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Materialer for fremtiden fremmer norsk industri

ABSTRACTS

Scrap-containing AA8xxx Alloys for Multilayer Pipe Applications

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AA8xxx-series aluminum alloys are widely used in multilayer pipe applications due to their favorable combination of formability, pressure resistance, and ability to act as an effective diffusion barrier. For these applications, the alloys are adhesively bonded to polyethylene layers, requiring stringent control of surface cleanliness to prevent the presence of organic contaminants.

The present study investigated the feasibility of incorporating up to 50% external scrap into an AA8006 alloy while maintaining chemical and performance requirements. Various scrap types were combined to achieve the target composition, with the remaining 50% consisting of primary metal, internal scrap, and alloying additions. Following conventional DC casting, rolling ingots were pre-heated at 560 °C for 12 h to reduce segregation, promote spheroidization of intermetallic constituents, and enable formation of fine dispersoids. The material was hot-rolled to 4.5 mm, cooled, and subsequently cold-rolled to a final thickness of 0.6 mm. After hot AC electrical degreasing to remove rolling residues, the alloy was annealed to achieve a fully recrystallized, soft condition (O temper).

Experimental evaluation demonstrated that the mechanical properties, microstructural characteristics, and, especially, surface quality of the scrap-containing alloys were comparable to those produced exclusively from primary ingots, confirming that high-scrap input for this application is possible.

Thermoelectrics Need Metallurgy: Lessons from tetrahedrites

Catarina Quitério, Kalpna Rajput, Konstantina Iordanidou, Vetle Øversjøen, Salah Amedi, Daniel Marchand, Ana Sá, Paulo Luz, Felipe Neves, Patricia Almeida Carvalho

Tetrahedrites are promising thermoelectric materials owing to their intrinsically low lattice thermal conductivity and earth-abundant composition. However, reported performance varies widely across the literature, and the origins of this dispersion remain unclear, hindering the development of a quantitative optimisation framework. The present work shows that this variability is largely governed by processing-related factors rather than dopant chemistry. A comprehensive meta-analysis of tetrahedrite transport properties is carried out by aggregating a literature-scale dataset of more than 6,000 datapoints from 58 independent studies on tetrahedrites synthesised by mechanochemical processing and plasma-assisted sintering. The data-driven approach is integrated with targeted experimental synthesis of samples and density functional theory calculations. Statistical analysis, after normalising for the intrinsic temperature dependence of the thermoelectric figure of merit *zT,* reveals that dopant identity has only a limited effect on performance. Instead, thermoelectric performance is largely affected by processing-related factors, particularly consolidation quality and microstructural porosity associated with gas evolution during sintering, which mask intrinsic transport behaviour and dopant-specific effects. The findings reconcile the broad discrepancies in reported performance and indicate that improved processing control, rather than further compositional tuning, is currently the dominant lever for enhancing *zT.* This shifts the optimisation paradigm for tetrahedrites and highlights the importance of stricter metallurgical fabrication methods and reporting standards to enable rigorous benchmarking and accelerate the development of high-performance thermoelectric materials.

Zeiss Gemini SEM: an automated in situ testing solution

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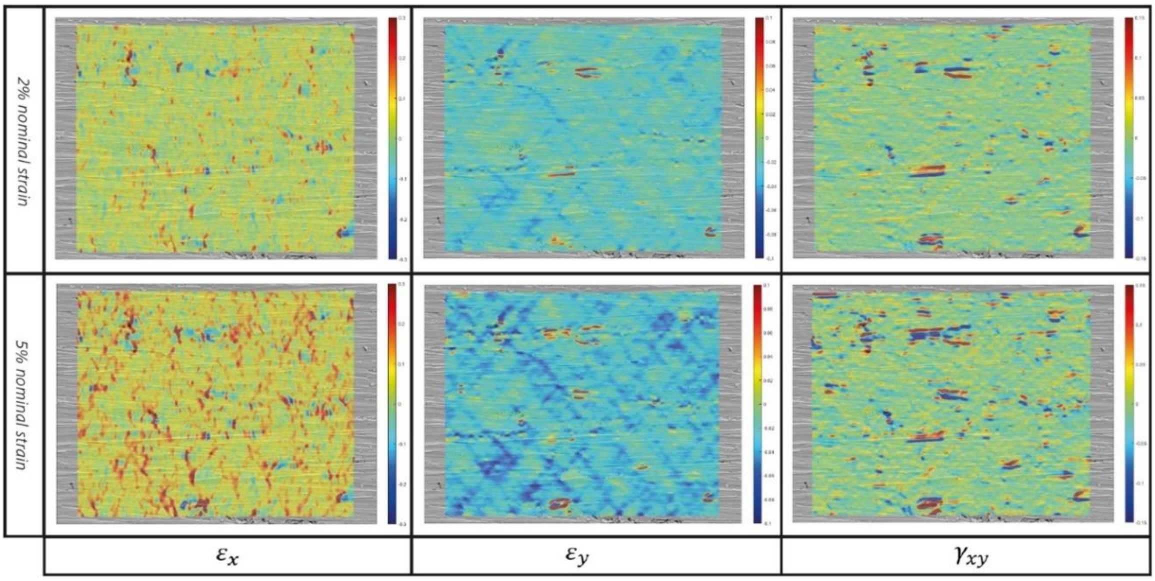
The new Gemini SEM design raises the bar for surface sensitive, distortion-free- and high-resolution imaging. The introduction of a new electron optical Gemini enables magnetic field-free imaging in materials and life science samples with sub 1 kV resolution below 1 nm without the need for sample biasing or monochromator. A completely new variable pressure mode and detection system provide superb images of non-conducting and vacuum sensitive samples.

In-situ materials testing in a SEM is an emerging trend among SEM applications, since it is a powerful method to design new material properties at nano and microstructures level and validate their mechanical behavior like grain misorientations through EBSD, defect formation and grain boundary migration caused by mechanical loading and subsequent tempering. Such in-situ materials testing approaches deliver experimental datasets for the validation and the improvement of computational materials models.

In this talk, a tailored in-situ automated workflows solution will be presented. The automated workflow can generate meaningful data with utmost reproducibility and precision. Further advancements such as automated feature tracking, autofocus and multiple regions of interest (ROIs) help to realize true one-button-start workflows and experiments. Results such as grain boundary transition or grain deformation imaged using backscattered electron detection (BSD) at high temperatures will be demonstrated.



Local strain distributions of the metal surface are analysed at different elongations during in-situ tensile testing. These results are visualised using digital image correlation (DIC).

SFI FAST: Kunnskap og teknologi for neste generasjons innovative aluminiumsprodukter

Ellingsen, Kjersti

SFI FAST er et forskningssenter ledet av Institutt for maskinteknikk og produksjon ved NTNU, i samarbeid med fire NTNU-institutter og fire forskningsavdelinger i SINTEF Industri. Sammen med 16 industripartnere utgjør senteret en sterk, tverrfaglig plattform for forskning og innovasjon.

Senterets mål er å utvikle kunnskap og teknologi som muliggjør bruk av opptil 100 % resirkulert aluminium i avanserte produkter og lastbærende konstruksjoner uten å kompromittere mekaniske egenskaper, holdbarhet eller sikkerhet. Aluminium kan resirkuleres i det uendelige og resirkulering krever kun rundt fem prosent av energiforbruket sammenlignet med primærproduksjon, men likevel fører dagens praksis ofte til nedgradering av materialkvalitet. FAST adresserer denne utfordringen gjennom utvikling av løsninger som forhindrer nedgradering (downcycling) og gjør resirkulert aluminium til et konkurransedyktig og klimavennlig alternativ for krevende anvendelser, som bilkomponenter, kraftoverføringslinjer og bruer.

Optimal design and additive manufacturing of polymeric and metallic mechanical metamaterials

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Metamaterials are architected materials with tunable mechanical properties, which makes them suitable for demanding engineering applications. This work addresses two classes of mechanical metamaterials: polymeric materials for energy absorption and impact mitigation, and metallic materials for battery casing. In both cases, the design is formulated as an optimization problem where the objective function represents the desired macroscopic response and the design variables define the internal topology of the metamaterial, subject to stress, geometric, and manufacturability constraints.

For polymeric metamaterials, two advanced concepts for impact mitigation were taken as references: the origami honeycombs of Townsend et al. (Materials & Design, 2020) and the plate-lattice metamaterials of Smith et al. (Advanced Materials Technologies, 2024). These architectures were unified into a single parametrized design. The objective was to maximize absorbed energy while limiting peak stress. The objective function was evaluated through post-processing of Abaqus results for compression tests on automatically generated designs. Selected samples were fabricated by fused filament fabrication using TPU and tested to validate the numerical predictions. An evolutionary optimization algorithm was employed, restricted to a small number of evaluations due to high Abaqus licensing costs. The results highlight the role of buckling in reducing initial peak stress and of contact interactions in enhancing post-peak energy absorption.

For the metallic metamaterial, inspired by the truss-based battery casing proposed by Huang et al. (Acta Mechanica Solida Sinica, 2021), optimization targeted either minimal deformation of the central battery cavity or minimal compliance. The design variables were the truss cross-sections, and optimization used the method of moving asymptotes. The whole computational framework was implemented in the free Octave package. Structures were fabricated by laser powder bed fusion using AlSi10Mg powder. Compression tests revealed brittle behaviour unsuitable for battery-casing applications, although the optimized structures achieved very low compliance, indicating potential as lightweight, high-stiffness materials.

Fra skrap til verdi: Hydros vei mot mer resirkulert aluminium

Gjedrem, Evy

Aluminium spiller en sentral rolle i den grønne omstillingen. Materialet kombinerer lav vekt, høy styrke og uendelig resirkulerbarhet, og brukes i alt fra elektriske kjøretøy og bygninger til folie og drikkebokser. Samtidig som det globale behovet for aluminium vokser, øker også presset på industrien for å redusere karbonfotavtrykket. En stadig større andel av fremtidens metall må derfor komme fra resirkulerte kilder. En viktig del av Hydros bærekraftstrategi er å øke sorteringskapabiliteten og utvikle mer resirkuleringsvennlige produkter og spesifikasjoner i tett samarbeid med kundene.

For å realisere et høyere resirkuleringsnivå er det nødvendig å håndtere skrapstrømmer med langt større presisjon enn tidligere. Skrap er en variabel råvare, der fraksjoner av prosess- og forbrukerskrap varierer i renhet, forurensninger og innhold av sporelementer. Forbrukerskrap kommer ofte i inhomogene fraksjoner med høyere forurensning og uforutsigbarhet. Dette stiller høye krav til prosesskontroll og gjør sorteringsteknologi til en nøkkelfaktor for å lykkes med resirkulering i praksis. Tradisjonelle separasjonsmetoder fjerner forurensninger som ikke-metalliske partikler samt kobber og stål, men gir begrenset kontroll over den kjemiske sammensetningen. Kjemibasert sortering, som røntgen og LIBS, gir derimot informasjon om sammensetningen i hver enkelt partikkel og muliggjør sortering av skrap i langt mer homogene fraksjoner. Dette øker presisjonsnivået betydelig og åpner for nye muligheter for å anvende skrap i produksjon av resirkulert aluminium.

For å utnytte dette potensialet fullt ut må også dagens spesifikasjonsgrenser vurderes. Dette arbeidet må gjennomføres i tett dialog med kundene for å sikre at produktkrav fortsatt tilfredsstilles. Slik kan kombinasjonen av mer avansert sortering og utvidede spesifikasjoner bidra til å frigjøre verdien som ligger i skraphaugen.

Standardisering av AM i DNV

Gurrik, Stian

ProGRAM JIP (2018-d.d.), et samarbeidsprosjekt ledet av DNV for kvalifisering og industrialisering av additiv tilvirkning (3D-printing)i industrien. Basert på pilot-caser har prosjektet dannet grunnlag for DNV-ST-B203, den første fullverdige industristandarden for kvalifisering og produksjon av 3D-printede komponenter i energi og maritim sektor. Nå i fjerde iterasjon, legger prosjektet til rette for akselerert digitalisering og standardisering av nye teknologier, - og grønnere, mer robuste forsyningskjeder.

Corrosion Resistance of 13Cr Stainless Steel in Seawater–Freshwater Mixtures Under Controlled Oxygen Conditions

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A series of corrosion-exposure experiments were conducted to evaluate the behavior of 13Cr - 2.5Mo stainless steel subjected to elevated chloride concentrations during temporary flooding conditions representative of subsea pipeline pre-commissioning. The objective was to determine whether short-term exposure to chloride-rich freshwater under controlled oxygenated conditions could compromise long-term performance after flushing and subsequent transition to production fluids.

Test scenarios were developed using chloride concentrations of 1,500 mg/L and 3,700 mg/L in freshwater, together with a fully aerated seawater reference condition. Exposure temperatures between 7 °C and 12 °C reflected typical subsea environments. Specimens were exposed for 47 days in chloride-containing freshwater, followed by staged transitions to oxygen-scavenged freshwater and finally to formation water representative of production conditions.

Corrosion performance was assessed through continuous Open Circuit Potential monitoring, allowing identification of key factors contributing to corrosion initiation during oxygenated chloride exposure and evaluation of whether shallow pits formed during the initial exposure would propagate after flushing. The integrated testing approach provides a representative assessment of corrosion behavior in 13Cr - 2.5Mo stainless steel subjected to mixed-salinity conditions during installation and transition to operation.

Overall, the results indicate that while short-term exposure to chloride-rich, oxygenated freshwater may induce minor corrosion initiation, subsequent exposure to oxygen-scavenged freshwater and formation water does not promote further pit propagation under the conditions evaluated.

Resirkulering av solcellemoduler – Hvordan få dem fra hverandre?

Hansen, Per Anders, IFE

The stream of discarded PV modules has previously been fairly small, but is rapidly increasing. It is expected that by 2050, 5-7 Mtons of discarded PV modules will have to be handled each year globally [1]. Still, there is no established method to recycle PV modules today. A major challenge is that neither old nor current PV modules were designed with recycling in mind. Separating a module back into its material components is difficult. Doing so in a way that preserves the various materials for further recycling while also being economically viable, even more so.

The industry is still in early explorations on how to do this. Many approaches has been suggested and tried out in practice: From thermal provessing, lasers, mechanical grinding or combinations. In the RETRIEVE EU project and the FME Solar national centre, we are working to establish a working European value chain and to understand and control how impurities enters and affects the recycling products.

In our own work, we have investigated three different method to separate the glass pane from the rest (metals, silicon and various polymers and laminate adhesives). The aim is to in one way or another sever the polymer bonding everything onto the glass, while at the same time keeping the glass intact in one piece.

10 år med studier av mikrostruktur og mekaniske egenskaper i additivt tilvirkede metalliske legeringer ved Universitetet i Stavanger

Vidar Hansen

Institutt for maskin, bygg og materialteknologi

Institutt for maskin, bygg og materialteknologi ved Universitetet i Stavanger har i nærmere 20 år hatt omfattende aktivitet innen tredimensjonal modellering og skanning av komponenter for datagrunnlag for additiv tilvirkning, samt de seneste 10 årene innen mekanisk testing og mikrostrukturanalyse av additivt tilvirkede metalliske legeringer.

Additiv tilvirking (3D-printing) av komponenter åpner for både økonomiske besparelser, reduksjon av klimaavtrykk og nye muligheter for mer optimalisert design**.** Forutsatt at mikrostrukturen er godt kontrollert ved optimaliserte printeparametre, kan 3D-printede materialer oppnå mekaniske egenskaper på nivå med tradisjonelt fremstilt materiale – og dermed fungere som et fullverdig, i enkelte tilfeller som et forbedret alternativ.

Aktiviteten innen mekanisk testing og mikrostrukturanalyse av industrielt fremstilt, additivt tilvirkede metalliske legeringer har, i tillegg til fast ansatte, siden 2015 involvert om lag 28 bachelorstudenter, 12 masterstudenter og 3 doktorgradsstudenter, som til sammen har arbeidet med 10 ulike legeringssystemer.

Instituttet har nylig anskaffet en Fronius-sveiserobot som kan bygge opp metalliske komponenter ved hjelp av Cold Metal Transfer (CMT)-teknikken. Våren 2026 produserte vi for første gang en komponent i rustfritt stål av typen SS316L

Våre studier har i hovedsak vært knyttet til mikrostrukturanalyse med lysoptisk og elektronmikroskopi i kombinasjon med mekanisk testing i form av Vickers hardhet, en-akset strekktesting og Sharpy-V slagseighets testing.

Materialene som er undersøkt, er produsert ved en av tre ulike additive tilvirkningsmetoder, wire-arc additive manufacturing (WAAM), laser powder bed fusion (PBF-LB) eller directed laser deposition (DLD).

Foredraget vil sette søkelys på hvordan mikrostruktur og mekaniske egenskaper i austenittisk rustfritt stål og dupleks stål påvirkes av de prosessbestemte termiske syklusene som oppstår ved de tre nevnte additive tilvirkningsmetodene.

Cold spray, dupleks og defekter

Hassel, Trond Arne

En kort gjennomgang av noen utvalgte fokusområder fra Equinors forskningsaktiviteter innen additiv tilvirkning: Additiv tilvirkning av dupleks-materialer med ulike AM-metoder, introduksjon til cold spray og kvalifikasjonstestingen utført for å ta i bruk cold spray offshore samt utfordringer knyttet til defekter i additivt tilvirket materiale.

Small–Size and Build Orientation Effects on the Fatigue Behavior of Laser Powder Bed Fused AlSi10Mg

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The ability of Laser Powder Bed Fusion (PBF–LB) to efficiently produce highly complex geometries enables unprecedented opportunities to achieve lightweight, functional designs. As a result, optimized lightweight components often exhibit thin features whose fatigue performance and its variation with build orientation remain, however, poorly understood. This study reveals a promising finding for lightweight, fatigue-critical applications: miniature PBF–LB AlSi10Mg features exhibit superior fatigue resistance to standard–size counterparts regardless of the build orientation. This result applies to the machined surface condition, but more importantly, to the economically compelling as–built state, both in the inherent PBF–LB microstructure or after homogenizing heat treatments. In addition, horizontally built features consistently exhibit the best fatigue performance independently of specimen size, which consolidates that the choice of reducing build time associated with vertically built features, or minimizing alterations in thermal history by avoiding support structures for overhangs, does not compromise, but prolongs fatigue lifetime. Finally, the work demonstrated that realistic, rapid, and non–destructive fatigue life predictions can be achieved from simple surface scans through fracture mechanics models, which were further improved with defect–sharpness corrections. The demonstrated reliability of the fatigue life estimates at different feature sizes and build orientations offers the potential to be integrated in a practical hybrid theoretical–experimental route toward faster conservative qualification of AM components without extensive testing. The results of the work contribute to resolving industry’s skepticism surrounding small-scale effects in fatigue critical applications, and challenge long–standing assumptions of a particularly detrimental role of surface roughness in smaller PBF–LB features. They highlight the effectiveness of miniature specimens in capturing as–built size effects on thermal history and fatigue performance, offering an efficient, non-destructive approach for characterizing thin features in complex AM components when used as witness specimens attached to the regions of interest.

Utvikling av nye materialer med moderne digitale verktøy – keiserens nye klær?

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Kunstig intelligens har i løpet av kort tid blitt allemannseie, og mange spår at dette kommer til å forandre hele samfunnet radikalt. Også innen materialteknologi har det dukket opp en rekke nye KI-baserte verktøy som kan utføre oppgaver som virket uoppnåelige for bare få år siden.
I denne presentasjonen vil vi gå gjennom en del av de nye digitale metodene til utvikling av nye materialer med et kritisk blikk. Ett eksempel er teknikker som gjør bruk av databaser med detaljert informasjon om fundamentale materialegenskaper for de fleste kjente uorganiske, krystallinske materialer – i størrelsesorden 100.000 forskjellige materialsystemer. Slike databaser gir et utmerket utgangspunkt for å trene maskinlæringsmodeller, og en rekke studier har brukt denne muligheten til å identifisere de mest lovende materialene til spesifikke anvendelser. I tillegg har det blitt utviklet flere metoder for å studere hypotetiske materialer, for eksempel ved hjelp av generativ kunstig intelligens. Disse metodene kan brukes til å foreslå materialer som aldri har blitt laget, men som sannsynligvis er mulig å lage. Her snakker vi om millioner av potensielle materialsystemer. Andre eksempler er metoder for å forutsi om materialer faktisk kan syntetiseres, hvordan et gitt materialsystem kan forbedres med for eksempel doping eller legering, og hvordan maskinlæringsmetoder kan drastisk akselerere tradisjonelle modelleringsteknikker.
Det er ikke måte på hvor mange studier som har levert sensasjonelle forutsigelser av nye materialer med enestående egenskaper, men så langt har ikke så mye nytt funnet veien til markedet. Hva kan det skyldes? Er datakvaliteten som danner grunnlaget for modellene, for lav? Eller er eksperimentell verifisering blitt en flaskehals? Og til sist: basert på det vi vet i dag, kan vi si noe sikkert om hvor denne nye vitenskapen fører oss?

An Integrated Cure Kinetics and Process Modelling Framework for Composite Manufacturing

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Thermosetting polymers play a central role in composite manufacturing, where their cure kinetics governs the formation of crosslinked networks through thermally and chemically activated reactions. The degree of cure, strongly dependent on polymer chemistry, initiators, catalysts, and processing conditions such as temperature, time, heating rate, and humidity, directly influences the mechanical performance, dimensional stability, and reliability of composite components. Inadequate cure schedules can lead to incomplete curing, excessive shrinkage, residual stresses, deformation, or premature failure, while overly slow curing increases production time and processing costs. Balancing these competing constraints remains a major challenge in composite production.

This work presents an integrated framework that combines empirical cure-kinetics modelling with advanced process simulations to address these challenges. The underlying chemical reactions governing cure progression are characterised experimentally, and the resulting kinetics models describe the evolution of degree of cure as a function of time and temperature. These models are then embedded within finite element simulations capable of predicting cure-induced heat generation, heat transfer, volumetric shrinkage, and the development of residual stresses within moulded and laminated composite structures. Experimental validation using representative thermoset composite parts ensures accurate prediction of thermomechanical behaviour throughout the curing process.

To support optimisation of composite processing, a multi-objective optimiser is incorporated into the framework to navigate trade-offs between conflicting manufacturing goals. Objectives such as minimising cure-cycle duration and shrinkage while maximising degree of cure and part performance are explored simultaneously. The optimiser generates Pareto-optimal cure profiles tailored for composite manufacturing, providing balanced solutions that enhance production efficiency, reduce defects, and ensure high material quality.

This integrated approach offers a robust framework for predictive processing, enabling more efficient design, reduced waste, and improved reliability in composite manufacturing.

Materials and opportunities in large scale AM

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Abstract:
Additive manufacturing is pushing new grounds, and larger and larger parts and structures are now feasible to be produced by additive manufacturing. This brings new challenges, some of which are material related. Internal stresses are present in most AM technologies involving heat, but as size grows these internal stresses become larger and needs to be countered in new ways. As the size grows so does the material use, and there is a greater need to find suitable materials not only in terms of performance and uniqueness towards the AM process, but also terms of cost and environmental aspects. This presentation will focus on some of the large scale AM processes that are emerging, give insight into typical applications and the materials related challenges.

Aluminium in the marine environment: Corrosion prevention and corrosion testing

Hydro Aluminium AS

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The low weight, corrosion resistance and design flexibility of aluminium can offer many advantages for uses in marine applications. This work highlights some use-cases, guidelines and developments for use of aluminium in the marine environment, focusing on corrosion.

Using aluminium alloys with an increased recycled content offers significant environmental benefits, due to the low energy demand of recycled compared to primary aluminium production. Increased post-consumer scrap content may give higher contents of trace elements, which can increase susceptibility to pitting or intergranular corrosion. This work will showcase this effect, and how it can be mitigated by scrap sorting, alloy design and material treatment.

To understand the corrosion susceptibility of different aluminium alloys, surface treatments and joining methods, corrosion testing is crucial. Hydro Aluminium has built an outdoor testing site in Karmøy to evaluate corrosion in a real marine environment. This work evaluates how results from accelerated tests of filiform and intergranular corrosion correlates with real-life outdoor corrosion behaviour. Findings indicate that accelerated tests are effective for ranking materials but do not reliably predict service behavior.

One of the major challenges faced when using aluminium in marine environments is galvanic corrosion. When aluminium comes into contact with more noble metals, corrosion accelerates, especially in the presence of seawater. These issues can largely be avoided by mindful design, in particular of steel-aluminium joints, to avoid a galvanic connection.

Zero Emission Silicon and Manganese Production Through Molten Oxide Electrolysis

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Silicon and manganese ferroalloys are important critical materials, as they are essential for industrial applications by being alloying elements in steel and aluminium, and for uses in the energy sector (wind, batteries and solar). Norway is a top producer of both silicon and manganese products in Europe and a significant player on the global stage. These metals are produced efficiently by carbothermic reduction in Submerged Arc Furnaces (SAF), emitting 0.9-1.3 kg CO_2/kg Mn ferroalloy and 5 kg CO_2/kg Si. Decarbonising the energy system is essential, but not sufficient because CO_2 is a by-product of the metal-producing reactions themselves. Some relatively mature technologies such as biocarbon reductants and carbon capture and storage or use (CCSU), may allow the industry to move away from fossil CO_2 emissions while continuing to use the carbothermic reduction route. However, there are many reasons to look beyond these carbon-based solutions and investigate possibilities to completely decarbonise the industry.

Electrolytic production of silicon and ferromanganese alloys is the most direct way to electrify and decarbonise the production processes, especially when renewable energy is readily available. Electrowinning processes using oxide raw materials in molten salts or molten oxides utilizing oxygen evolving anodes will eliminate all process-related CO_2 emissions. This is investigated in the ZeSiM project (Zero emission Silicon and Manganese Production through electrowinning).

Molten oxide mixtures are generally less suitable as electrolytes than molten salts, with their less ionic structures resulting in lower electrical conductivity and higher viscosities. High temperatures and corrosive electrolyte chemistry also cause challenges for material selection. Manganese electrolysis experiments from a molten oxide electrolyte (MnO, Al_2O_3, SiO_2, MgO, and CaO) using a CrFe metal alloy as the oxygen-evolving inert anode and different cathode materials have been conducted, with a goal of obtaining fundamental knowledge of electrolytic production of manganese and identifying suitable materials.

Characterization of Gas-Atomized Aluminium-Silicides for Laser

Powder Bed Fusion Applications

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Keywords: Aluminium-silicides

ABSTRACT

Nowadays additive manufacturing (AM) is a topic that is raising interest as the industry is shifting towards more sustainable parts production. Among the different AM processes, laser powder bed fusion (L-PBF) established itself as one of the main AM technologies for the manufacturing of parts in industry thanks to its precision and low material waste. Aluminium silicides with high silicon content (above 12 %) produced by gas atomization have high potential to serve as feedstock for L-PBF due to their good mechanical properties, castability as well as a low number of defects (shape defects or satellites). However, to our knowledge, these alloys have not yet been studied extensively for 3D printing applications. In order to optimize the AM process, it is required to improve the understanding of the alloy system prior printing. Thus, extensive characterization needs to be performed to enhance our awareness on the different materials parameters. To gather such information, the powders were analyzed by scanning electron microscopy (SEM) to assess the particle's shape, the homogeneity of the batch as well as the presence of satellites. Coupling the SEM with energy dispersive X-ray spectroscopy (EDS) can also allow to have an insight on the particle's composition and the repartition of the different elements. The powder composition was established by glow discharge mass spectrometry (GD-MS). Lastly the particle size distribution (PSD) was determined by laser diffraction analysis as well as micrographs analysis coupled with ImageJ

post treatment. This work should bring out a new insight on the methodology to characterize aluminium-silicides with high Si content to improve the understanding of the batch, as well as the powder's microstructure which can be used to refine the L-PBF process parameters optimization.

Recycling of silicon PV modules - what impurities do with solar cells lifetime

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Keywords: Silicon, Solar Cells, Recycling

ABSTRACT

Silicon-based solar cells are still dominating the photovoltaic (PV) marked and, currently, account for approximately 95 % of the total commercial solar cells. A typical silicon solar cell undergoes different manufacturing steps, which start with quartz and C-bearing compounds, which are the two main raw materials to produce the silicon feedstock. Then a monocrystalline ingot is grown in the Czochralski process, in which fused quartz crucibles are used to contain molten silicon for several hundred hours. The wafers, which are cut from the monocrystalline ingot, go through many steps including emitter diffusion and metallic contacts deposition. Thereafter, a PV module is made, which consists of several solar cells connected in series, sandwiched between two layers of polymeric materials, a transparent glass on top and an aluminum frame.

As most of the PV modules are guaranteed for 25 years of operation, most of the solar cells which were installed at the beginning of 2000 are now approaching their end of life, and it is expected that approximately 80 million metric tons of waste globally will be generated by PV by 2050. Therefore, recycling silicon solar cells is a growing research field, and it needs to be addressed as it would facilitate the recovery of a large stock of raw materials and other components from this waste, including silicon as well as glass and aluminum.

In this work, we will describe the status of silicon solar cells manufacturing and recycling possibilities. The main focus will be on presenting the role of impurities that can originate from the recycled material, on silicon solar cell performance, and why it is important to control their levels. We will also focus on the fused quartz crucible, which is a key component of the silicon ingot manufacturing, as it is only used for one heating cycle, and there is no industrial recycling process available for the crucible yet. The impurities present in its inner wall may enter the silicon melt, the grown silicon ingot and potentially degrade the final solar cells. Therefore, controlling the crucibles impurities plays also a key role in preventing any detrimental effect on the final performance of the solar cell.

AI-Supported Metallography in Aluminium: Methodology, Challenges, and Early Insights

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The aluminium industry increasingly depends on fast, consistent, and high-quality microstructure evaluation to support product qualification, casting control, and process development. Artificial Intelligence (AI) offers promising opportunities to improve these workflows by assisting with the interpretation of complex and heterogeneous aluminium microstructures. Our ongoing work investigates how AI can enhance consistency and reduce manual effort in selected steps of metallographic analysis, particularly in the identification and quantification of microstructural features.

Early tests suggest that AI-assisted methods can help standardize parts of the evaluation process and accelerate tasks that traditionally require significant expert time. However, developing reliable models for aluminium systems remains challenging. Aluminium microstructures contain diverse and sometimes rare features, and robust model training requires large volumes of high-quality, well-annotated images. Variations in sample preparation, imaging conditions, and alloy systems further complicate model performance and limit generalizability at this stage. An additional challenge is ensuring alignment between new AI-derived measurements and historical manual evaluations. Maintaining continuity with legacy data is crucial for preserving established trends, qualification criteria, and long-term comparability.

To address these constraints, we have initiated a structured data strategy. This includes compiling expert-annotated images across different alloy families, applying targeted data augmentation and calibration procedures. Integrating metallurgical domain knowledge into annotation and model development is a central element of our approach, ensuring that recognized features correspond to meaningful physical phenomena and supporting user confidence in early outputs.

Rather than presenting finalized results, this contribution outlines our methodological framework, key challenges, and lessons learned while building AI-supported

Fra industriell utfordring til forskningsbasert utslippskutt – nærings-PhD som bro mellom industri og akademia

Sindblad, Caroline

Sammendrag:
Metallproduksjon er både energi- og karbonintensiv, og den kraftforedlende industrien står samlet for en betydelig andel av Norges CO_2-utslipp. Samtidig er materialene vi produserer – som silisium – helt avgjørende for produksjon av solceller, vindmøller, silikon og andre komponenter for det grønne skiftet. Skal vi videreutvikle produksjonen i Norge og samtidig redusere utslipp, kreves det både bedre utnyttelse av eksisterende proseskompetanse og målrettet oppbygging av ny, anvendbar kunnskap.
Dette bidraget diskuterer hvordan en nærings-PhD kan fungere som en praktisk bro mellom industri og akademia: ved å oversette konkrete driftsutfordringer til forskbare problemstillinger, utvikle metoder og data som kan brukes direkte i forbedringsarbeid, og samtidig bidra til varig kompetanseoverføring mellom miljøer.
Som konkret eksempel presenteres arbeid fra et PhD-prosjekt innen silisiumsproduksjon, med fokus på silisiumkarbid (SiC). SiC er et nødvendig mellomprodukt i prosessen, men uforbrukt SiC kan akkumulere og omdannes til mekanisk sterk, lav-resistiv α-SiC. Dette kan forstyrre materialflyt og elektrisk strømfordeling i ovnen, med konsekvenser for prosessstabilitet, energieffektivitet og kostnad. Ved å kombinere industriobservasjoner, prøvetaking og materialkarakterisering med laboratorieforsøk på SiC-reaktivitet mot SiO-gass, oppnås ny innsikt i forbruks- og akkumuleringmekanismer.
Arbeidet settes videre i sammenheng med industrisektorens pågående satsinger på utslippskutt gjennom biokarbon, karbonfangst og karbonlooping – områder som alle stiller høye krav til ny kompetanse. Erfaringene så langt viser at ambisiøse utslippskutt er teknisk mulig, men fortsatt forbundet med betydelige kostnader. Videre utvikling av robuste og konkurransedyktige løsninger vil derfor kreve langsiktig teknologiutvikling, tett samspill mellom forskning og industri, og forutsigbare rammevilkår for metallproduksjon i Norge.

Impurity reactions and corrosion in carbon capture and storage systems

Presenter: Gaute Svenningsen, Institute for Energy Technology
Abstract: Carbon capture and storage (CCS) has received increasing attention during the last decade as a realistic method to reduce anthropogenic CO_2 emissions. CCS has been used for several decades, but the CO_2 sources have mainly been natural gas and natural CO_2 domes, free from for example oxygen. As CCS is expanding it will also include new CO_2sources and flue gasses containing oxygen, SOx and NOx, for which there is less experience. One particular problem is that certain components from flue gasses (and other sources) may follow the CO2 through the capturing and liquefaction processes. Even if these components (impurities) only are present at ppm-levels, they can in certain undesirable situations react and form corrosive species (e.g. sulfuric acid or nitric acid) or solids that can introduce risk of clogging and erosion. From an integrity point of view it is important to avoid such reaction products. This is foreseen to be a particular problem in large transportation systems where CO_2 from different sources are mixed before injection and storage. The present work describes a methodology that has been developed to study impurity reactions and corrosion in simulated CO_2 transportation systems.

About the presenter: Gaute Svenningsen received his PhD from NTNU in 2005, where he studied corrosion of aluminium. Since 2007 he has been working at the Institute for Energy Technology (IFE) at Kjeller/Norway. His work has mainly been with CO_2 and H_2S corrosion, and almost only with CCS during the last 10 years.

Feltundersøkelse av metalliske mikrostrukturer

Søfferud, Mario

Feltmikroskopi har over de siste tiårene sett utvikling og framskritt i metoder og utstyr. Men grunnleggende gjenstår de samme utfordringene med behov for spesialisert utstyr og særlig kompetanse og erfaring for å preparere, undersøke og bedømme mikrostruktur i felt. Store prosjekter de siste 20 årene har krevet langvarige og kompliserte feltundersøkelser spesielt av duplex rustfrie stål. Presentasjonen tar for seg utstyr, metoder, utfordringer og erfaringer fra feltarbeid.

Harvesting primary and secondary CRMs from minerals and waste

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The ongoing transition toward renewable energy systems, essential for reaching the net zero target by 2050, necessitates substantial quantities of critical raw materials. To cover this demand, it will be important to develop both primary and secondary raw material routes.

There are several mines in Norway based on sulfides currently under development. Process technologies for the extraction of primary raw materials from ores represent a critical step in enabling their effective exploitation. Over the past years, ReSiTec has developed processing routes for metal extraction from sulfide minerals, involving gravity and magnetic separation, flotation and hydrometallurgical steps achieving sulfide concentrate ready for pyrometallurgical refining to copper metal as well as produced 99% pure copper metal from hydrometallurgy routes.

Silicon is essential for the photovoltaic- and semiconductor industries and considered as the next generation anode material for lithium-ion batteries (LIBs) due to its high energy storage capacity. Primary silicon production and refining of silicon through chemical vapour deposition carries heavy carbon footprints. Thus, converting to recycled silicon for targeted applications can give significant economic and environmental benefits. A major secondary silicon source is kerf-loss which is generated in the wafering process of silicon ingots for the photovoltaic industry (> $3*10^5$ tons/annum), developing efficient upcycling routes for this source is important [1]. ReSiTec has established a low energy-intensive industrial scale process route for the silicon kerf-loss filter cake to a powder material targeted for advanced applications, with an estimated carbon footprint of 1 kg CO_2 eq/kg product. Testing of the recycled silicon kerf-loss into LIBs show promising electrochemical results, that are comparable to primary silicon materials for LIBs, see figure 1. When the recycled silicon kerf-loss is incorporated into a silicon-carbon composite anode solution, a high cycling stability is also achieved, demonstrating a promising upcycling route for the waste/side-stream.

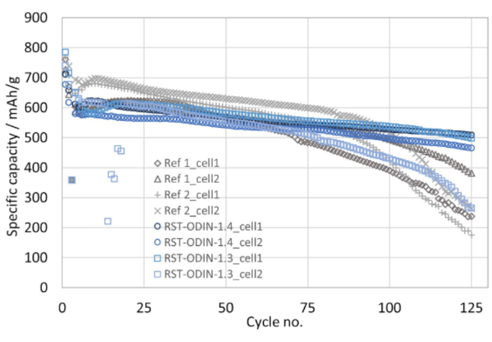

Figure 1: Specific capacity for half cells with processed recycled silicon kerf-loss and reference silicon (commercially available nano-sized silicon) as a function of cycle number, cycling rate after formation cycles are C/3 and 1.0 V to 50 mV vs. Li/Li+.

The connection between Theory of Sampling, Process Control and Profitability by practical examples

Hilde Tellesbø, IFE

Surprisingly, most industries are not fully aware of the details in the variances of their process and the factors contributing to it. Knowing the different contributors will make it possible to increase yield and profitability.

For practical purposes there are three main contributors to the overall variance:

V(j)max=V0+V2(j)+V3

V_0 is a constant dependent of the nature of the material and the sampling procedure (including online measurements). If the sampling is not in accordance with Theory of Sampling (TOS), it will increase variances. If the samples taken are physical samples, any sample dividing and handling after the primary sampling will increase V0, especially if it is conducted incorrectly. If V0 is high, the process will be out of control and difficult to run. Wrong decisions to adjust the process will be made. V0 can easily be reduced by improved sampling protocols. An example is a Copper mine with loss of 2.000.000.000 USD to tailings during a 20-year period due to bad sampling routines.

V_2(j) is generated by continuous trends, which are not random and non-cyclic. V2(j) is not easily improved.

V_3 is cyclic periodicity, typically introduced by process parameters, such as regulations between set limits, mechanical movements, differences between full and empty hoppers etc. To get rid of or reduce cyclicity normally increases profitability significantly. One practical example is a kiln line which increased the net income by 670.000 Euro per year with the same consumption of raw material.

A quite common “explanation” to high variance is natural raw material with high heterogeneity. By experience, this is only partly true. Often sampling procedures and cyclicity is far higher contributors to the overall variance. Contributions to the variance is easily found from variographic analysis. From the analysis the main contributors can be identified and improved.

Revisiting precipitation hardening of Inconel 718 for optimized mechanical properties

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Abstract

Inconel 718 is utilized in vital application fields, especially in aerospace (jet engines, rockets), oil and gas (downhole tools, valves), and nuclear energy production (turbines), because of its unmatched combination of high strength, excellent corrosion resistance, and remarkable fatigue resistance in extreme conditions (ranging from cryogenic to 650°C). Being a nickel-chromium-based superalloy, post-production precipitation hardening or aging plays a crucial role in designing the material to achieve the desired properties for a given application area. In this study, following homogenization heat treatment at 1100 °C for two hours, single-stage and double-stage precipitation hardening were systematically carried out on conventional Inconel 718 specimens between 600 °C and 800 °C for 8 to 48 hours. Aging temperature and incubation duration were optimized according to hardness measurements. The tensile properties were assessed in relation to hardness. The microstructure was characterized, and the precipitates were quantified using a transmission electron microscope (TEM) and a scanning electron microscope (SEM). The findings and details of the experimental studies are presented and discussed.

Development of Digital Twins for Aluminium Casthouse Furnaces

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Casthouse furnaces are critical for melting, holding, and treating aluminium. Improved furnace operation can significantly reduce energy consumption and emissions while increasing productivity and product quality. However, these furnaces operate in batch mode, with variations in alloy types, scrap additions, alloying elements, and cycle times. Such variability complicates the assessment of furnace performance and its internal state.

To address this, we develop numerical CFD-based simulations together with data-driven machine learning models to predict the evolving furnace state throughout the process. By modelling the transient nature of furnace operation, we obtain a more detailed and continuous representation of key thermal and process conditions. The resulting models enable the detection of furnace anomalies and provide short-term forecasts of furnace state, offering new opportunities for optimized and efficient furnace operation.

A Novel Route to Phase-Controlled Alumina from Anorthosite via Single-Step Calcination

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AlSiCal method presents a novel approach for producing alumina from aluminum chloride hexahydrate (ACH), offering a simplified alternative to conventional two-step calcination. This method integrates a controlled neutralization step with closed-loop acid recovery, allows single-step thermal treatment while minimizing hydrochloric acid during calcination. This significantly reduces equipment corrosion risks and removes the need for complex and expensive corrosion-resistant kilns typically required in conventional ACH-based production. Thermodynamic simulation using OLI Flowsheet was employed to investigate the neutralization of ACH with NaOH, examining aqueous speciation, alumina hydrate precipitation (gibbsite/bayerite, Al(OH)3 and boehmite, AlOOH), and chloride partitioning as functions of NaOH dosage and temperature. These insights guided the experimental design by identifying conditions that favor effective neutralization and the initiation of alumina hydrate nucleation. Laboratory validation confirmed that effective neutralization improves control over the purity of alumina produced, phase evolution during calcination and may contribute to circular chemical use through acid regeneration. Overall, this approach offers a cleaner, more efficient, and infrastructure-friendly pathway for high purity alumina production.

High Performance Hypereutectic Al-Si alloys Developed for Metal Additive Manufacturing

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Abstract: Metal additive manufacturing (AM), especially powder bed fusion (PBF) has already matured from lab development into industrial implementations nowadays and can be found in most demanding applications. Despite these advancements, the additive manufacturing of aluminium alloys has remained largely limited to Al–Si casting alloys near the eutectic composition, such as AlSi10Mg. In this work, we present the development of a new class of hypereutectic Al–Si alloys tailored for AM, along with the powder production, corresponding PBF process parameters, resulting material properties, and potential applications. The alloy set includes binary AlSi20 and AlSi40 compositions, as well as a multicomponent AlSi18FeMnCr alloy High-quality, spherical metal powder for each alloy was produced with gas atomization at Future Materials Catapult Center. The process, equipment and learnings from powder production will be presented. With increasing Si content, the linear coefficient of thermal expansion (CTE) decreases and can approach that of selected steels and copper alloys. Such CTE compatibility enables the potential substitution of these heavier materials in multi-material assemblies. The hypereutectic Al–Si alloys developed here also demonstrate superior retention of mechanical strength after high-temperature annealing compared with the conventional AlSi10Mg alloy. In particular, the AlSi18FeMnCr alloy exhibits excellent high-temperature strength, making it a promising candidate for applications requiring lightweight components that maintain mechanical integrity at elevated temperatures.