blomgren from RISE (Research Institutes of Sweden) has developed a sensor system to monitor the quality of 3D printing filaments by scanning the magnetic field pattern around them. These analysis methods provide quality control and valuable insight into potential deviations in the production process.

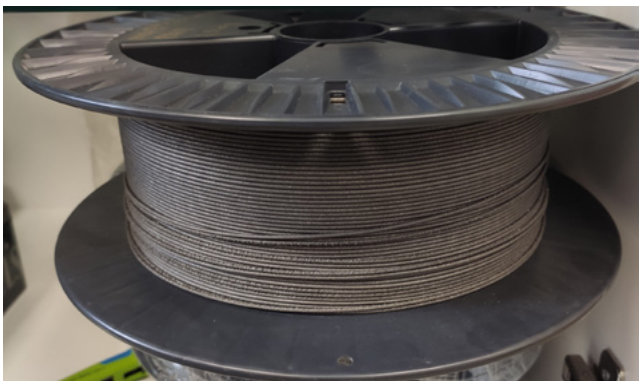


Fig 3: Filaments for aProMag project

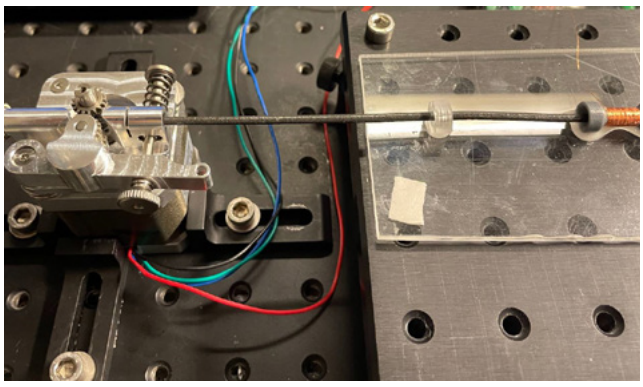


Fig 4: Filament quality investigation through induction process

> In a major technological breakthrough, the aProMag team has developed a special holder to apply a magnetic field in-situ during the 3D printing process. This innovation enables the precise alignment of anisotropic particles during the printing process, which is crucial for creating magnets with superior magnetic properties. The ability to control particle alignment in real-time is a game-changer in the field of 3D printed magnetic materials.

Demonstrating its versatility, the aProMag technology has been successfully used to produce magnets with complex shapes, including intricate ring designs. These complex shapes, which were previously difficult to produce, open up new possibilities in magnet design, prototyping and application, underlining the technological strengths of the project.

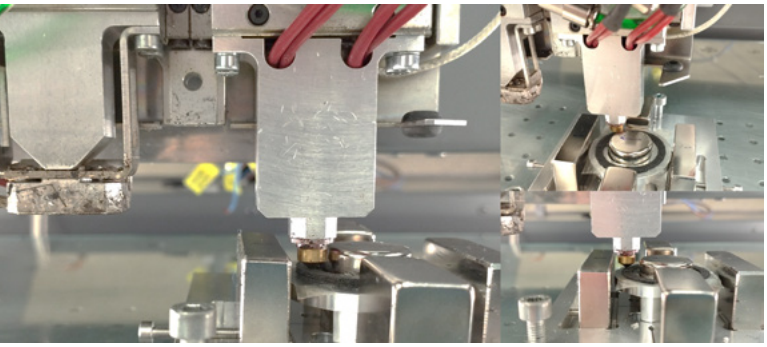


Fig 6: Printing of ring-shaped magnets

The practical applications of aProMag's innovations are vast, particularly in the manufacture of brushless DC motors. The magnets produced using this technology can significantly improve the performance and efficiency of these motors, making them ideal for a wide range of industrial and consumer applications. This not only represents a significant leap forward in motor technology but also highlights the potential for wider adoption of sustainable manufacturing practices.

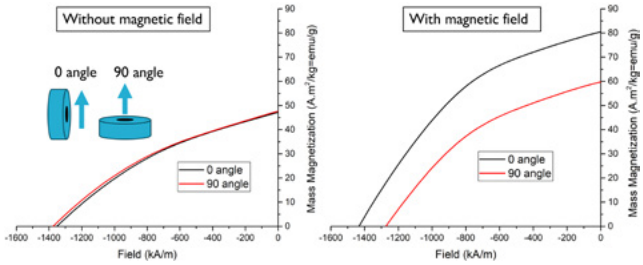


Fig 5: Magnetic properties of ring-shaped magnets with and without external magnetic field

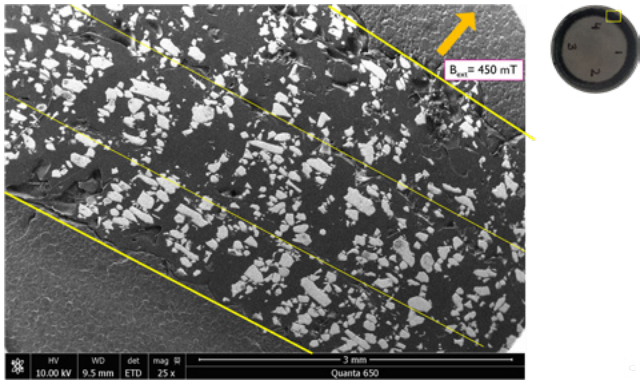


Fig 7: Particle Alignment due to the external magnetic field during printing process

Fig 8: Ring-shaped magnets

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The aProMag project is a testament to the power of innovation in bridging the gap between sustainability and advanced manufacturing. By optimizing the use of recycled materials to produce high-quality, complex-shaped polymer-bonded magnets, aProMag is not only redefining the standards in 3D printing, but also making a significant contribution to more sustainable manufacturing practices. As this technology continues to evolve, its impact on the scientific and business landscape will be profound and far-reaching.

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Project Partners:
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Kolektor KFH d.o.o.
Pforzheim University
RISE
University of Ljubljana, Faculty of Mechanical Engineering
Valeo

Project Website:
www.apromag.eu

> **3D printing is a game-changer for product development, allowing for faster and more efficient prototyping and manufacturing.**

John Kawola, CEO of Boston Micro Fabrication, 3D printing industry veteran

Kolektor

Founded in 1963, the Slovenian-based Kolektor Group d.o.o. has established itself as a major player in various industries, managing some 30 companies in sectors such as automotive, building and construction. In particular, its Magnetics division is recognised as Europe's leading manufacturer of polymer-bonded magnets and enjoys a strong global reputation with an extensive network in Europe, the USA and beyond. The company's commitment to innovation and customer satisfaction is reflected in its Gold Award from the Postojna Regional Chamber of

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KOLEKTOR

Commerce and Industry. With nearly 60 years of experience, Kolektor has evolved from a primary focus on the automotive sector to a global supplier of mobility components and systems, demonstrating its adaptability and global reach.

Kolektor KFH d.o.o., a subsidiary, operates in the automotive, industrial, energy and home appliance sectors, offering a wide range of products and services, including magnetic components, hybrid/electric mobility solutions and energy infrastructure solutions. One of Kolektor KFH's outstanding projects is the aProMag project, where the company is responsible for the development of a polymer-based compound and filament for 3D printing. This project underlines Kolektor's commitment to advanced technologies and the pursuit of new market opportunities. Overall, the Kolektor Group's commitment to quality, technological advancement and customer satisfaction has cemented its status as a dynamic and forward-thinking leader in the industry.

University of Ljubljana, Faculty of Mechanical Engineering

The Faculty of Mechanical Engineering at the University of Ljubljana is the leading institution in Slovenia for education and research in the field of mechanical engineering. Through our in-house design and research efforts, we strive to provide high-quality education and transfer valuable knowledge to our students and research as well as industrial partners. This enables us to effectively compete and integrate into the international environment.

The research process at the Faculty of Mechanical Engineering is conducted within 17 chairs and divided into four different but complementary platforms: Factories of the

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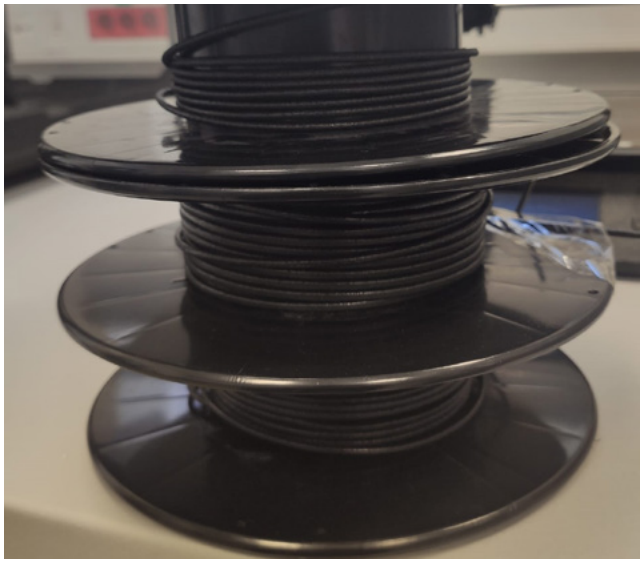
Future, Green and Safe Mobility Health, and Sustainable Energy. With access to state-of-the-art research equipment, we are able to develop new production concepts that enable the manufacturing of unique, customized products. Our researchers utilize, among others, micro and nano technologies, 3D printing, and advanced software solutions for material behavior prediction to create smaller, more sustainable, and powerful devices. Our focus on green technologies, based on renewable energy sources, energy-saving processes, and materials with advanced properties, allows us to obtain flexibility in product development. We are committed to creating innovative solutions that prioritize sustainability and environmental responsibility.

The Laboratory of Experimental Mechanics at the Faculty of Mechanical Engineering focuses on conducting educational and research activities in the field of polymer behavior, which includes polymers, polymer composites, melts, suspensions, and their related applications. Research activities include basic research as well as applied research related to specific industrial applications. Following the recent global trends to increase the use of engineering polymers and composites due to their good strength-to-weight ratio and simple processing or manufacturing, the activities conducted within our laboratory are related also to the preparation of functional, i.e., magnetic materials. Especially in the development of polymer-bonded magnetic filament, this gives the possibility of manufacturing custom shaped permanent magnets using 3D printing technology. Sophisticated, up-to-date equipment, i.e., lab-scale extrusion and filament production line enable the preparation of different formulations and optimization of processing conditions for the development of filaments filled with a high concentration of magnetic and other particles.



Pforzheim University

With its faculties of Design, Engineering and Economics and Law Pforzheim University combines creativity with business education and technical precision. This combination makes the university an attractive science and research partner. Qualifications and practical experience of the teaching staff on the one hand and intensive cooperation with successful companies on the other hand lay the foundation for the university's outstanding position in the rankings. Pforzheim University offers 28 bachelor's and 19 master's courses in the faculties of design, technology, business, and law.

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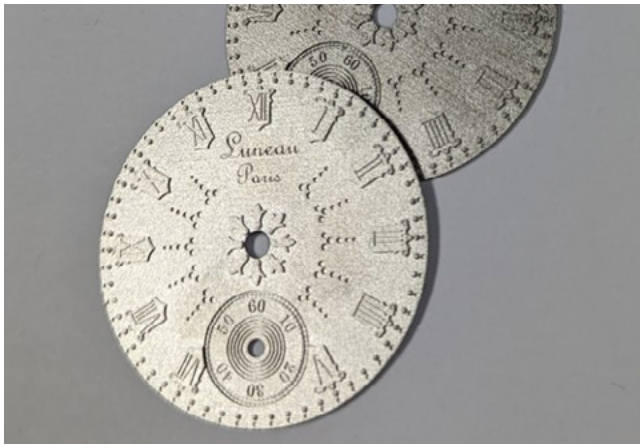
In the close connection between theory and practice, the university and its 11 institutes cooperate with more than 100 partner universities and project consortia worldwide in international networks and attach great importance to economic and business ethical issues. The university was one of the first in the world to commit to compliance with the "Principles for Responsible Management Education" (PRME) initiated by the UN.

The Institute for Precious and Technology Metals (STI) is active in materials analysis and failure analysis of parts and components for the precision industry, development and characterisation of materials, coatings and manufacturing technologies with more than 25 years of successful industrial collaboration. Its two research groups cover (a) the recycling of rare earth-based permanent magnets and (b) sinter-based additive manufacturing.

The Institute is equipped with a state-of-the-art metallographic laboratory including SEM, XRD, optical microscopy, O/N/H and C/S analysis, mechanical testing equipment, heat treatment facilities and a mechanical workshop for prototyping. A newly equipped laboratory for additive manufacturing of precision metal parts and metal injection moulding of stainless steel, titanium and Ni-based alloys is perfectly equipped for the investigation of new materials, with staff having more than 15 years of experience in MIM-type materials and more than 5 years in sinter-based additive manufacturing.

Department head Prof. Dr. Carlo Burkhardt has been instrumental in the development of Metal Material Extrusion (MEX/FDM/FFF) and Lithography-based Metal Manufacturing (Vat-Polymerisation/LMM) for AM of precision metal parts, making his institute a pioneer in sinter-based metal AM.

The Magnets Research Group coordinates two of the largest recycling projects in the EU Horizon programme (SUSMAGPRO and REEsilience) and is involved in eight other international and national research projects with a total budget of over €45 million €. Embedded in a network of more than 60 academic and industrial partners, STI is one of the leading magnet recycling institutes in Europe.



RLS

At RLS, we have been dedicated to mastering the art and science of sensor technology for over three decades. Founded in 1989, our journey began with a vision to revolutionise the world of magnetic encoders. Today, we are a globally recognised developer and manufacturer pushing the boundaries across a broad spectrum of industries.

INNOVATION DRIVEN BY VALUES

Beyond our technological achievements, RLS is celebrated for its vibrant company culture. We are honoured to be regularly recognised as 'Best Employer' and for 'Best Organisational Energy' in Slovenia. These awards reflect our commitment to creating a workplace that fosters innova-

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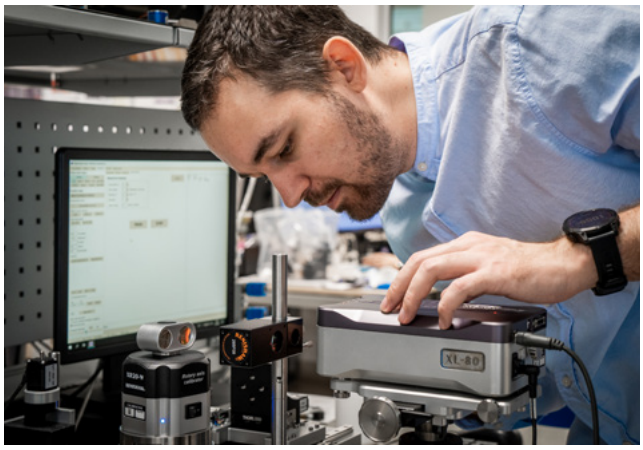
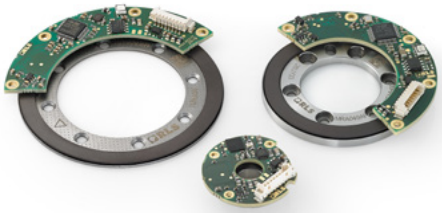
tion, collaboration and employee wellbeing. In addition, our commitment to excellence in business practises was recently recognised by Slovenia's largest media house, which presented us with a prestigious business award for exceptional business results. These awards are a testament to our ongoing commitment to excellence, both in our technological endeavours and in our corporate ethos.



ENCODER SOLUTIONS FOR A DIVERSE WORLD

At the heart of RLS is our unwavering commitment to providing solutions suitable for a wide range of applications. From the precision required in robotics and electric motors to the robustness needed in aerospace and submarine applications, our encoders are designed to fulfil the most demanding specifications. Our presence in industrial automation, printing, machine tools, medical devices, green energy and more is a testament to our versatility and adaptability.



GLOBAL REACH, LOCAL IMPACT

Our global presence spans European, American and Asian markets, where we work hand-in-hand with leading companies and brands. As an associate company of Renishaw, we utilise their extensive global network to bring our advanced sensor solutions to the world. This international perspective, coupled with our deep understanding of local markets, enables us to deliver technologies that resonate on a global scale while meeting specific local needs.

LOOKING AHEAD: THE FUTURE OF SENSOR TECHNOLOGY

Our goal is to remain at the forefront of sensor technology. We are constantly exploring new technologies and ensuring that our solutions not only fulfil, but anticipate the evolving needs of our customers. With a heritage of over 30 years, a culture of accolades and a clear vision for the future, RLS is more than just a company. We are your trusted partner in innovation, a driver of technology and a living embodiment of our values.

Magneti Ljubljana

Magneti Ljubljana is a European manufacturer of permanent metallic magnets, bonded magnets and magnetic systems with a long-lasting tradition, since 1951. Through its regular operation and various development projects, frequently in cooperation with research institutions, the company and its employees have gained broad competencies in basic permanent magnet production process, as well as supporting technologies, measurement techniques and in the design of materials, machines and automated magnet or magnetic system production lines.

We are a development and market-oriented company characterized by financial stability and business success. Through innovation and business excellence, we contin-

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ue to fulfill our customers' demands and aim to create a working environment that encourages the development of our employees and the company as a whole in a sustainable and responsible manner. Our vision is to become a global manufacturer in the global market for permanent metallic magnets and magnetic systems. Our aim is to fulfill our customers' demands and expectations by focusing on the development of technologically advanced products and processes.

The future of our company is dependent on our capability to develop new products and produce innovative solutions to meet our customers' future needs. By supporting innovative thinking mutual respect and teamwork we aim to build a working environment that encourages individuals to reach their full potential for the benefit of both the individual and the company.

The majority of production in Magneti Ljubljana is based on product design and specifications provided by customers, the production process being designed and developed by our company. However, in several cases the design of individual magnets or magnetic systems, based on basic functional requirements and limitations provided by customers is either supported or even carried out in major part by Magneti. The cooperation in the product design phase is particularly favorable and encouraged because it enables Magneti to contribute to the functionality and also cost-optimized design by repeated evaluations of manufacturability and improvement proposals.

It is necessary to constantly monitor the advancement in new magnetic materials development and is quite successful in developing its own materials and production processes in the attempt to be able to produce as "state-of-the-art" materials as possible. The main motive is the sustainable growth and profitability of the company. We have our own R&D department which, frequently in cooperation with external institutions, runs internal material development projects. Observing the risk analysis based on raw material markets and also on general environmental impacts of magnets supply chain we are also very active in international projects focused on recycling magnet materials, where our work is focused on achieving the best possible material properties, comparable to those of magnets produced with "virgin" raw materials.

> 3D printing is the future of manufacturing, and it's happening now.

Chris Anderson, Wired Editor-in-Chief


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