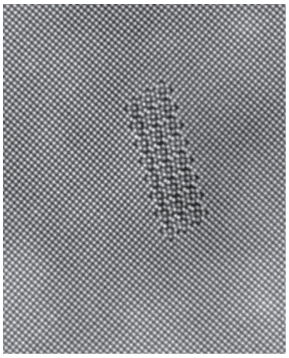
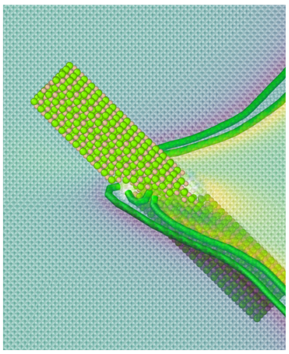
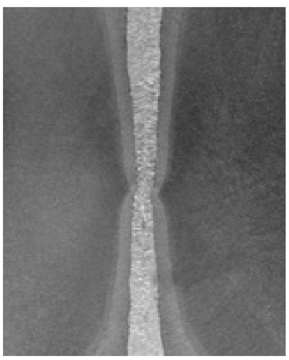
Centre for Sustainable and Competitive Metallurgical and Manufacturing Industry

# ANNUAL REPORT 2020

SFI PHYSMET








PhysMet

sfi Centre for Research-based Innovation

**Host:**
NTNU, Faculty of Natural Sciences, Department of Materials Science and Engineering

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**Homepage:**
www.ntnu.edu/physmet

**Frontpage:**
Main picture: *Morten Høgseth Danielsen in the laser processing laboratory.* Photo by Nikolai Marhaug, SINTEF
Small pictures, from top:

- *Atomic scale resolution image of a beta"-hardening precipitate in aluminium obtained by scanning transmission electron microscopy*. Figure by Sigurd Wenner, SINTEF
- *Model of a dislocation shearing a beta''-precipitate in aluminium using molecular dynamics and a MEAM potential*. Figure by Inga G. Ringdalen, SINTEF
- *Cross-section of laser hybrid weld, 45 mm thick steel plate*. Figure by Ivan Bunaziv, SINTEF

**Layout and production:** Ida Følstad, NTNU Grafisk senter

# CONTENT

## ANNUAL REPORT 2020
## SFI PHYSMET

# SUMMARY

BY CENTRE MANAGER
**KNUT MARTHINSEN, NTNU**

Centre for Sustainable and Competitive Metallurgical and Manufacturing Industry, SFI PhysMet, has been appointed by The Research Council of Norway as a centre for Research-based Innovation from 2020-2028. SFI PhysMet is an interdisciplinary centre in the field of physical metallurgy, which in brief refers to the ***science of making useful product out of metals***.

The physical metallurgy environment in Norway is internationally recognized for its expertise and has throughout the last century been the foundation for strong metallurgical and manufacturing industries in Norway. SFI PhysMet will be an important vehicle to consolidate, further develop and strengthen this position, through world-class knowledge and skills, improved educational programs, and researcher training.

SFI PhysMet is hosted by NTNU, through the Department of Materials Science and Engineering (DMSE), with Professor Knut Marthinsen as the Centre Manager. SINTEF and IFE are the research partners. User partners involved are based in the metal producing industry (Hydro, Elkem), metal manufacturing industry (Benteler, Raufoss Technology), and end users (Equinor, Norwegian Public Roads Administration (NPRA)). In addition, comes an international partner, ThermoCalc (Sweden), a world-leading software company in the field of computational materials science and thermo-dynamical software in particular.

SFI PhysMet brings together companies that rely on physical metallurgy in their operations but have mostly worked with the research partners in projects according to their specific material domains and with limited synergies. Bringing all these stakeholders into a joint centre brings added value by strengthening the generic and fundamental aspects of physical metallurgy in next decade and beyond, e.g., by materials analysis from nano- to macro scale, and through-scale and through-process modelling, with applications to Al-, Fe- and Si-based materials and related processes. SFI PhysMet will integrate industrial participants working with different materials and positions in the different value chains, from materials producers to manufacturers and end users.

This will facilitate innovations and new industrial collaborations and will also accelerate the uptake of scientific findings and tools by a larger industrial community. The centre will therefore foster innovation across the traditional business areas.

The research activities will combine advanced characterization of structure and properties at all length-scales with development of numerical models adapted to industrial processing conditions that the industry can use in their own R&D and innovation activities. SFI PhysMet will make use of the comprehensive infrastructure and 'state-of-the-art' laboratories for synthesis, processing, and characterization available at NTNU, SINTEF og IFE, and collaborate with leading international partners.

We organized the first consortium meeting in August 2020 and the official kick-off seminar in January 2021 with more than 80 participants. All partners from industry and research organizations were well represented. The main focus in the first meetings has been discussions and input on activities included in the annual work plans for 2020 and 2021, which will provide a platform for the coming years.

The leaders of the research areas have started the recruitment of the first PhD candidates to the centre. An important academic objective of SFI PhysMet is education and training the next generation of physical metallurgists. We want to provide candidates with a combination of digital skills and fundamental metallurgy competence. During the 8 years centre period we will recruit and educate numerous PhD candidates, Post doctors and master students.

An interim board was appointed in 2020 to ensure that the intentions and plans underlying the contract for the establishment of the centre are fulfilled. The interim board was crucial in the process of finalization of the Consortium Agreement, that was signed by all partners in December 2020.

There is a plan for co-location of the centre at campus Gløshaugen from autumn 2021. PhD candidates and Post doctors recruited to the centre will work closely together and with short distance to the project leaders and supervisors, and co-location will ensure more effective collaboration between the research groups.

The overall communication aim of SFI PhysMet is to inform and engage relevant target groups and ensure that inputs from stakeholders at all levels can influence and improve the results and impact of the centre. Relevant stakeholders are the centre partners, students and researchers, other industry sectors, the general public, international research communities etc.
Papers in international scientific journals with peer-review and presentation at relevant international conferences will be the main forum for scientific dissemination. However, an important aim will also be popular science presentations of the research activities and important results to a broader audience through articles in relevant newspapers and in technical and popular science media. A special focus will be on recruitment, to attract good students and in particular female candidates to SFI PhysMet and the physical metallurgy field in general.

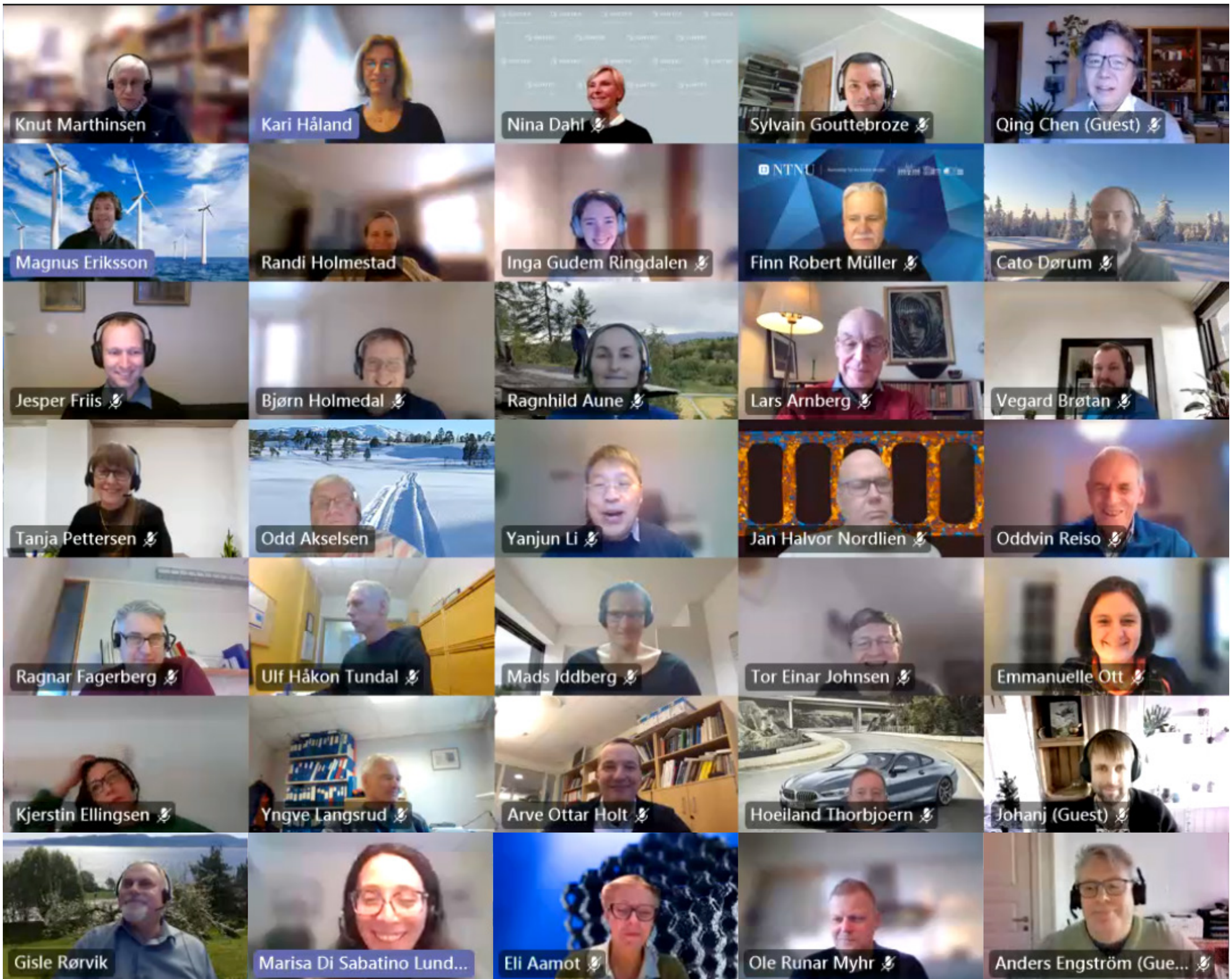
An important arena to reach out to the public and making information easily available is the centre website www.ntnu.edu/physmet/, which already has been established and will be further developed in 2021.

We are looking forward to presenting exciting results in the coming years and we trust that the centre activities will enhance the ability of the business sector to innovate in the field of physical metallurgy.

# KICK-OFF SEMINAR JANUARY 12TH 2021

January 12th 2021 SFI PhysMet organized a kick-off seminar that officially marked the opening of the centre. More than 80 participants from industry and research partners joined the seminar.


*Vice rector for innovation at NTNU, Toril Hernes, cut the chain and congratulated centre manager Knut Marthinsen and co-manager Marisa Di Sabatino. Photo: Per Henning*

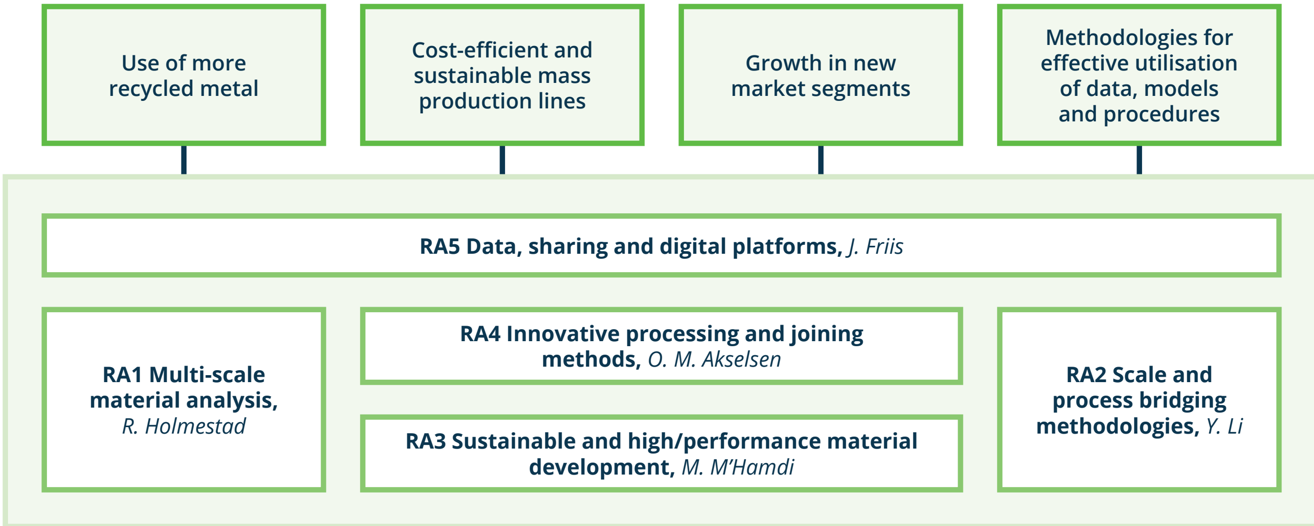



*Screenshot with some of the kick-off-participants. The opening was organized as a digital webinar due to the corona virus restrictions.*

The kick-off started with congratulations from Vice rector Toril Hernes (NTNU), Executive Vice President Eli Aamot (SINTEF) and Executive Director Kristin Danielsen (RCN). This was followed by presentations of the five research areas that define the centre activities. The industry partners presented their expectations and their ambitions for centre participation.  SFI PhysMet will, among other things, assist the metal industry with research on the use of new materials and recycling to achieve a more sustainable production. All partners are looking forward to collaborate in the years to come, to enable implementation of important results from the centre activities!

# VISION AND RESEARCH STRATEGY

***Vision:*** *SFI PhysMet aims to be a world leading research centre in the field of physical metallurgy, required to accelerate the transformation of the national metal industry towards more sustainable and cost-effecient production and future material products, solutions and improved processing methods.*




## RESEARCH STRATEGY

The energy-demanding land-based industry sectors in Norway, i.e., the *metallurgical and manufacturing industry* have been of vital importance for Norwegian export and national value creation. However, *their presence and future sustainable growth in Norway depend on a competitive advantage in terms of high-technology competence and superior quality in their businesses*. In order to secure their position and prepare for further growth, four main industrial technology challenges that need to be solved to enable future new jobs, competitiveness and sustainable growth have been identified, and described in detail in the SFI PhysMet project description:

- Use of more recycled metal
- Cost-efficient and sustainable mass production lines
- Growth in new market segments
- Methodologies for effective utilisation of data, models and procedures

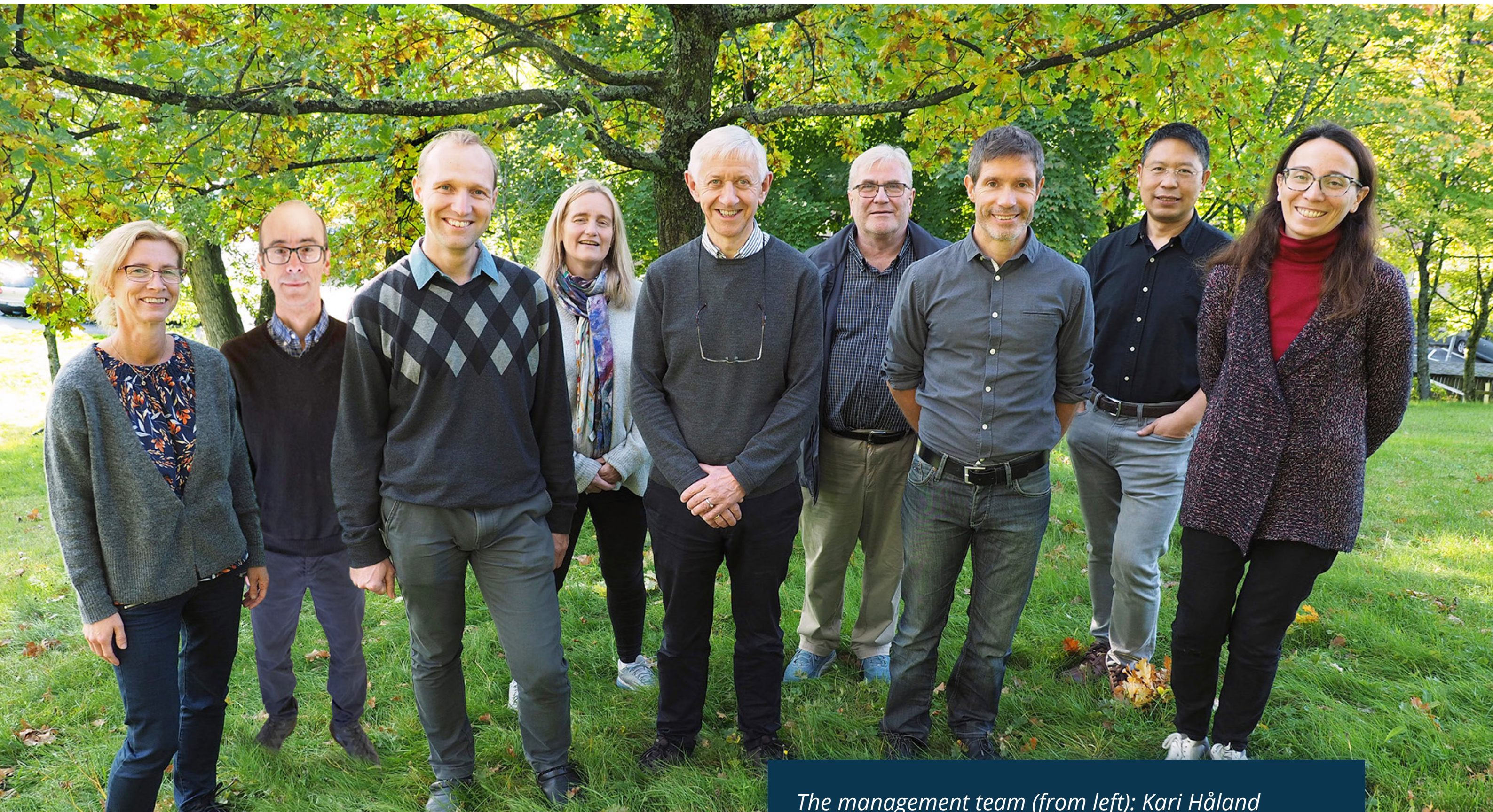
Even though these four main industrial challenges are comprehensive, requiring new innovative alloys, materials and processes, their basic knowledge needs are overlapping and generic. Extensive knowledge is required, about the mechanisms for formation and evolution of microstructures, and about the underlying principles.

Then processing routes can be designed or improved, to provide cost-efficiently the desired properties of the products. Progress and innovations are accelerated when the knowledge and associated methodologies, models and data are efficiently stored and made available to academic and industrial researchers and engineers in the centre.

The figure above illustrates the structure of SFI PhysMet, for which five *Research Areas* (RA1-RA5) are designed to meet the targeted industrial knowledge needs. Material characterisation in RA1 and modelling in RA2 represent the basic research required for developing the desired material design in RA3 and innovative processing in RA4. A separate RA5 is dedicated for developing a platform for storage and sharing of data and models, facilitating accelerated progress in RA1-RA4 and making results available for exploitation.

The targeted industrial knowledge needs serve as the basis for the specific work plans in each Research Area for 2020/2021 as further described in this report.

# ORGANIZATION



*The management team (from left): Kari Håland (NTNU), Mohammed M'Hamdi (SINTEF, RA 3 manager), Jesper Friis (SINTEF, RA 5 manager) Randi Holmestad (NTNU, RA1 manager), Knut Marthinsen (NTNU), Odd Magne Akselsen (SINTEF, RA 4 manager), Magnus Eriksson (SINTEF), Yanjun Li (NTNU, RA 2 manager), Marisa Di Sabatino (NTNU).*

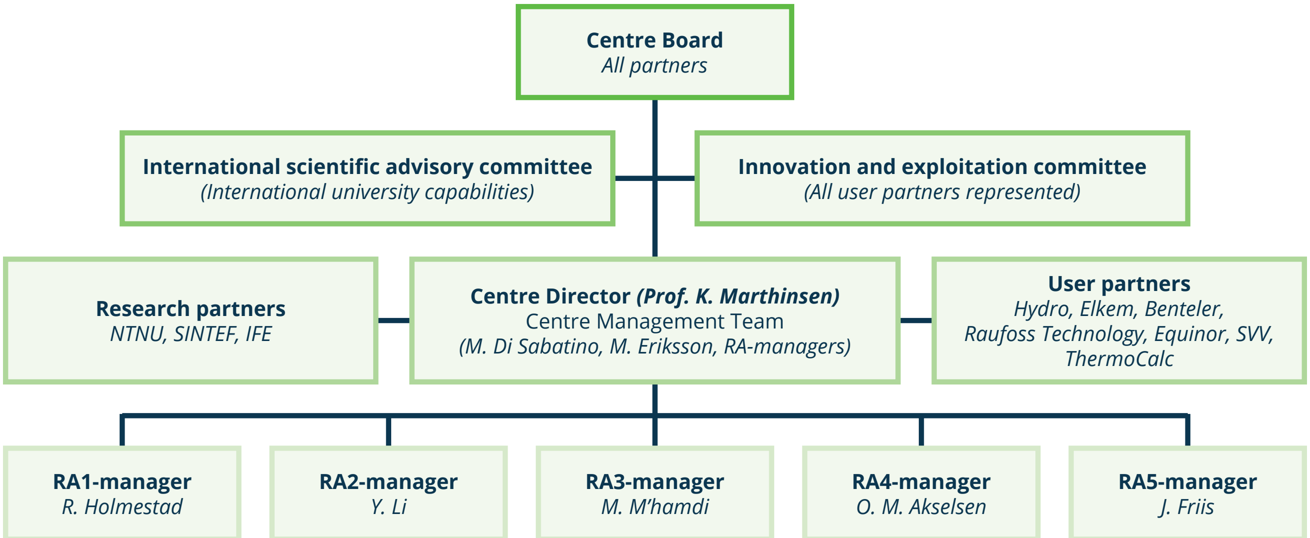
**THE CENTRE BOARD**

The responsibility of the SFI board is to ensure that the intentions and plans underlying the contract for the establishment of the centre are fulfilled. In 2020 an interim board has been appointed. Members of the interim board are:

Tor Grande, NV NTNU (Board leader)
Gro Eide, Elkem
Nina Dahl, SINTEF Industri
Trond Furu, Hydro
Yngve Langsrud, Benteler
Stein Olsen, Equinor

**THE CENTRE MANAGEMENT TEAM**

The centre manager is Knut Marthinsen. Co-manager is Marisa Di Sabatino and administrative coordinator is Kari Håland. Magnus Eriksson represents SINTEF in the management team. The five Research Area (RA) leaders are also part of the management team.




## THE SCIENTIFIC ADVISORY COMMITTEE

In order to secure that the centre activities hold an excellent scientific standard and that we are closely connected with leading scientific groups in metallurgy around the world, we have appointed a scientific advisory committee (SAC). The members of SAC are:

Professor **Dierk Raabe**, Max Planck Institute for Iron Research, Düsseldorf, Germany

Professor **Aude Simar**, UC Lovain, Belgium

Professor **Dorte Juul Jensen**, DTU Technical university of Denmark

## LOCATION

SFI PhysMet is hosted by NTNU, Department of Material Science and Engineering. The centre consists of research groups located in Trondheim at campus Gløshaugen and (one group) at SINTEF Industry in Oslo. Today the groups are located in different building complexes. There is a plan for co-location at campus Gløshaugen from autumn 2021. PhD candidates and Postdoctors recruited to the centre will work closely together and with short distance to the project leaders and supervisors, and co-location will ensure more effective collaboration between the research groups.

*Campus Gløshaugen, Trondheim*

# THE PARTNERS

The SFI PhysMet consortium consist of three research partners (NTNU, SINTEF and IFE) and seven user partners (Equinor, Hydro, Elkem, Benteler, Raufoss Technology (Neuman Aluminium Raufoss), Thermo-Calc Software, The Norwegian Public Roads Administration). The user partners include metal and material producers, downstream material processing industries as well as end users of metals and alloys (energy sector).

## COOPERATION BETWEEN THE CENTRE'S PARTNERS

The partners will actively participate in the governance, financing, and research activities at the centre. The centres' research results and expertise are to provide a platform for innovation and value creation among the user partners.

In order to obtain a common understanding and cooperation between the centre's partners we will organize bi-annual consortium meetings. The meetings will be used to discuss aims, activities, and results, and to promote implementation of results in the industry. We will establish effective means to share results and documents to ensure effective knowledge transfer to user partners.

The leaders of the five Research areas (RA) are responsible for the involvement of all relevant partners in the planning and implementation of the various RA activities. In order to involve all partners, we will organize quarterly meetings at the RA-level.

The centre workspace will also provide offices and access to advanced laboratories to enable members from the user partners to work at the centre premises and interact directly with other partners.


Photo: Bård Gudim, Hydro

# PRESENTATIONS OF SFI PHYSMET'S PARTNERS →

## USER PARTNER:
## HYDRO ALUMINIUM

Hydro is a fully integrated aluminium company with 35000 employees in 40 countries, combining local expertise and unmatched capabilities in R&D. It is one of the largest aluminium companies worldwide.

Hydro is a leading industrial company committed to a sustainable future. Hydro's purpose is to create more viable societies by developing natural resources into products and solutions in innovative and efficient ways.

Physical metallurgy is a corner stone for Hydro's business today and will continue to be of vital importance also in the coming years in the tough competition of offering cost-efficient Al-products for more and more demanding customers. Maintain and further develop the world class competence in aluminium physical metallurgy at NTNU and SINTEF is of very high priority for Hydro. Secure long-term competence building makes Hydro more sustainable.

Hydro has several researchers in our R&D units with high competence in the area of physical metallurgy and will actively participate as discussions partner and contribute with industrial relevant challenges/topics. Our focus is to transform the generic knowledge obtained in the centre into practical industrial innovations and implement new results as fast as possible.

Hydro has state-of-the art laboratories for implementation (e.g. pilot reference centre for casting, pilot lines in extrusion, rolling, welding, forming, and surface treatment,.... ) as well as modelling capabilities (e.g. microstructure-based modelling and process-modelling for casting, extrusion, rolling, forming, and welding).

Hydro will focus on continuous implementation of project results during the SFI-period in our cast houses, rolling mills, extrusion plants and wire/rod plant.

# USER PARTNER:
## ELKEM

Elkem is one of the world's leading companies in the environmentally responsible manufacture of metals and materials. Elkem is a fully integrated producer with operations throughout the silicon value chain from quartz to silicon and downstream silicone specialities as well as ferrosilicon alloys and carbon materials. Elkem's more than 6.700 skilled employees and significant R&D activities provide a solid basis for further technology-driven growth and optimization.

Elkem will have two main focus areas for materials development in the context of SFI PhysMet: Ferroalloys for cast iron and steels and specialty silicon products.

Elkem is a global supplier of ferro-alloy based additives for the cast industry. Elkem sees the increased urge to design innovative products to be able to keep cast iron as a competitive material and to maintain a market for Elkem in the automotive industry. Further, the windmill energy sector is also an important market and solutions are needed especially for the development in the Arctic areas. Silicon rich alloys (silicides) is another potential area for Elkem's product portfolio. Silicides are in general materials with high strength and good corrosion resistance for a wide range of temperatures. Still their use in commercial applications have been limited, due to low temperature brittleness of intermetallics, making direct casting and machining of these materials difficult. Additive manufacturing has a potential to overcome these difficulties and open for mass production of tailor-made components.

For silicon-based materials Elkem is also looking into new opportunities in the fields of additive manufacturing and battery applications, both requiring fine powder of very specific properties.

Elkem has several researchers of high competence in the area of physical metallurgy. A focus for Elkem is to transform the generic knowledge obtained in the centre into industrial innovations as fast as possible. Elkem's products are powder materials of different particle sizes, thus the optimization of production route from a solidified material to a product meeting the required customer specifications requires fundamental knowledge of how the material properties can be controlled.

Internal activities will mainly be related to experimental verification to provide industrial data and testing to implement the new knowledge into advanced products.

# USER PARTNER:
# EQUINOR

Equinor is a broad energy company with 21000 colleagues committed to developing oil, gas, wind, and solar energy in more than 30 countries worldwide. Equinor is dedicated to safety, equality, and sustainability. As the largest operator in Norway, Equinor is a leading international offshore operator and a growing force in renewables, committed to shaping the future of the energy sector.

A high level of expertise within physical metallurgy is seen a one of the key success factors for Equinor as an operator in the oil and gas industry. The SFI PhysMet will be an important contributor to overcome the challenges within the oil and gas industry (deeper waters, harsher environments, competitiveness at low oil/gas prices) and the transition to a low carbon society (e.g. growing dimension in offshore wind turbine structures). The SFI PhysMet can enable more efficient fabrication methods and play a central role in making renewable energies (in general) and Norwegian fabricators (in particular) more competitive.

Equinor's main target is the introduction of new advanced fabrication methods (like LASER hybrid welding) with a high level of automation, robotization and digitalization for control of parameters, repeatability, and prediction of mechanical properties. This shall enable, not only more efficient, but also more reliable and therefore safer fabrication and repair. Understanding the metallurgical interactions is hereby of fundamental importance.

As an end-user of technologies, Equinor can contribute with long term experience from existing applications or in field trials and case studies. The two company laboratories within materials testing and corrosion may be utilized for collaboration, depending on capacity at each point in time. The company internal professional network will be used as a resource with high expertise in physical metallurgy. This may be supplemented with a wide range of contacts within the industry.

## **USER PARTNER:**
## BENTELER AUTOMOTIVE RAUFOSS

BENTELER is a metal processing specialist, who produces safety-relevant solutions for the global automotive industry.

BENTELER Automotive is the development partner for the world's leading automobile manufacturers, and design and develop solutions where quality, safety and efficiency are decisive. The products comprise components and modules for chassis, body, engine, and exhaust systems.

Benteler Automotive Raufoss (BAR) produces crash management systems (CMS), structural components and rear spring links for the automotive industry, all based on extruded and formed profiles. The production site in Raufoss has delivered CMS in aluminium 7xxx alloys (and also 6xxx alloys) for nearly 50 years. The production steps for production of CMS in aluminium, such as casting, extrusion, forming and finishing, are all situated at Raufoss. BAR aims to be an important supplier of all structural parts for the automotive industry, including profiles for protection of batteries in electrical cars. In order to develop and expand the product portefolio BAR believes that a high level of competence within physical metallurgy is crucial. In this respect, SFI PhysMet will be an important centre for BAR, and we intend to utilize the competence for future products and innovative solutions.

Based on our experience, using material  and processing knowledge to develop new products and improve processes,  we believe the potential for generating innovation and value creation is high. Due to the high level of cost in Norway BAR always needs to be in the forefront with respect to competence and know-how. In the last years we have experienced that the customers have more demanding requirements to the properties of the material and the performance of the product. In order to responds to this, it is important for BAR to take part in pushing the state-of-the-art forward with respect to physical metallurgy, material competence and processing competence. The value chain of BAR has several process steps, and knowledge with respect to all process steps are relevant. In particular, increased knowledge of the heat treatment response (in all the production steps) of alloys used in our production is if high importance for future innovations. In addition, increased competence on forming of aluminium is crucial to be able to develop new products.

Benteler will contribute to the centre with specific process and material expertise. Researchers from BAR's unit, with strong metallurgical competence, will take part in the planned work in SFI PhysMet.

## USER PARTNER:
## RAUFOSS TECHNOLOGY AS

Raufoss Technology, a division of Neuman Aluminium with over 2400 employees, is a leader in design, development, and manufacturing of aluminium chassis components for the automotive industry. Neumann Aluminium are a family privately owned Austrian-based aluminium group with over 200 years of metal product and metal fabrication experience of High Value Aluminium Solutions.

Research and Development typically involves increasing demands on the performance of the products. Materials technology is, and will continue to be, a central part of Raufoss' ambition to become the world leader at integrating materials, manufacturing processes and products. This is why we use aluminium alloys specifically tailor made for our processes and that we have successfully developed our own ball joint solutions.

Key competence areas for which SFI PhysMet will be useful and instrumental for Raufoss Technology, include:

- Materials science fundamentals
  - The link between material science («nano-level») process impact and the performances in field.
  - Not only aluminum, but all materials that we apply including QT Steel, POM etc..
- Transformation of aluminium;
  - Hot and cold forming processes of aluminum
  - Hybrid processes (e.g. integrated hot forming and in-die quenching (HFQ) heat treatment)
- Creating new products and process windows, by linking these sciences
- Material models and development methodology

The target and goals for Raufoss Technology in SFI PhysMet are to build competence and balance/align this with ongoing other R&D projects, where the target is to take out more synergies, i.e. use the resources of SFI to get more out of our Innovation projects. Raufoss Technology will coordinate and find tasks and following synergies to other projects and take part in teaching/supervision within the frame of theses for master and PhD students. These thesis works should balance fundamental material science, with practical issues, daily process challenges and measurable results.

## **USER PARTNER:**
## THERMO-CALC

Thermo-Calc is a small to medium size enterprise (SME) that develops computational tools in the field of materials engineering, providing licenses and connected services world-wide to customers in industry, government, and academia. Customers benefit by being able to access faster, cheaper, and more sustainable innovation in the fields of development and production of materials and components. The company is globally well-recognized in this field by researchers and engineers for its products, e.g. Thermo-Calc and DICTRA and associated databases. The company's headquarter and main development office is located in Stockholm, Sweden, where 40 individuals are based, of which approximately 60% hold a PhD from international universities.

Being a software company developing computational tools that are essential to almost any Integrated Computational Materials Engineering ('ICME') framework, SFI PhysMet is expected to include activities highly aligned with Thermo-Calc core business. In particular, Thermo-Calc has a strong interest in mechanisms and services for creating through-scale and through-process modelling work-flows, which could integrate with Thermo-Calc's software products. Connected to this is the ongoing digitalization of materials science, i.e. Materials 4.0, and specifically its relation to net-centric manufacturing, which is expected to grow in importance, is also of interest. Thermo-Calc is also excited by the opportunity to accelerate its knowledge on the use of machine learning to generate new knowledge and making predictions.

By supporting and participating in SFI PhysMet, Thermo-Calc expects to generate knowledge that allows to develop new ICME models that can be incorporated into its software products, but also knowledge related to the requirements on products for effective linkage to other software tools present in an ICME framework or net-centric manufacturing environment.

## USER PARTNER:

## NORWEGIAN PUBLIC ROADS ADMINISTRATION (NPRA) – STATENS VEGVESEN

Statens vegvesen

The NPRA is the roads authority for national roads, and is responsible for managing, researching, planning, building, operating national roads. NPRA have a sectorial responsibility to follow national tasks for the entire transport system. The NPRA serves society through three roles, as a contracting client, as an authority body, as an expert agency. The national government and the Parliament set the national goals for transport policy in Norway through the National Transport Plan. The National Plan identifies investment priorities for transport policy in Norway for the next 12 years. Participation in SFI PhysMet will provide knowledge to help achieving the goals 'More for the money' and 'Efficient use of new technology'.

The main target for NPRA is the introduction of new advanced manufacturing methods like automated laser- and laser-hybrid welding. Implementation of new manufacturing methods shall enable more cost-efficient, reliable, and safe production of steel bridge structures. NPRA also see a potential for significant $CO_2$-savings.

As an end-user, NPRA can contribute with experience from existing applications or in case studies. During 2020/2021 we are building a pedestrian bridge using laser-hybrid welding technologies and are also planning more bridges with laser- and/or laser-hybrid welding in the years to come. With new welding technology NPRA sees a potential for both reducing the cost and improving the quality of steel-bridge structures. In particular, the potential cost savings is believed significant for the E39 fjord crossing project, where extremely large bridge structures are being planned. In this context, laser welding of aluminium structures is also of interest (cf. Langenuen suspension bridge – R&D-project on concept development of aluminium bridge girder).

# RESEARCH PARTNER:
## SINTEF

SINTEF is one of Europe's largest independent research organizations with 2000 employees and a turnover of 330 million € in 2018. SINTEF is an independent non-commercial organization. In 2018, SINTEF supported the development of more than 3500 companies via research and development in materials technology, applied chemistry, biotechnology, technology management and other fields. Contract research carried out by SINTEF covers all scientific and technical areas, and ranges from basic research through applied research to commercialization of results into new products and business ideas.

The subsidiary companies are committed to working closely with industry, generating value and developing solutions to some of the great challenges facing society today. SINTEF utilises its outstanding solution-oriented research and knowledge production to generate significant value and innovation for its clients in Norway and abroad. SINTEF with multidisciplinary top competence within technology, natural and social sciences is in the forefront of international research, which is essential to realise its vision "Technology for a better society" and to promote sustainable development and value creation for its clients.

Within the SINTEF Foundation two SINTEF Group units (SINTEF Industry and SINTEF Manufacturing) participate in the centre scientific activities. The SFI PhysMet initiative addresses two of SINTEF's main strategic priorities "Manufacturing" and "Process Industry". NTNU and SINTEF have collaborated extensively in the field of physical metallurgy over several decades. There are significant overlaps in the competence fields of the two organisations and there are strong synergies in the joint operation.

SINTEF Industry and SINTEF Manufacturing have a permanent staff of researchers and engineers set up to perform contract research. This staff will be utilized in all Research Areas and will also be involved in co-supervision of candidates at NTNU. SINTEF Industry will lead Research Area 4. "Innovative processing and joining methods", as well as Research Area 5 "Data, sharing and digital platforms".
SINTEF has implemented several national research infrastructures with state-of-art experimental equipment that will be essential to SFI PhysMet.

# RESEARCH PARTNER:
## IFE

IFE, Institute for Energy Technology, is one of the largest research institutes in Norway. Since 1948, IFE has been a frontrunner in international energy research.

IFE build bridges between research, education and industry. We have extensive infrastructure and full-scale laboratories where theoretical models are transformed into commercial activities and strive to be an important partner for companies that want to research, develop and produce new solutions for renewable energy.

The sector Materials and Processing has more than 80 employees and conducts research within renewable energy systems, hydrogen and batteries, energy materials and nanotechnology and material processing. In SFI PhysMet, IFE participates with high expertise and infrastructure related to CVD production, thermal processing, characterisation, as well as market knowledge related to new advanced materials for AM. Personnel from the Department of Battery Technology at IFE will contribute to SFI PhysMet due to long-term experience with energy material production in powder form.

IFE will primarily contribute in Research Area 3 *Sustainable and high-performance material development*, where we will introduce powder production to the methodology of the SFI. IFE will also participate in Research Area 5 *Data, sharing and digital platforms*.

## RESEARCH PARTNER:
NTNU

NTNU, Norwegian University of Science and Technology, is a university with an international focus, with headquarters in Trondheim and campuses in Ålesund and Gjøvik. NTNU's strength is our competence in science and technology combined with a variety of programmes of professional study, academic breadth and interdisciplinarity.

NTNU aims at being an important contributor to research-based sustainable value creation, innovation and increased competitiveness, in collaboration with partners in business and the public sector.

SFI PhysMet is hosted by Department of Materials Science and Engineering (DMSE) at Faculty of Natural Sciences. Physical Metallurgy is firmly anchored in the strategic priorities for advanced materials at NTNU and DMSE. There is a particular focus on how advanced metallic materials can contribute to solve societal challenges with strong reference to UN's sustainable development goals, including "*Responsible Consumption and Production*", "*Industry, Innovation and Infrastructure*" and "*Affordable and Clean Energy*". This complies well with the primary objective of SFI PhysMet.

NTNU has a prime responsibility in the centre for education, researcher training and long-term competence building. A centre workspace will be established at the NTNU campus in Trondheim available for personnel from all partners. NTNU is primarily involved in Research Areas 1-4, and will in particular contribute with expertise (experience, competence and skills) through supervision and be actively involved in the research and innovation activities together with the other research partners and industry. NTNU will provide access and use of characterisation research infrastructure essential for implementation of the centre activities.

Photo: Colourbox.com

# SCIENTIFIC ACTIVITIES AND RESULTS

Since the SFI formally started late 2020 actual results are so far limited. Fall 2020 was mainly used for planning and detailing of the research plans, in collaboration with our user partners and with focus on the research plans for 2021.

The following gives a brief overview of the Research Areas in terms of contributions to the centre objectives, main challenges to be met, research activities and then the specific activities for 2021. In addition to the activities below described, we have also initiated recruitment of PhD and master students.

# **RESEARCH AREA 1.**
# MULTI-SCALE MATERIAL ANALYSES

RESEARCH AREA LEADER:
**RANDI HOLMESTAD**
*NTNU*

CONTRIBUTIONS TO CENTRE OBJECTIVES

- Develop a world leading platform and corresponding methodologies for multiscale and multidimensional structure characterization and high-sensitivity chemical analysis of metals, alloys and advanced nanomaterials.
- Contribute to other RAs by providing detailed characterization information, revealing in-depth mechanisms, providing reliable experimental data, and validating through-process modelling.

MAIN CHALLENGES TO BE MET

- Develop correlative use of transmission electron microscopy (TEM) and atom probe tomography (APT).
- Develop and establish a framework for multiscale studies of material joints.
- Establish in-situ characterization techniques.

The research activities in this Research Area are organized into three main research tasks, listed below, together with their main objectives and initial activities as part of work plans for 2021.

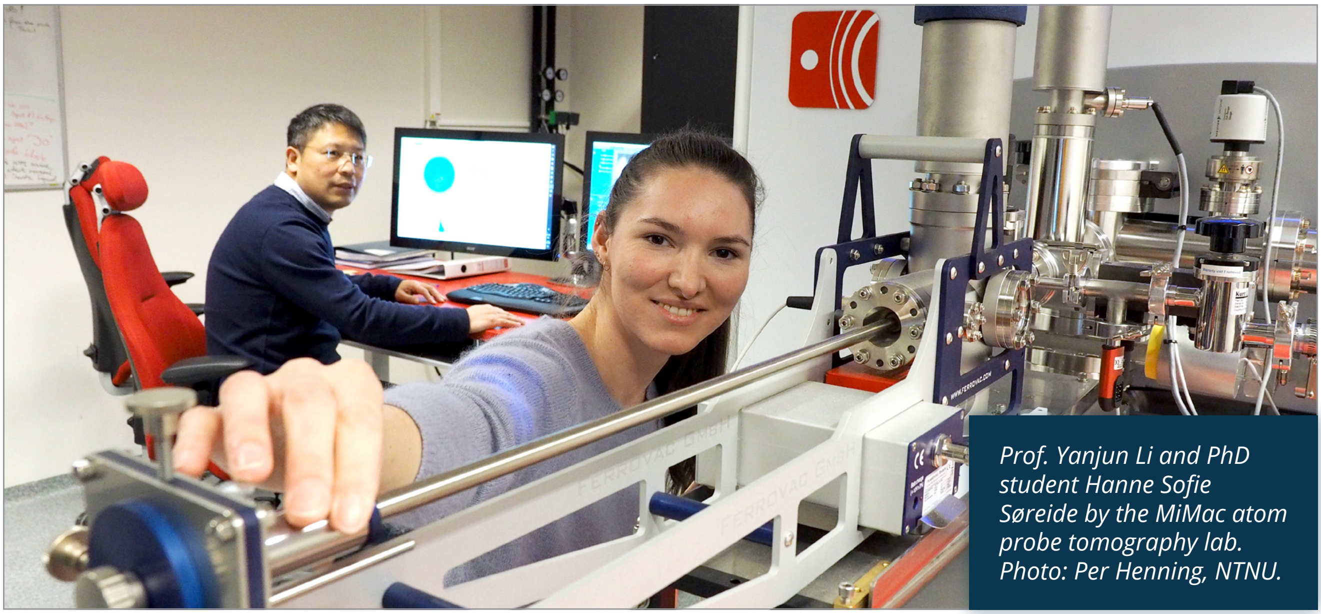
### TASK RA1.1A: CORRELATIVE TEM AND APT FOR STEELS *(PART OF WORK PLANS 2020-2021)*

State-of-the-art TEM and APT are complementary and provide experimental data on the crystal structure and chemistry down to the atomic scale - crucial for developing and validating atomic scale simulations and micro scale through-process models.

The objective is to build up competence on correlated APT and TEM, in particular on nanoscale characterization of steels/iron.
This will take place in collaboration with RA4 and industry and involve studies of the M-A phase, grain boundaries and different phases which are detrimental for the properties of this structural steels.

### TASK RA1.1B: CORRELATIVE TEM AND APT IN DENSE AL ALLOYS *(PART OF WORK PLANS 2020-2021)*

In this task correlative APT and TEM will be used to measure accurately the solute distribution across bulk (in-between needle precipitates) → precipitation free zones → grain boundaries as a function of thermomechanical treatment.



*Prof. Yanjun Li and PhD student Hanne Sofie Søreide by the MiMac atom probe tomography lab. Photo: Per Henning, NTNU.*


*PhD Jonas K. Sunde on the NORTEM transmission electron microscope at NTNU. Photo: Per Henning, NTNU.*

The results obtained here will relate to material behavior and will also be used in RA2 to further develop micro-structural models.

### TASK RA1.2: MULTISCALE STUDIES OF MATERIALS JOINTS *(PART OF WORK PLANS 2020-2021)*

The multiscale microstructure and complicated chemistry created when dissimilar materials (e.g. steel-Al) are joined together require use of the entire characterization toolbox.

A PhD student will be hired to continue the previous work in the TEM-group, Dept. of Physics connected to joining of steels and aluminium, - paired with PhD student in RA4.

### TASK RA1.3: ESTABLISH IN-SITU CHARACTERIZATION TECHNIQUES

Advanced in-situ characterization tools will be utilized to quantify the kinetics of micro-structure evolution during solidification, heat treatment and deformation, at several length and time scales.

# **RESEARCH AREA 2.**
# SCALE AND PROCESS BRIDGING METHODOLOGIES

RESEARCH AREA LEADER:
**YANJUN LI**
*NTNU*

CONTRIBUTIONS TO CENTRE OBJECTIVES

- Provide fundamental material data and understanding through high-throughput calculations and simulations from atomistic to micro-structure scale.
- Develop and validate specific models for alloy recycling, AM and innovative processing.
- Establish and validate multiscale and multi process modelling framework and AI methods, providing smart design and developing tools for innovative alloys and products.

MAIN CHALLENGES TO BE MET

- How to reach a deeper understanding on the mechanisms and kinetics behind the physical metallurgical phenomena down to atomic scales.
- How to realize computational engineering based smart design of alloys and products with tailored properties.
- How to realize digitalization and automatization of the production in physical metallurgical industry.

The research activities in this Research Area are organized into four main research tasks, listed below, together with their main objectives and initial activities as part of work plans for 2021.

### TASK RA2.1: ATOMIC SCALE CALCULATION AND SIMULATION *(PART OF WORK PLANS 2020-2021)*

First principles atomic scale calculations of materials will be carried out to achieve thermodynamic and kinetic material data for atom clusters, precipitates and intermetallic phases, including bonding energy, formation enthalpy, interfacial energy, segregation energy and diffusivity of impurities in relevant alloys (aluminium, steel, cast iron).

Initially, the influences of impurity elements on the formation of atom clusters, and on the diffusivity of major solute elements will be studied, using a Kinematic Monte Carlo (KMC) model recently developed at NTNU/SINTEF. The aim is further testing and improvements of the model for future simulations of atom clustering and age-hardening precipitates in 6xxx and 7xxx alloys.

Temperature Dependent Effective Potential (TDEP) method based on DFT calculations will be applied to calculate thermodynamic data for metastable precipitates as a function of temperature. The data will be used for precipitation models.

### TASK RA2.2: DEVELOPMENT AND FURTHER IMPROVEMENT OF MICROSTRUCTURE MODELS FOR RECYCLING-BASED ALLOYS, AM AND WELDING. *(PART OF WORK PLANS 2020-2021)*

The objective is to develop microstructure prediction models for solidification and heat treatments of recycling based aluminium alloys, cast iron, AM alloys and welding of dissimilar metals. The influences of impurity elements on the solidification path, defect formation and heat treatment response will be investigated.

For AM processing of alloys, the influence of high cooling rate and high temperature gradient on the nucleation and growth kinetics of grains, solute re-distribution and solubility, and formation of metastable phases will be included. For welding of dissimilar metals, a special focus will be put on the formation of intermetallic phases at bonding interfaces.

Initial focus will be on a grain size prediction model for AM and welding – In the model the influence of following parameters on grain size will be quantitatively addressed: Cooling rate, Temperature gradient; Size distribution and number density of inoculant particles.

A PhD work will be started in 2021 to further develop precipitation models for age hardening precipitates in aluminium alloys. Significantly improved models on the atom clustering kinetics, nucleation and growth of precipitates will be developed. The influences of impurity elements, vacancies, dislocations, and grain boundary precipitation/segregation will be addressed.

### TASK RA2.3: THROUGH-PROCESS MODELS UNDER REALISTIC INDUSTRIAL CONDITIONS

The objective is a generalization of existing microstructure evolution models for heat treatment, recrystallization and work hardening, which will be used as sub-models in finite element simulation software to simulate the transient conditions experienced during complex thermomechanical processes and predict the material performance and failure behavior and properties of products.

### TASK RA2.4: DEVELOPMENT OF AI METHODS FOR ALLOY DESIGN AND PROCESS PARAMETER OPTIMISATION.

The objective is the development of machine learning techniques for big data analysis of  alloy chemistry, process parameters, and mechanical properties to generate constitutive equations and quantitative correlations of chemistry-structure-process-properties of alloys with complex chemistry, processing steps and parameters. A combination of AI methods with through-process modelling tools will be implemented, applying for design and development of innovative new alloys for AM and recycling-friendly aluminium alloys with broader chemistry window and high concentration impurity elements.

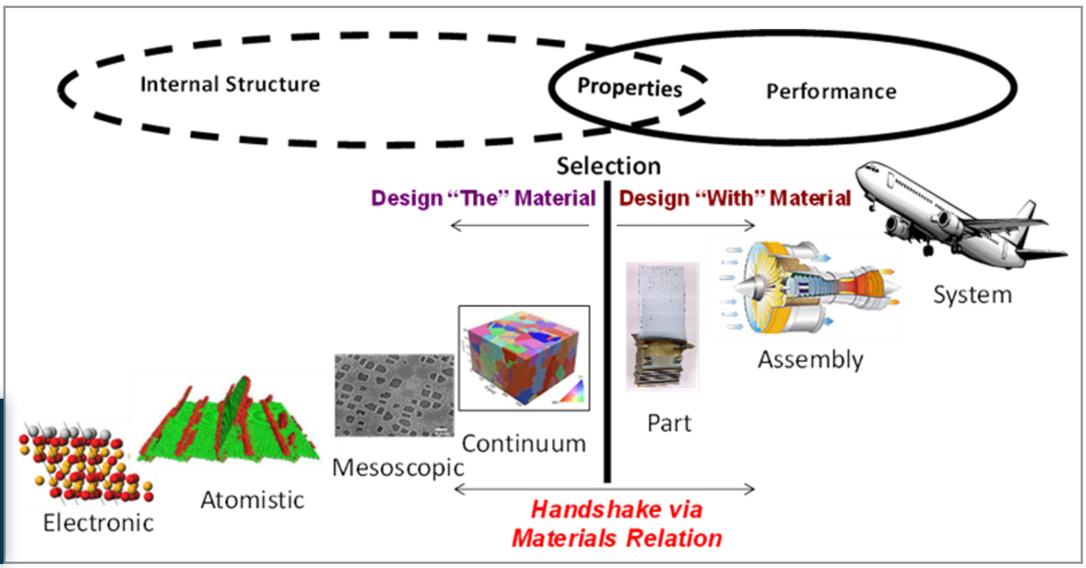



*Figure: Arnold et al., Integrating Materials 4 (2015) 37*

# **RESEARCH AREA 3.** SUSTAINABLE AND HIGH-PERFORMANCE MATERIAL DEVELOPMENT

RESEARCH AREA LEADER:
**MOHAMMED M'HAMDI**
*SINTEF*

CONTRIBUTIONS TO CENTRE OBJECTIVES

- The aim of RA3 is to establish fundamental knowledge and understanding of materials with recycled content and/or materials for new processes and applications (e.g. rapid solidification, additive manufacturing, and screw extrusion).
- To accelerate the design of new materials and alloys and/or industrial processes, relationships will be systematized using modelling tools in collaboration with other RAs combined with experimental work.

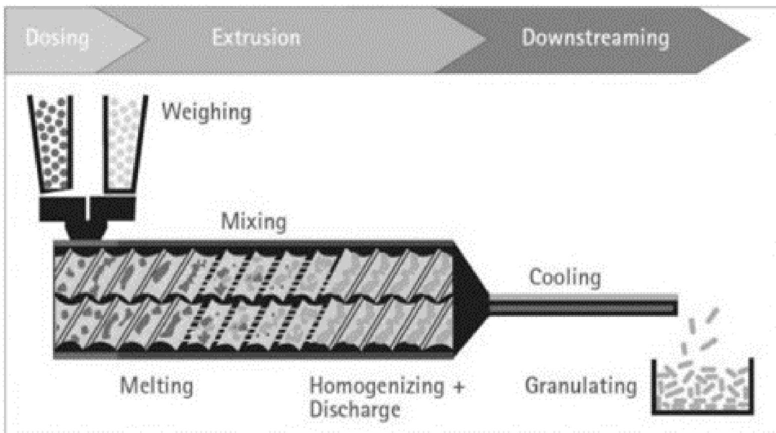
CHALLENGES TO BE MET:

- How to compensate for unwanted elements from recycled materials and develop robust/novel alloys.
- How to develop and tailor-make the microstructure of AM/rapid solidification materials.
- How to recover or improve material properties through post-processing.

The research activities in this Research Area are organized into four main research tasks, listed below, together with their main objectives and initial activities as part of work plans for 2021.

### TASK RA3.1: SOLID-STATE MIXING BY SCREW EXTRUSION *(PART OF WORK PLANS 2020-2021)*

Preparation of novel materials with superior properties by solid state mixing of granular solid feedstocks, for example metal scraps, strips produced




*Reddy et al, DARU Journal of Pharmaceutical Sciences Vol. 19 (2011) 365* by rapid solidification and powders of different materials by using a novel Screw extrusion (SE) process will be done. The mechanism for SE synthesis and the final structure and properties will be studied. Initial activities will involve:

- Collect information about of the process and the pilot
- Overview of capabilities and limitations of the present pilot for mixing of materials including recycled materials, silicon powder and fines.
- Initiate Master student project with NTNU.
- Presentation to industry for synergies and collaboration.

### TASK RA3.2: COMPENSATION METALLURGY AND ALLOY DESIGN *(PART OF WORK PLANS 2020-2021)*

Enable the development of materials with a higher recycled content by understanding of the relationships between alloy composition (with recycled content) and solidification, heat treatment and mechanical processing. A focus will be put on the influence of impurity elements on nucleation, growth and morphology of grains and intermetallic particles, precipitation behavior of secondary phases, grain boundary segregation and processability of the alloys, etc. Initial activities will involve:

- Material selection for demonstration and material formulation with recycled content, and elements and composition window.
- Methodology for material formulation, preparation, and experimental program.
- Characterization of resulting microstructure from experimental program.
- Design for a mathematical framework for alloy formulation, consequences and processability.

### TASK RA3.3: POWDER MATERIALS AND RAPID SOLIDIFICATION *(PART OF WORK PLANS 2020-2021)*

Develop powder-based materials with improved properties based on rapid solidification technology. Expanding the range of AM materials is targeted by tailoring the microstructure through-process control (solidification conditions), mixing powders with inoculants (to favor equiaxed instead of columnar structures) and additives (e.g. nanoparticles for improved properties), and mixtures of elemental powders. Initial activities will involve:

- Material selection for aluminium and iron-based cases.
- Methodology establishment including material preparation, alloying and preparation.
- Fast screening, printing, and characterization of resulting microstructures (e.g. with NP).
- Production of silicon-based powder material (chosen from IFE library), suitable to the SFI needs.
- Initiate activities on modelling framework including process and microstructure formation. Availability of thermodynamic and mobility databases for selected materials (e.g. fully austenitic steel).

### TASK RA3.4: TAILORED PROPERTIES THROUGH POST-PROCESSING

Microstructure tailoring during heat treatments of Al (e.g. AM and rapid solidification or with recycled content) products to compensate for unwanted detrimental secondary phases and precipitates (e.g. Fe containing phases due to recycled content) and to promote desired phase transformations (in steels) is the target of this activity.

# **RESEARCH AREA 4.**
# INNOVATIVE PROCESSING AND JOINING METHODS

RESEARCH AREA LEADER:
**ODD MAGNE AKSELSEN**
*SINTEF*

CONTRIBUTIONS TO CENTRE OBJECTIVES

- Develop knowledge basis for new wires for welding of aluminium alloys, using nanoparticles for grain refinement and particle strengthening
- Develop laser beam/laser-arc hybrid welding of dissimilar metals (e.g., Al- Fe, Al-Ti, Al-Cu)
- Develop laser-arc hybrid welding for heavy steel (process-microstructures-properties)
- Develop AM and cladding laser assisted processes

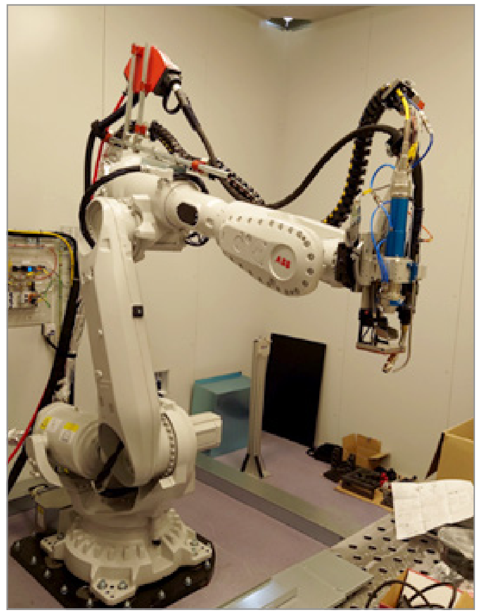
CHALLENGES TO BE MET

- Steel welding: Welding of heavy steel is challenging with laser-arc hybrid welding. Double-sided welding may induce problems with key-hole stability.
- Aluminium welding: Strength loss in soft parts of the heat affected zone (HAZ) represents a major challenge in aluminium welding. Both HAZ and weld metal will be addressed through adjustments of the welding process and the addition of nanoparticles, respectively.  For additive manufacturing (AM) of aluminium alloys there is an urgent need for new wires and powders for direct energy deposition (DED).
- Cladding: Silicides may have excellent corrosion and wear resistance but have very limited applications so far. Tungsten carbides deposited by thermal spraying has dominated this business. More knowledge is needed on silicides as coating and actual coating processes will be important.

The research activities in this Research Area are organized into four main research tasks, listed below, together with their main objectives and initial activities as part of work plans for 2021.

### TASK RA4.1: NEW WIRES FOR WELDING OF ALUMINIUM ALLOYS *(PART OF WORK PLANS 2020-2021)*

The overall objective is to develop knowledge basis for new wires for aluminium welding and direct energy deposition that prevents cracking problems and results in enhanced weld metal strength. The target application will be in welding and AM for aluminium structures such as buildings, bridges, telescopes, gangways, etc.

## TASK RA4.2: LASER WELDING OF ALUMINIUM ALLOYS AND DISSIMILAR METALS (AL- FE, AL-TI, AL-CU)

Here, laser welding will be used to weld AA6082 to various steels and Ti alloys.  A special focus will be put on the process optimization to increase the wetting between aluminium melt and the joining metals and reduce the thickness of intermetallic layers forming at the interface.

## TASK RA4.3: LASER-ARC HYBRID WELDING OF HEAVY STEEL *(PART OF WORK PLANS 2020-2021)*

Laser-arc hybrid welding technology will be applied for welding of heavy structures (>15-20 mm thickness), which is the typical case in the oil and gas industry and now very relevant for offshore windmills. Both the solidification behaviour and structure of the weld and the microstructure evolution and phase transformation of the heat affected zone will be systematically studied. The welding process parameters will be optimised to achieve optimum mechanical properties, especially for applications at temperatures at -40°C and even below.

## TASK RA4.4 LASER CLADDING

The laser source will also be applied for studies of cladding to metals to provide functional properties like corrosion and wear resistance, e.g., by using silicides in steel clad. This task will connect with Task 3.3 and Task 1.2.

## TASK RA4.5 AM BY DIRECT ENERGY DEPOSITION (DED)

DED is one of the many additive manufacturing (AM) methods, using laser or arc as heating methods. In this project, high strength aluminium wires synthesized by the screw extrusion method will be used as the feeding stock for the DED based AM process. It is expected that aluminium components with superior structure and properties will be achieved. Systematic process optimization, microstructure studies by advanced characterization techniques and mechanical testing will be conducted.

# **RESEARCH AREA 5.**
# DATA, SHARING AND DIGITAL PLATFORMS

RESEARCH AREA LEADER:
**JESPER FRIIS**
*SINTEF*

CONTRIBUTIONS TO CENTRE OBJECTIVES
- Make research results (data and models) accessible and easy to combine and reuse
- Enabling both industry and research partners to make efficiently use of the project results promoting rapid innovation

CHALLENGES TO BE MET
- How to formulate an ontology for physical metallurgy that covers all relevant quantities and at the same time is easy to learn and use?
- How to realize the FAIR data principles? The main strategy here, is to reuse experience and state-of-art technology developed in collaborative European efforts.
- How to exploit the platform for increased quality and productivity in research and industrial innovation? Important steps when addressing this are involvement of all stakeholders from the beginning and early demonstrations.

The research activities in this Research Area are organized into three main research tasks, listed below, together with their main objectives and initial activities as part of work plans for 2021.

### TASK 5.1: PLATFORM DESIGN *(PART OF WORK PLANS 2020-2021)*

This task will start by collecting a set of user stories from all partners on requirements and how they expect/wish to use the PhysMet Digital Platform. An important part of this task is to create a domain ontology for metals and alloys, focusing on the needs for RA1-RA4. Close collaboration with international collaboration partners, like ACCESS, AC2C, EMMC core team and other leading actors will ensure that this ontology will be part of a widely adopted standard for metals and alloys. Initial activities involve:
- Establish an international standard for physical metallurgy enabling easier integration of characterization, data analysis and physics-based microstructure modelling covering the needs by RA1-RA4.
- Collect user stories and requirements for the PhysMet Digital Platform based on input from all actors in the centre.
- Architecture design of the PhysMet Digital Platform based on the user stories.
- Provide input to the Data Management Plan.
- Overview and coordination with related projects working with potential synergies for shared digital infrastructure.

Activities so far:

- Provided input to the data management plan.
- Planned collection of user stories and requirements.
- Organised a set of dedicated meetings to discuss user stories, wishes and requirements with individual industry partners.
- Started the development of a microstructure domain ontology.
- Established an EMMC task group lead by representatives for the SFI, for further development of the microstructure domain ontology in collaboration with key international collaboration partners.

### TASK 5.2: PLATFORM IMPLEMENTATION
*(PART OF WORK PLANS 2020-2021)*

The platform will be implemented using core technology from MarketPlace and tailored to the user needs expressed in task 5.1. It will combine existing and new components: i) database management and associated search and visualization tools, ii) interoperability modules to apply seamlessly various numerical models, iii) secured and user-friendly web interface. Initial activities involve:

- Set up and maintain shared collaboration tools and infrastructure
- Implementation of a PhysMet Digital Platform realizing the FAIR data principles and enabling rapid innovation
- Provide a system for setting up workflows for data analysis, through scale/process modelling

Activities so far:

- Evaluated different alternatives for code sharing and hosting services. Summarised in a short report.
- Code repositories on https://gitlab.com/sfi-physmet with continuous integration services have been set up.

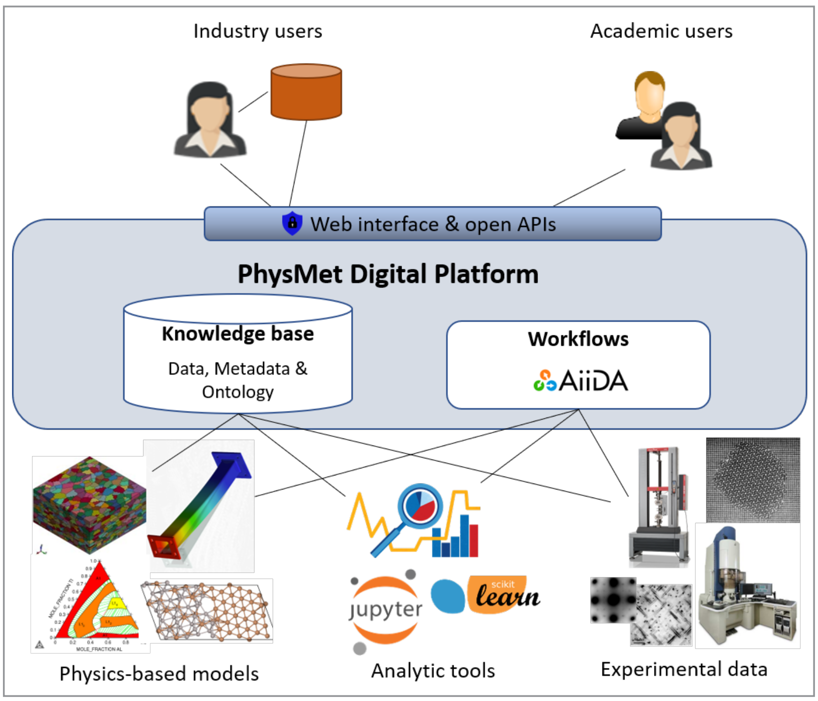
### TASK 5.3: PLATFORM EXPLOITATION
*(PART OF WORK PLANS 2020-2021)*

This task will focus on exploiting both the data and available models to produce new analysis and support innovation. This task will involve workflow demonstrators, development of application specific interfaces for data analysis, as well as training and frequent user meetings to encourage the active use of the platform in all RAs. Initial activities involve:

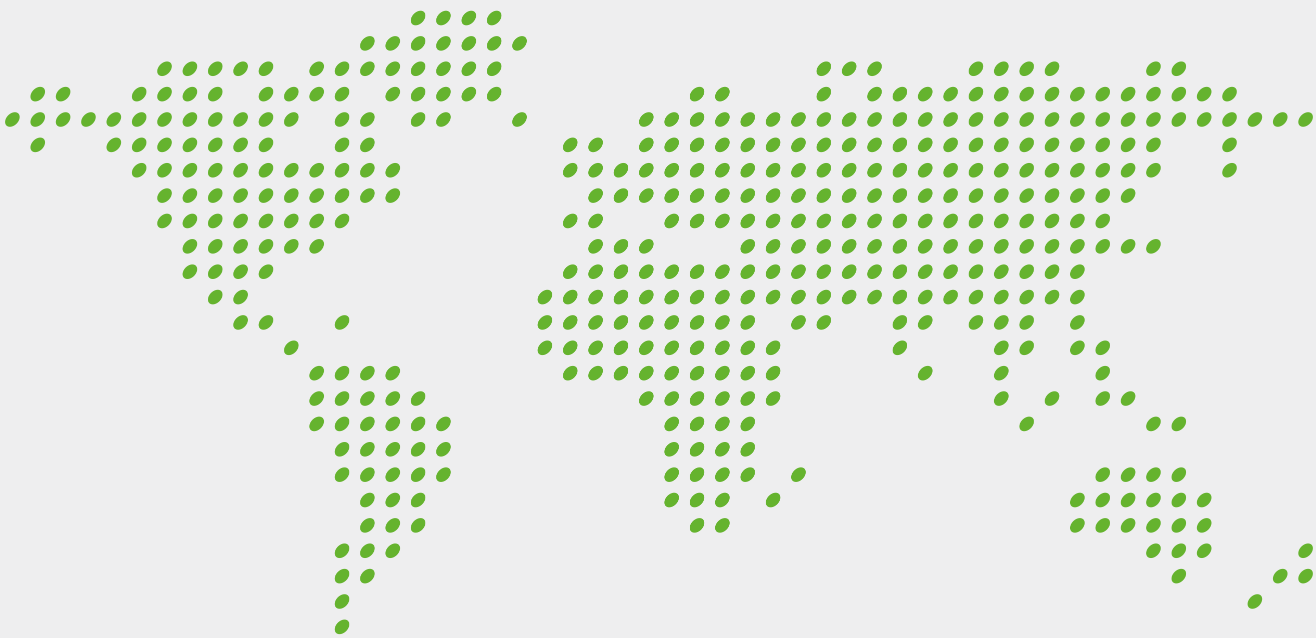
- Promote use of the Digital Platform to strengthen the metallurgy environment in Norway.
- Gather and communicate expected usage and requirements of the platform.
- Share and collect best practices for data sharing and digital corporation and provide training in how to use the tools and services developed in the RA.
- Provide "success stories" demonstrating the platform.

Activities so far:

- Organised a workshop in December 2020 about git and use of GitLab.
- Started to implement a demo showing how the platform can be used to connect experimental data from EBSD and X-ray, with different data analysis and modelling tools.



# INTERNATIONAL COLLABORATION



OUR AIM
The areas covered by SFI PhysMet are internationally competitive, with strong international industrial- and academic actors. Access to cutting-edge knowledge, facilities and networks through collaboration with key organisations abroad, is therefore essential for further competitiveness and value creation in Norway.

We aim at enhancing the centre impact through activities with funding from the Horizon Europe program, and peripheral funding schemes, e.g., ERA-NETs. NTNU, SINTEF and some user partners in the centre have long experience in initiating and running EU framework programme projects. Our ambition is to increase the involvement in European stakeholder organisations such as SPIRE, EMIRI and EMMC to promote research topics covered by the centre.

INTERNATIONAL COLLABORATORS AND ACTIVITIES ALREADY STARTED

## INTERNATIONAL SFI PARTNER

The SFI partner Thermo-Calc Software is world-leading on computational thermodynamics. Their expertise will be essential for effective integration of highly accurate thermodynamics data into industrially modelling workflows. They have special interest in the work on software interoperability and linkage to various simulation platforms and machine learning. They will provide licenses for software and databases to NTNU/SINTEF and provide 2 training courses on the use of their products to all partners. Thermo-Calc will mainly contribute in Research area 2 and 5.

## SAC-MEMBERS

The centre has an international Scientific Advisory Committee (SAC) with three members of high scientific standing:

- Professor Dierk Raabe, Max Planck Institute for Iron Research, Düsseldorf, Germany
- Professor Aude Simar, UC Lovain, Belgium
- Professor Dorthe Juul Jensen, DTU, Denmark

We are looking forward to the collaboration with the SAC. Spring 2021 they are invited to give guest lectures at the webinar series starting from March.

## INTERNATIONAL CONFERENCES

The researchers in SFI PhysMet normally participate in broad range of international conferences and workshops during a year. 2020 was a special year where very many conferences were postponed or cancelled due to the COVID-19 pandemic. However, some conferences were turned in to virtual conferences, which also will be the normal for many conferences in 2021.

The 17th International Conference on Aluminum Alloys ICAA17, initially scheduled to take place in Grenoble on June 14-18, 2020 and then postponed to October 26-29, 2020, finally took place in virtual conference mode. Out of ~400 participants 22 came from Norway (NTNU, SINTEF, Norwegian light metals industry), most of them somehow connected to SFI PhysMet.

## INTERNATIONAL COLLOBARATION

An EMMC task group lead by representatives from the SFI has been established, for further development of the microstructure domain ontology in collaboration with key international collaboration partners, like ACCESS (Germany), AT2T (Austria) and ANSYS/Granta (UK). This is an important step to ensure impact and that the ontology we develop will be an upcoming standard within physical metallurgy and metallic microstructures.

SFI PhysMet and RA5 will be presented at the EMMC International Workshop, March 2-4, 2021.

## INTPART-PROJECTS

**International Materials Science and Engineering education and research network (IntMat)** (2020-2024: Project leader Assoc. Prof. Ida Westermann)

Partners: NTNU, Massachusetts Institute of Technology (MIT), Shanghai Jiao Tong University, Jilin University, Chongqing University and Nanjing University of Science and Technology, The Jiangsu Industrial Technology Research Institute and the Research centre at the Aluminum Corporate of China.

**Norwegian-Japanese Aluminium alloy Research and Education Collaboration - Phase-2** (2019-2023; Project leader Prof. Randi Holmestad)

Partners: NTNU, SINTEF, Hydro, University of Toyama, Tokyo Institute of Technology, Kyushu University, Japanese Aluminium Association, and Toyama Aluminium

In addition, SFI PhysMet is co-applicant for a new project **Advanced Manufacturing process control – collaboration on research and higher education between Norway, USA and Canada (AM-PRO)**. (Project leader Prof. Geir Ringen, Department of Mechanical and Industrial Engineering, NTNU)

Partners: University of Southern California (USC), University of Florida (UF), University of British Columbia (UBC), Michigan Technological University (MT) and Texas A&M (TAMU).

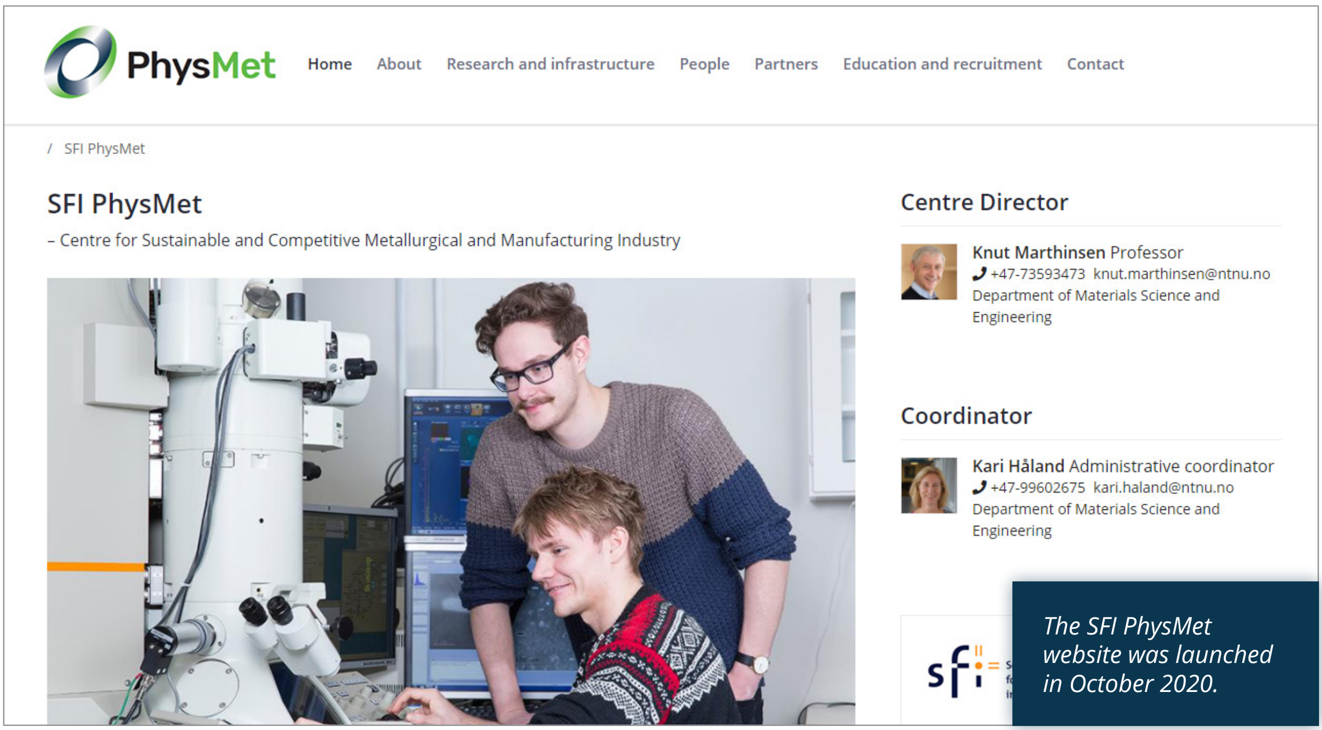
## PHD EXCHANGE AND GUEST LECTURES

The PhD projects in the centre will include plans for shorter or longer stays at selected research organisations abroad. Furthermore, guest researchers will be included in the research education at NTNU, through guest lectures on specific topics.

# COMMUNICATION AND DISSEMINATION ACTIVITIES

The overall communication aim of SFI PhysMet is to inform and engage relevant target groups and ensure that inputs from stakeholders at all levels can influence and improve the results and impact of the centre. Relevant stakeholders are the centre partners, students and researchers, other industry sectors, the general public, international research communities etc. Scientists have a responsibility to build bridges between science, industry and society, and to transfer the new knowledge to potential user groups and society as a whole. Our aim is that results from SFI PhysMet shall be visible and implemented at internal and external/public arenas in the years to come.

An important arena to reach out to the public and making information on the centre easily available is **the centre website** www.ntnu.edu/physmet/ which will be further developed in 2021.




*The SFI PhysMet website was launched in October 2020.*

The centre got media attention when receiving the SFI funding from RCN in June and from the official kick-off of the centre, January 12th 2021:


Dekan gratulerte med det nye senteret for forskningsdrevet Innovasjon (SFI) SFI PhysMet

Fakultet for naturvitenskap 23.06.2020 Av Pernille Feilberg

I dag ble det holdt en enkel markering av at fakultetet får et nytt Senter for Forskningsdrevet Innovasjon: SFI PhysMet. Senteret skal ledes fra faggruppen for Fysikalsk metallurgi på Institutt for materialteknologi.


UA UNIVERSITETSAVISA.NO

Korona Ytring Politikk Student

Tips oss tips@universitetsavisa.no

Nytt senter ved NTNU:

Norsk metallindustri skal få hjelp til å bli mer bærekraftig

Et nytt senter for forskningsdrevet innovasjon ble åpnet i dag, tirsdag - og har fått navnet SFI PhysMet.

*Article about the centre opening in Universitetsavisa January 2021.*


NTNU TekNat - En blogg om teknologi, naturvitenskap, forskning og undervisning ved NTNU

Metallurgi for fremtiden og det grønne skiftet

by Kari Håland 14. januar 2021 MATERIALTEKNOLOGI



## INTERNAL MEETINGS AND COMMUNICATION ACTIVITIES

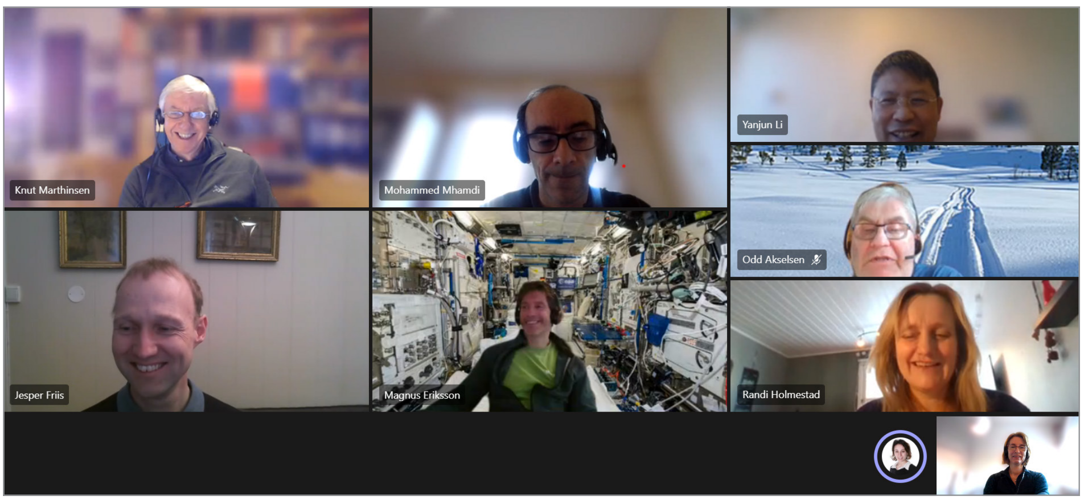
An important task when organizing a new centre is to establish effective and practical routines for meetings, information sharing and internal communication in general.

**The management group** has weekly meetings to discuss progress and coordinate centre activities. Due to the corona virus situation most of the meetings in 2020 have been digital on TEAMS.

**From 2021 we will establish a meeting structure that involves all members of the centre:**
The leaders of the five Research areas (RA) are responsible for the involvement of all relevant partners in the planning and implementation of the various RA activities. In order to involve all partners, we will organize **quarterly meetings on an RA-level.** The RA-leaders organize these meetings and the main focus on the agenda for the first meetings will be: Implementation of the projects described in the annual work plan for 2021, recruitment of PhD candidates and planning of summerjobs/student projects for bachelor- and masterstudents.

**Bi-annual SFI meetings for all partners**: The purpose of these meetings will be to exchange information on major results as well as presenting overall thoughts and strategies vital to the centre progress.

In addition, we want to establish an arena for sharing of information on results, plans and inspiration (for instance guest lectures) between the set meeting points. In March 2021 we will start **monthly webinar series.** The webinar schedule and the topics will be announced to all SFI PhysMet members. Digital meetings are easily available to participants from the industry and research institutions outside Trondheim, and the webinar format enables rapid dissemination to all partners.



# PERSONELL SFI PHYSMET

## CENTRE ADMINISTRATION

| | | |
|---|---|---|
| Knut Marthinsen | NTNU | Centre Director |
| Marisa Di Sabatino | NTNU | Deputy Centre Director |
| Magnus Eriksson | SINTEF Industry | Scientific coordinator |
| Kari Håland | NTNU | Administrative coordinator |

## KEY RESEARCHERS

### RESEARCH AREA 1. MULTI-SCALE MATERIAL ANALYSES

| | | |
|---|---|---|
| **Randi Holmestad** | NTNU | Multi-scale material analyses |
| Ida Westermann | NTNU | Thermo-mechanical processing, microstructure and mechanical properties (steel and aluminium) |
| Sigrud Wenner | SINTEF Industry | Nano-/microstructure characterization (TEM and APT) |
| Ruben Bjørge | SINTEF Industry | Multi-scale material analyses |
| Marisa Di Sabatino | NTNU | Material-processing and characterization (GDMS and GDOES) |
| Calin D. Mariora | SINTEF Industry | Nano-/microstructure characterization (TEM and APT) |
| Yanjun Li | NTNU | Scale and process bridging methodologies |
| Siri Marthe Aarbo | SINTEF Manufacturing | Materials, processing and properties |

## RESEARCH AREA 2. SCALE AND PROCESS BRIDGING METHODOLOGIES

| | | |
|---|---|---|
| **Yanjun Li** | NTNU | Scale and process bridging methodologies |
| Bjørn Holmedal | NTNU | Crystal Plasticity, microstructure- and property modelling |
| Knut Marthinsen | NTNU | Microstructure-, texture and property modelling |
| Tomas Manik | NTNU | Crystal plasticity modelling |
| Inga Ringdalen | SINTEF Industry | Atomic scale modelling |
| Jesper Friis | SINTEF Industry | Data, sharing and digital platforms |
| Sylvain Gouttebroze | SINTEF Industry | Materials modelling |
| Qiang Du | SINTEF Industry | Thermodynamical and microstructure and |
| Mohammed M'hamdi | SINTEF Industry | Sustainable and high-performance material development |
| Stephane Dumoulin | SINTEF Industry | Materials modelling |
| Ole Martin Løvvik | SINTEF Industry | Atomic scale modelling |
| Yijang Xu | SINTEF Industry | Materials modelling |

## RESEARCH AREA 3. SUSTAINABLE AND HIGH-PERFORMANCE MATERIAL DEVELOPMENT

| | | |
|---|---|---|
| **Mohammed M'Hamdi** | SINTEF Industry | Sustainable and high-performance material development |
| Marisa Di Sabatino | NTNU | Material-processing, properties and characterization |
| Yanjun Li | NTNU | Scale and process bridging methodologies |
| Hans Jorgen Roven | NTNU | Thermo-mechanical processing, microstructure and mechanical properties (steel and aluminium) |
| Hanne Flåten Andersen | IFE | Powder synthesis and characterization |
| Mohammed M'Hamdi | SINTEF Industry | Sustainable and high-performance material development |
| Morten Onsøien | SINTEF Industry | Thermomechanical processing |
| Kjerstin Ellingsen | SINTEF Industry | Sustainable and high-performance material development |
| Qiang Du | SINTEF Industry | Thermomechanical processing |
| Sylvain Gouttebroze | SINTEF Industry | Sustainable and high-performance material development |
| Amin Azar | SINTEF Industry | Sustainable and high-performance material development |
| Kai Zhang | SINTEF Industry | Sustainable and high-performance material development |
| Astrid Mathinsen | SINTEF Industry | Sustainable and high-performance material development |

## RESEARCH AREA 4. WELDING AND WELDABILITY OF METALS, PHASE TRANSFORMATIONS AND MECHANICAL PROPERTIES

| | | |
|---|---|---|
| **Odd Magne Akselsen** | SINTEF Industry | Welding and weldability of metals, phase transformations and mechanical properties |
| Ivan Bunaziv | SINTEF Industry | Laser materials processing; process study and stability, microstructure and properties |
| Sigurd Wenner | SINTEF Industry | Nano-/microstructure characterization (TEM and APT) |
| Magnus Eriksson | SINTEF Industry | Thermo-mechanical processing and welding |
| Hans Jørgen Roven | NTNU | Alloy-design and process developments (screw extsruion, AM) |
| Anette B. Hagen | SINTEF Industry | Thermo-mechanical processing and welding |
| Ida Westermann | NTNU | Thermo-mechanical processing, microstructure and mechanical properties (steel and aluminium) |
| Siri Marthe Aarbo | SINTEF Manufacturing | Materials, processing and properties |
| Xiaobo Ren | SINTEF Industry | Materials, processing and properties |
| Bård Nyhus | SINTEF Industry | Materials, processing and properties |
| Ruben Bjørge | SINTEF Industry | Nano-/microstructure characterization (TEM and APT) |
| Ragnhild Aune | SINTEF Industry | Materials, processing and properties |

## RESEARCH AREA 5. DATA, SHARING AND DIGITAL PLATFORMS

| | | |
|---|---|---|
| **Jesper Friis** | SINTEF Industry | Data, sharing and digital platforms |
| Sylvain Gouttebroze | SINTEF Industry | Materials modelling |
| Thomas Manik | NTNU | Crystal plasticity modelling |
| Inga Ringdalen | SINTEF Industry | Atomic scale modelling |
| Terence Coudert | SINTEF Industry | Materials modelling |
| Stephane Dumoulin | SINTEF Industry | Materials modelling |

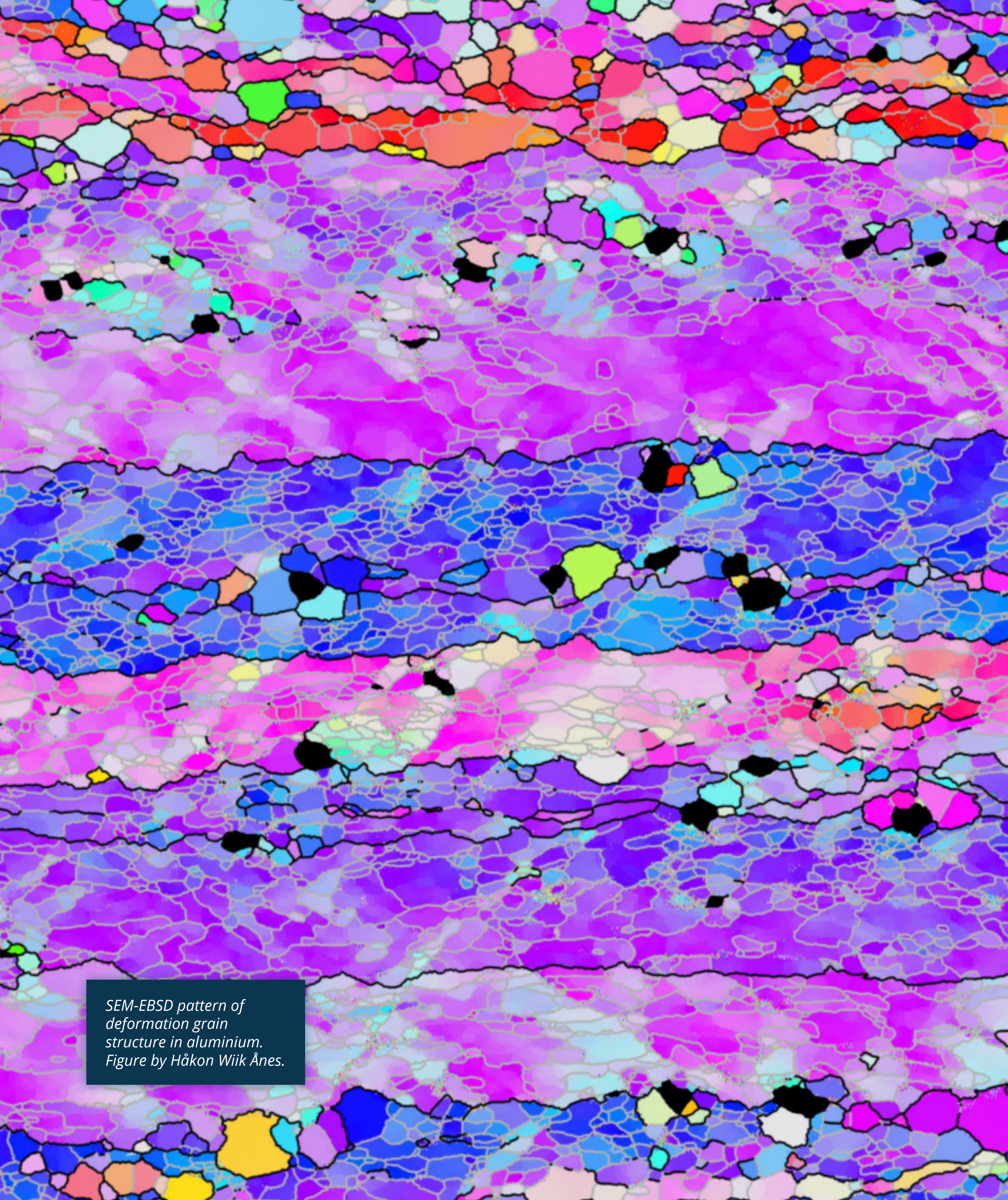
# ANNUAL ACCOUNTS 2020

The total budget for the eight year SFI PhysMet centre periode is 208 mill NOK. The financing of SFI PhysMet are based on contribution from The Research Council of Norway and cash and in-kind contribution from the user partners and NTNU.

| Funding (1000 NOK) | Amount |
|---|---|
| Research Council | 485 |
| Host Institution (NTNU) | 296 |
| Research Partners* | 0 |
| User Partners** | 1 777 |
| **Total** | **2 558** |

| Costs (1000 NOK) | Amount |
|---|---|
| Host Institution (NTNU) | 631 |
| Research Partners* | 875 |
| User Partners** | 1 052 |
| Equipment | 0 |
| **Total** | **2 558** |

* *SINTEF AS, SINTEF Manufacturing and IFE.*
** *Hydro Aluminium AS, Elkem AS, Equinor, Benteler, Neuman Aluminium, Thermo-Calc Software, The Norwegian Public Roads Administration.*



*SEM-EBSD pattern of deformation grain structure in aluminium. Figure by Håkon Wiik Ånes.*

PhysMet

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Statens vegvesen