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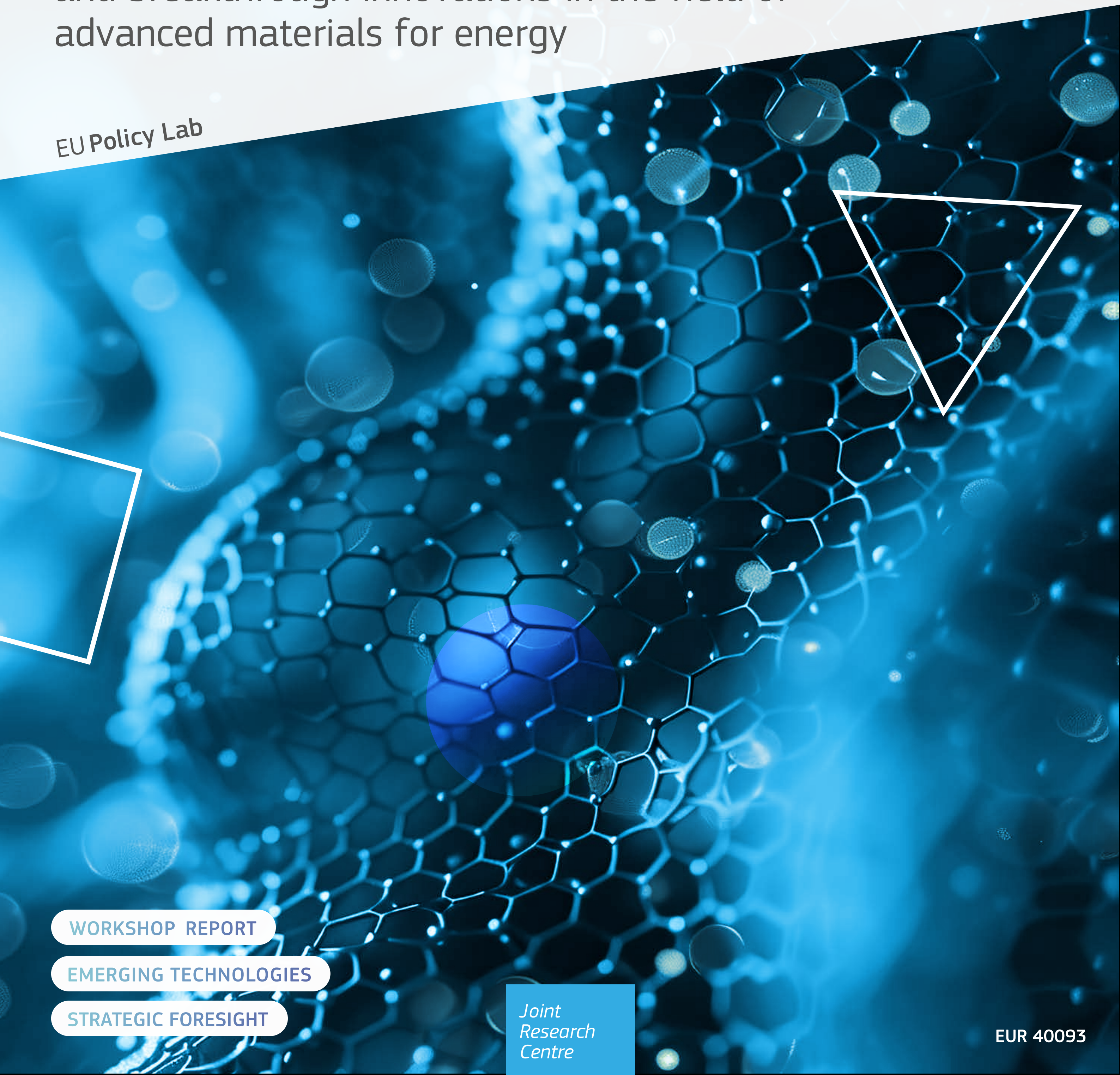
MATERIALISING THE FUTURE

Horizon-scanning for emerging technologies and breakthrough innovations in the field of advanced materials for energy

EU Policy Lab



WORKSHOP REPORT

EMERGING TECHNOLOGIES

STRATEGIC FORESIGHT

Joint Research Centre

EUR 40093

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MATERIALISING THE FUTURE

Horizon scanning for emerging technologies and breakthrough innovations in the field of advanced materials for energy

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This report is part of the project FUTURINNOV, (FUTURe-oriented detection and assessment of emerging technologies and breakthrough INNOVation), a collaboration between the European Commission's (EC) Joint Research Centre (JRC) and the European Innovation Council (EIC), the EC's flagship program for deep tech, implemented by the European Innovation Council and SMEs Executive Agency (EISMEA).

This report contains the results of a thematic Horizon Scanning process, including a brief description of the methodology followed. It is the result of a participatory process involving external experts. Therefore, the views expressed herein do not necessarily reflect the views of the European Commission.

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Abstract

This report documents the process and findings of a horizon scanning exercise, part of a series under the FUTURINNOV (FUTURe-oriented detection and assessment of emerging technologies and breakthrough INNOVation) project, a collaboration between the European Innovation Council (EIC) and the Joint Research Centre (JRC), aiming to bolster the EIC's strategic intelligence through foresight and anticipatory methodologies.

The workshop, held on 13 May 2024, had as its primary goal the evaluation and prioritisation of trends and signals on emerging technologies and breakthrough innovation, across all technology readiness levels (TRLs), within the EIC's Advanced Materials portfolio and with a particular focus on their use in the Energy sector.

Signals for the workshop were gathered from experts, literature review, and text/data mining of patents, publications, and EU-funded projects. These signals were then scrutinised for their significance to the field's future by a diverse group of sector experts which led to the identification of nine key topics: accelerated material design/synthesis; biomaterials as part of the circular economy; advanced materials allowing new applications; closed loop battery recycling; innovations in catalysis; organic batteries for sustainable energy storage; design to performance batteries; design to cost batteries; and electrochemical water treatment.

Furthermore, the workshop identified additional wild cards with high novelty and disruptive potential such as: circularity of materials (safe and sustainable by design); membranes / separators; process optimisation; 3D printing of electrode materials for energy and environmental engineering applications; and use of AI for the study of materials.

Participants also highlighted various factors that could influence the development, adoption, and promotion of these emerging technologies, which can be grouped under the following categories: governance and compliance frameworks; funding; collaboration and knowledge exchange; sustainable and efficient development; infrastructure and technological advancement and limitations; industry and market dynamics and constraints; innovation and risk management; supply chain and raw materials; and talent development.

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Executive summary

The Advanced Materials for Energy horizon-scanning workshop on 13 May 2024 was the fourth in a series of horizon-scanning workshops carried out as part of the FUTURINNOV project.

FUTURINNOV, a joint project of the European Innovation Council (EIC) and the Joint Research Centre (JRC), is designed to support the EIC in building strategic intelligence capacity through foresight and other anticipatory approaches.

The objective of this workshop was to assess and prioritise trends and signals of novelty within all Technology Readiness Levels (TRLs) in the scope of the EIC portfolio of Advanced Materials for Energy.[1]

This initiative is framed by a growing strategic focus of the EU on Advanced Materials, that gave body to policy initiatives such as the European Commission's Communication on Advanced Materials for Industrial Leadership, as well as the Commission's Recommendation on critical technology areas for the EU's economic security. [2] [3]

The workshop was based on signals which were sourced from experts [4], a literature review and text/data mining of patents, publications and projects. Section 2.1 provides a more detailed description of how the signals were sourced.

These signals were assessed for their importance to the future of this domain during a participatory workshop with a group of experts, all well-versed in the issues but coming from different sectors. This diversity of perspectives is a key success factor for harnessing the collective intelligence of the group. The methodology used is described in Section 1.4.

Through the process of clustering and filtering, nine topics related to emerging technologies and disruptive innovations were deemed to be of particular interest:

— Accelerated material design / synthesis
— Biomaterials as part of the circular economy
— Advanced materials allowing new applications
— Closed loop battery recycling
— Innovations in catalysis
— Organic batteries for sustainable energy storage
— Design to performance batteries (semi solid and solid state batteries)
— Design to cost batteries
— Electrochemical water treatment (e.g. capacitive deionization, electrocatalytic oxidation)

Additionally, participants selected the following wild cards as individual signals that bear the most novelty and disruptiveness potential:

— Circularity of materials (SSbD - Safe and sustainable by design)
— Membranes / separators (horizontal topic)

[1] The EIC PM portfolio names used throughout this report are a simplification of the official denomination, agreed with the EIC Strategic Intelligence Team.

[2] For more information on recent EC initiatives in the general field of Advanced Materials please consult the European Commission's communication on Advanced Materials for Industrial Leadership: https://op.europa.eu/en/publication-detail/-/publication/38970bfd-d61e-11ee-b9d9-01aa75ed71a1/language-en

[3] https://defence-industry-space.ec.europa.eu/commission-recommendation-03-october-2023-critical-technology-areas-eus-economic-security-further_en

[4] A wider pool of experts, which included all those invited to the workshop, was approached to contribute signals.

- Process optimization.
- 3D printing of electrode materials for energy and environmental engineering applications
- Use of AI for the study of Materials

The signals that were highlighted in the workshop can be found in Section 2.

Participants were also asked to identify factors that could drive, enable or hinder the development, take-up and promotion of emerging technologies, with a particular focus on the selected topics. The identified factors fall into one or more of the following categories:

- Governance and compliance framework
- Funding
- Collaboration and knowledge exchange
- Sustainable and efficient development
- Infrastructure and technological advancement and limitations
- Industry and market dynamics and constraints
- Innovation and risk management
- Supply chain and raw materials
- Talent development

1 Introduction

1.1 Project objectives

FUTURINNOV (FUTURe-oriented detection and assessment of emerging technologies and breakthrough INNOVation) is a collaboration between the European Commission's (EC) Joint Research Centre (JRC) and the European Innovation Council (EIC), the EC's flagship program for deep tech, implemented by the European Innovation Council and SMEs Executive Agency (EISMEA).

FUTURINNOV was designed to support the EIC in building strategic intelligence capacity through foresight and other anticipatory approaches. In this way, it supports activities focused on funding targets, programme design, policy feedback, and institutional governance.

1.2 Work Package objectives and methodology

The project is structured into 5 work packages (WP), one of which focuses on Horizon Scanning (HS) in fields that are relevant to the EIC.

HS is a qualitative method of undertaking foresight which is aimed at the early discovery of developments not yet on the radar of most experts, decision makers, or the general public, and whose potential is not widely recognised.

HS is not a predictive tool. It encourages the exploration of novelties that offer opportunities and challenges in the medium or long-term.[5] [6] [7]

This WP is formed of a series of workshops that follow a tailor-made approach to HS. This approach uses collective detection, clustering, and sense making of signals, trends and contextual factors relating to emerging technologies and breakthrough innovations.

The understanding of what constitutes a signal or a trend may vary [8] [9]. As it is not yet consensual, for the purposes of this project they are understood as tangible manifestations of novelty in science, technology, innovation, markets, media, and other fields. What distinguishes a trend from a signal in this context is a different level of consolidation. Both can be drawn from scientific literature, reports and news articles on early technological developments, patents and other data sources.

Each workshop is dedicated to a specific EIC Programme Manager's (PM) portfolio and is anchored in a participatory exercise preceded by stakeholder engagement, qualitative desk research and quantitative data analytics.

Outcomes will support the strategic intelligence activities of the EIC and may be used to inform future funding topics for EIC Challenges and other EC calls. They can also provide input for EIC and EC reports, as well as to support other EU policy making initiatives.

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[5] Amanatidou, E., Butter, M., Carabias, V., Könnölä, T., Leis, M., Saritas, O., ... & van Rij, V. (2012). On concepts and methods in Horizon Scanning: Lessons from initiating policy dialogues on emerging issues. Science and Public Policy, 39(2), 208-221.

[6] Farinha, J., Vesnic Alujevic, L. and Polvora, A., Scanning deep tech horizons: participatory collection and assessment of signals and trends, Publications Office of the European Union, Luxembourg, 2023, doi:10.2760/48442, JRC134369

[7] Dannemand Andersen, P., Bevolo, M., Ilevbare, I., Malliaraki, E., Popper, R. and Spaniol, M.J., Technology Foresight for Public Funding of Innovation: Methods and Best Practices, Vesnic Alujevic, L., Farinha, J. and Polvora, A. editor(s), Publications Office of the European Union, Luxembourg, 2023, doi:10.2760/759692, JRC134544.

[8] Rossel, P. (2012). Early detection, warnings, weak signals and seeds of change: A turbulent domain of futures studies. Futures, 44(3), 229-239. https://doi.org/ 10.1016/j.futures.2011.10.005

[9] van Veen, B. L., & Ortt, J. R. (2021). Unifying weak signals definitions to improve construct understanding. *Futures*, *134*, 102837.

This was the fourth in a series of horizon-scanning workshops carried out as part of the FUTURINNOV project.[10]

1.3 Workshop objectives and scope

The objective of this workshop was to assess and prioritise trends and signals of novelty within all Technology Readiness Levels (TRLs) in the scope of the EIC portfolio of Advanced Materials for Energy.

This initiative is framed by a growing strategic focus of the EU on Advanced Materials, that gave body to policy initiatives such as the European Commission's communication on Advanced Materials for Industrial Leadership, as well as in the Commission's Recommendation on critical technology areas for the EU's economic security. [11] [12]

The decision to focus specifically on Advanced Materials for Energy, rather than Advanced Materials in general, was driven by three main considerations:

- Alignment with the EIC Portfolio, ensuring coherence with the EIC's priorities and initiatives.
- Narrowing the scope to Advanced Materials for Energy allows a more targeted and effective exploration of innovations and developments within this critical sector.
- Relevance for EU strategic priorities, such as the twin green/digital transition. Energy, in parallel with mobility, construction and electronics is set up in the EC's communication as a preliminary priority for advanced materials R&I.

1.4 Process

The workshop was held online on 13 May 2024. 26 experts attended, alongside the EIC Programme Manager Francesco Matteucci and the project team. The selection of experts included researchers, representatives from startups, established businesses and international organisations, and policy makers. This diversity was key to bringing different perspectives to the conversation and their collective intelligence helped to build significant insights around the topics at hand.

The workshop was split into four broad sections.

1.4.1 Introduction

The main facilitator started the workshop with an explanation of the objectives as described in section 1.3. At this point it was made clear that no comments or statements would be attributed directly to individual participants.

Following a short presentation of the EIC, focused on the agency's objectives, budget and funding mechanisms, all participants were invited to introduce themselves, including the EIC Programme Manager Francesco Matteucci.

The methodology, namely the steps and objectives of the session, was also explained to participants, including how outputs might be used as an evidence base for future EIC funding

[10] From this series, only the report on Quantum Technologies has been published to date: European Commission, Joint Research Centre, Mochan, A., Farinha, J., Bailey, G., Rodriguez, L., Nik, S. and Polvora, A., (Dis)Entangling the Future - Horizon scanning for emerging technologies and breakthrough innovations in the field of quantum technologies, Publications Office of the European Union, Luxembourg, 2024, https://data.europa.eu/doi/10.2760/6199218, JRC139022

[11] For more information on recent EC initiatives in the general field of Advanced Materials please consult the European Commission's communication on Advanced Materials for Industrial Leadership: https://op.europa.eu/en/publication-detail/-/publication/38970bfd-d61e-11ee-b9d9-01aa75ed71a1/language-en

[12] https://defence-industry-space.ec.europa.eu/commission-recommendation-03-october-2023-critical-technology-areas-eus-economic-security-further_en

topics or in EIC feedback to policy activities with other services of the European Commission.

1.4.2 Breakout groups

The participants were then assigned to three breakout groups. The groups had been allocated in advance to ensure a mix of profiles. Involving people who are subject matter experts but bring different perspectives to the discussion can create more interesting outcomes.

In the breakout groups, participants were first asked to select the signals (see section 2.1) that they considered *most interesting for the future of advanced materials for energy* and then to assign them to broad Technology Readiness Levels. They presented their selections to the group, explaining why they had chosen those specific topics. The participants in each group then asked questions about the individual selections and were invited to cluster together signals that were closely connected.

Next, participants were invited to add any relevant topics not yet raised in the discussion. These additional points were added and identified as such.

The following stage was to invite the participants to identify signals they felt answered the question: *What are the technologies and innovations that are more likely to breakthrough/grow/advance in the next 5 to 10 years?*

Once the signals were filtered in this way, there was a further discussion on inter-connections aiming to reach a final 5-10 signals and/or clusters of signals which were agreed by the group.

The final step of the group exercise was to select individual signals that participants considered the most novel and potentially disruptive, that could act as a wild card[13] for this EIC portfolio. Participants had three votes to select signals from the pool captured before the workshop or proposed during the previous steps. All voted signals were taken to the next stage.

1.4.3 Plenary discussion and selection of topics

The groups returned to the plenary after the break-out groups for a collective presentation and discussion.

As the presentations took place, connections between the results of each group were mapped on the virtual board by the facilitators.

Following this step, a consolidated list that encompassed all topics identified by the three groups was highlighted and participants were given three votes to allocate to items on the list. This led to a ranking of the items discussed during the workshop. The results are set out in Section 2.3.

A second round of voting was then organised, to select the top wild cards. Participants were given one vote each. Those results, identifying the top wild cards, are also presented in Section 2.3.12.

1.4.4 Contextual factors

In the final exercise of the workshop, participants were asked to identify contextual factors that could drive, enable or hinder the development and uptake of the selected signals, and their underpinning emerging and disruptive technologies and innovations.

Some of these contextual factors were identified during the signal collection process and so were added in advance by the facilitators.

[13] The idea of the wild card is to guard against potentially impactful innovations being lost through the process of clustering.

2 Workshop outcomes

2.1 Signal collection

The signals presented at the workshop were collected from three main sources.

The first source of signals was a literature review. For this review, the JRC gathered third party reports[14] - both sector- and non-sector-specific - which were recent (since 2022) and represented a wide geographic coverage. The JRC then extracted from these reports those signals which were assessed as sufficiently novel and impactful.

The second source of signals was a pool of experts[15]; who submitted signals via an online collection form. For each signal, they were asked to provide:

- Title
- Summary
- Domain(s) of application
- Maturity level
- A source URL or bibliographic reference
- An indication of the underlying technology

Experts were also provided with a guidance document to explain the process of signal collection.

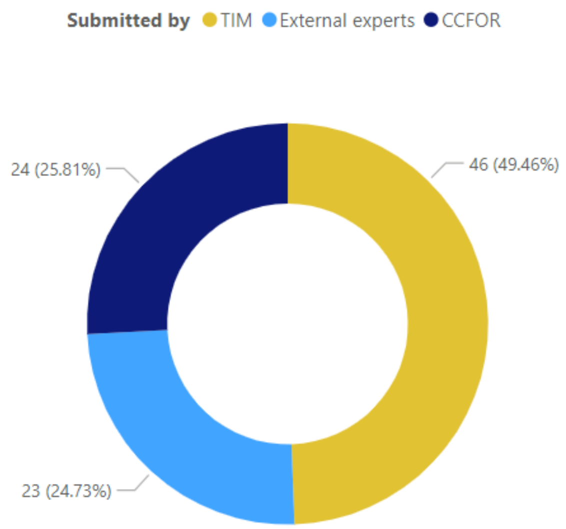
The third source of signals was the JRC's text and data mining service, TIM Analytics. This service scours scientific publications/patents and EC funded proposals and uses a customised indicator to determine the "activeness" of certain keywords/sets of documents.[16]

This indicator is defined as the ratio between the number of documents retrieved for a certain recent period and the total number of documents retrieved for the total period. A sudden increase in the activity in a certain domain area could suggest a weak signal becoming a strong(er) signal.

From the three sources, the JRC collected 93 signals: 24 from the literature review, 23 from experts, and 46 from text and data mining.

Figure 1 below shows the diversity of sources for the signal collection. The literature review sources are marked as coming from CCFOR, or Competence Centre on Foresight. The signals coming from text and data mining are marked as submitted by TIM.

Figure 1. Signals collected for use in the Advanced Materials for Energy workshop by different streams.



Source: Authors.

Figure 2 (on the next page) shows the diversity of signals collected in terms of maturity of the

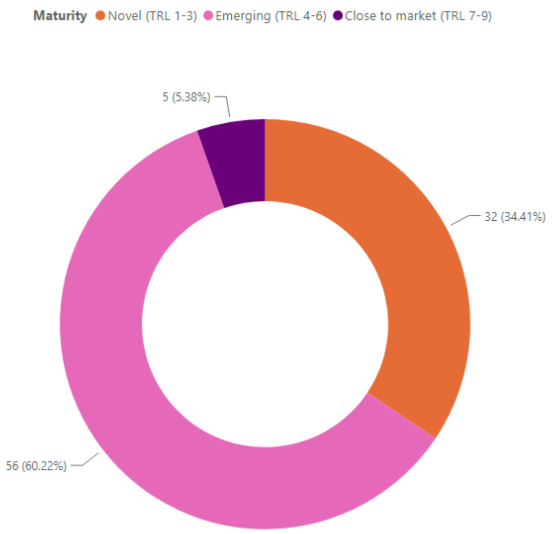
[14] Reports not authored or published by the European Commission.

[15] A wider pool of experts, which included all those invited to the workshop, was approached to contribute signals

[16] For these signals, descriptions were generated from the abstracts of the most cited scientific papers, with AI assistance. See annex 2 for more details.

technology, where identified. 32 were considered as novel, 56 as emerging, and 5 as close to market.

Figure 2. Diversity of maturity of signals used in the Advanced Materials for Energy workshop.



Source: Authors.

2.2 Group results

The following sections contain the results of the breakout groups' work, namely the micro-clusters[17] and signals that were considered of high relevance by participants. Some signals have a number, which refers to the original list sent to participants before the workshop (see Annex 2). Signals without a number were proposed by participants during the workshop.

2.2.1 Group A

Group A selected the following signals and micro-clusters as most interesting to explore:

— **Fuels**

- Thermal and electrocatalyst for CCU (Carbon Capture and Utilisation)
- Electrically rechargeable liquid fuel (826)
- Sustainable Ammonia fuel (828)

— **Design to performance batteries**

- Semi solid and solid state batteries (150)
- Silicon anodes (149)
- Li-sulphur batteries (697)

— **Design to cost batteries**

- Multivalent batteries for lower cost chemistries (106)
- Next-Gen Batteries (62)

— **Organic batteries for sustainable energy storage (713)**

— **Accelerated Material Design/Synthesis**

- DeepMind discovers 2 million new materials (135)
- Material Acceleration Platforms - MAPs (712)

— **Biomaterials as part of the circular economy**

— **Self-healing ionogel (866)**

The group selected the following as **wild cards** (see Section 1.4.3):

— **Process optimization**

— **MXene (563)**

During the discussion, the group highlighted the fact that signals were related to new materials but there should also be more consideration of new processes, which was a horizontal topic. They stressed the importance of developing these new processes to effectively scale and economically transform these materials to

[17] The term "micro-clusters" refers to small aggregations of around three connected signals.

products. In other words, processes should be developed for synthesising the new materials which were proven to be good in the lab.

2.2.2 Group B

Group B selected the following signals and micro-clusters as most interesting to explore:

- **Innovations in catalysis**
  - Ir-free catalysts for PEM Electrolysers
  - Heterojunction catalysts (857)
  - Sustainable aviation fuel (838)
  - Biopolymer or more sustainable[18] membranes for electrolyser
  - Janus monolayers (853)
- **Advanced materials allowing new application**
  - New 2D topological materials (918)
  - Organic batteries for sustainable energy storage (713)
  - MXene (563)
  - Hybrid energy storage with aluminium (710)
  - Double active membranes for CO2 capture and management (704)
- **MAPs - Material Acceleration Platforms (712)**
- **Closed loop battery recycling (835)**

The group selected the following as **wild cards** (see Section 1.4.3)

- **Solar cell quantum efficiency (823)**
- **New 2D topological materials (918)**
- **Closed loop battery recycling (835)**
- **Spin and magnetic enhancement of catalysis (711)**

During discussions, Group B emphasised the need for significant advancements or breakthroughs in advanced materials technology. They noted that most of the signals or developments discussed in their group were categorised as being at a low TRL.

They also mentioned that Material Acceleration Platforms, MAP (712) are particularly significant for those materials at TRLs 4 to 6. MAPs should also be more accessible to promising materials, enabling these materials to benefit from accelerated synthesis and characterisation.

In general, the group emphasised three key areas during their discussion. Firstly, in catalysis, they stressed the need to innovate in the design of catalysts, including heterojunction and monolayer catalysts, and to develop new advanced materials for electrolysis that do not rely on iridium or other critical raw materials[19], integrating these with polymers to create advanced membrane electrode assembly (MEA).

Secondly, in energy storage, the group remarked on the importance of developing organic batteries, specifically those utilising redox-active organic molecules, which offer more sustainable chemistry and easier synthesis compared to traditional inorganic ones.

Lastly, the group underscored the importance of not only identifying materials to achieve desired performances but also understanding how to efficiently synthesise and scale these materials. They noted the critical need to bridge the gap between theoretical research and pilot-

[18] Sustainable is understood throughout the report as being at the convergence of environmental, social and economic dimensions.

[19] https://single-market-economy.ec.europa.eu/sectors/raw-materials/areas-specific-interest/critical-raw-materials_en

scale testing, particularly for scaling up production.

2.2.3 Group C

Group C selected the following signals and micro-clusters as most interesting to explore:

- **Next-Gen Batteries (62)**
- **Semi-solid and solid state batteries (150)**
- **Transparent perovskite solar cell (840)**
- **Electrochemical water treatment (e.g. capacitive de-ionization, electrocatalytic oxidation etc.)**

The group selected the following as **wild cards** (see Section 1.4.3):

- **Solid state battery recycling (77)**
- **3D printing of electrode materials for energy and environmental engineering applications**

During the discussion, group C highlighted the importance of transparent photovoltaics and noted that future innovations might shift away from silicon-based technologies. They emphasised the need to invest in technologies like perovskite absorbers, despite their current durability challenges.

Additionally, the conversation underscored the significance of next-generation batteries and their recycling, underlining the need for ongoing innovation and investment in both solar and battery technologies.

2.3 Final results

After further clustering and a final voting step (see section 1.4.3) the following topics were selected as the most interesting for further exploration by the EIC.

2.3.1 Accelerated Material Design / Synthesis

In advanced materials for energy, the integration of AI and automated systems is revolutionising the field, transforming traditional, time-consuming processes into rapid, efficient, and cost-effective methods.

Recent breakthroughs like the use of Google's DeepMind to discover 2.2 million new crystal structures, a leap 45 times larger than the total known substances in scientific history, is a clear example of the potential of AI to accelerate the discovery of new materials and improve products and processes.

Complementing this, Materials Accelerated Platforms (MAPs), combining AI, computational materials science and robotically-driven materials synthesis and characterisation, will accelerate lab-to-market development duration, significantly reducing costs. With ongoing projects like BIGMAP[20] and DECODE[21], MAPs aim to reduce the typical 10-20 year implementation time for new advanced materials lab-to-market time by a factor of 5-10, enhancing technological sovereignty and sustainability.

Together, these breakthroughs underscore the transformative potential of AI in advancing material design and synthesis for energy applications.

[20] The Battery Interface Genome – Materials Acceleration Platform (BIG-MAP) project is part of the large-scale and long-term European research initiative. https://www.big-map.eu/big-map

[21] DE-centralised Cloud labs fOr the inDustrialisation of Energy materials (DECODE) aims to create and demonstrate a cloud platform that will link multiple labs to accelerate materials development and integration for the clean energy technology sector. https://decode-energy.eu/

2.3.2 Biomaterials as part of the circular economy

Recent breakthroughs in biomaterials are transforming sustainable energy solutions, closely aligning with the Safe and Sustainable by Design (SSbD) framework.[22]

Researchers are developing bio-inspired materials that mimic natural processes, such as photosynthesis, to create efficient, eco-friendly energy sources. Innovations include algae-based biofuels and chemicals, offering carbon-neutral renewable alternatives to fossil fuels, and chemicals that enhance the circularity of solar cells and batteries.

Microbial fuel cells, converting organic waste into electricity, further exemplify SSbD principles by integrating waste management with energy production.

These advancements not only provide more sustainable energy solutions but also ensure safety and sustainability throughout the material lifecycle, supporting the EU's green and digital transitions.

2.3.3 Advanced materials allowing new applications

This topic represents a cluster created by the experts to aggregate how the latest discoveries in advanced materials are opening new avenues for energy applications.

Among them, new 2D topological materials have revolutionised thermoelectric technology by significantly enhancing the zT value[23], promising thermoelectric generators with over 50% efficiency, breaking current technological stagnation.

MXene, a unique two-dimensional material, offers exceptional properties for creating lightweight electromagnetic interference (EMI) shielding materials, crucial for spacecraft, aircraft, and smart electronics. Its integration into superelastic and superhydrophobic hybrid sponges highlights its scalability for large-scale production.

Double active membranes for CO_2 capture and conversion into renewable fuels, combine advanced polymers and bi-functional catalysts in a single device, exemplifying advanced material integration.

Additionally, experts raised the topic of hybrid energy storage using aluminium to produce hydrogen, electricity, and heat efficiently, supporting a circular economy with virtually unlimited storage capacity and no geographical restrictions.

These advanced materials are pivotal in driving the future of sustainable energy solutions.

2.3.4 Closed loop battery recycling

Closed loop battery recycling refers to an innovative, sustainable technology designed to manage the entire lifecycle of batteries by extracting and reusing valuable materials. This approach addresses environmental and health concerns associated with battery's end of life, crucial amid the rising demand for lithium-ion batteries in electric vehicles and renewable energy storage.

The process includes collection, sorting, mechanical treatment, hydrometallurgical or

[22] https://research-and-innovation.ec.europa.eu/research-area/industrial-research-and-innovation/chemicals-and-advanced-materials/safe-and-sustainable-design_en

[23] In the context of advanced materials for energy, particularly thermoelectric materials, zT value stands for the dimensionless figure of merit used to evaluate the efficiency of a thermoelectric material. A higher zT value indicates better thermoelectric performance, meaning the material is more efficient at converting heat into electricity or vice versa.

pyrometallurgical processes, and purification of extracted materials for reuse in battery production.

Unlike traditional methods, which extract only a few key materials, closed loop recycling aims to recover and reuse as many materials as possible, aligning with the circular economy model.

This comprehensive method reduces waste and enhances economic viability. However, challenges such as technical complexity and high initial costs need to be addressed to enable wider adoption of this transformative technology.

2.3.5 Innovations in catalysis

Recent breakthroughs in advanced materials for energy have led to significant innovations in catalysis. Areas where there is particular innovation include the development of iridium-free catalysts for Proton Exchange Membrane (PEM) electrolysers and more sustainable membranes. Iridium-free catalysts, using abundant materials like transition metals and novel composites, will offer a sustainable and cost-effective alternative to traditional iridium-based catalysts, enhancing the scalability and economic viability of hydrogen production.

Complementing this, bio-polymer based and eco-friendly membranes, derived from renewable resources, provide excellent performance while minimising environmental impact. Together, these innovations reduce reliance on critical raw materials and promote sustainability in hydrogen production.

Additionally, heterojunction catalysts, combining different materials at the atomic level, and advancements in Sustainable Aviation Fuel (SAF) technology further illustrate the potential of catalytic innovations to transform energy systems by improving efficiency, reducing costs, and supporting the circular economy.

2.3.6 Organic batteries for sustainable energy storage

Organic batteries, utilising redox-active organic molecules, are emerging as a transformative solution to the challenges faced by traditional battery technologies. With the EU's ambitious goal of a fossil-fuel-free society by 2050, there is a pressing need for sustainable and scalable energy storage systems.

Rechargeable batteries, reliant on Lithium, Nickel, and Manganese, are projected to encounter raw material shortages within the next decade[24]. Organic batteries offer an innovative alternative by enabling efficient and reversible electron absorption and release using renewable materials. In addition, if using non-toxic biodegradable materials, these batteries will be easier to recycle when compared with those using heavy metals. This simplifies disassembling, requires less energy, and reduces environmental hazards. The absence of toxic components makes the recycling process safer and more eco-friendly, contributing to sustainable and environmentally responsible energy storage solutions.

This breakthrough technology addresses both raw material scarcity and enhances the sustainability and safety of energy storage (as described in Section 2.3.3), supporting the future of electric mobility and renewable energy systems in alignment with the EU’s Green Deal goals.

2.3.7 Design to performance batteries

In the field of advanced materials for energy, design to maximise performance batteries are driving significant advancements in battery technology. Semi-solid and solid-state batteries replace traditional liquid electrolytes,

[24] https://single-market-economy.ec.europa.eu/sectors/raw-materials/areas-specific-interest/critical-raw-materials_en

enhancing energy density and enabling fast charging.

This innovation, if combined with less expensive productions processes, could be crucial for scaling up and reducing costs associated with the electrification of mobility, where high voltage and high energy is key. Integrating silicon nanostructures into anodes, alongside traditional graphite, further increases energy density, supporting this transition to electric vehicles.

Another promising development is the Li-sulphur battery, which combines a lithium-metal anode with a sulphur cathode. Although still in early stages, with only hundreds of cycles tested, Li-sulphur batteries show potential for improved and longer-lasting performance. They would allow for reduced reliance on conventional critical raw materials, within the same energy density range of Li-ion batteries, addressing range anxiety in electric vehicles.

2.3.8 Design to cost batteries

In the realm of advanced materials for energy, design to cost batteries are at the forefront of recent innovations, aiming to reduce costs while enhancing performance. This includes using low-cost, affordable materials with moderate voltage and energy density.

Multivalent batteries, which utilise ions with multiple charge states like magnesium or aluminium, potentially offer higher energy density and lower production costs compared to traditional lithium-ion batteries. Despite challenges in ion movement and efficiency, these batteries hold promise for improving energy storage in electric vehicles and stationary applications.

Complementing this, Next-Gen batteries, such as sodium-ion, aqueous, lithium-sulphur, and metal-air technologies, are being developed to address the growing scarcity of critical raw materials like cobalt and lithium.

2.3.9 Electrochemical water treatment

Electrochemical water treatment leverages advanced materials and techniques to enhance the efficiency and effectiveness of water purification, allowing its further use for different energy applications (water-energy nexus) such as renewable hydrogen production, thereby aligning with sustainable energy goals.

Key technologies include Capacitive Deionisation (CDI) and Electrocatalytic Oxidation. CDI utilises an electric field to adsorb charged particles like salts onto electrode surfaces, making it ideal for desalination and water softening due to its energy efficiency and circularity.

Electrocatalytic Oxidation uses electrocatalysts to produce reactive species, such as hydroxyl radicals, that break down organic contaminants, effectively treating wastewater and pollutants resistant to conventional methods.

These innovations provide scalable, sustainable water treatment solutions, crucial for energy applications using high purity water.

2.3.10 Wild card final selection

As mentioned in Sections 1.2.2 and 1.2.3, each group selected a short-list of signals as wild cards. During the plenary, participants considered those results and selected the following signals as their final wild cards:

Circularity of materials, SSbD Safe and sustainable by design framework

This framework integrates safety, sustainability, and environmental considerations into material and product design, ensuring non-toxic, resource-efficient, and circular-by design materials and minimising energy use and emissions.

Membranes / separators, as a horizontal topic

Membranes are a key enabler throughout the field of advanced materials for energy.

Membranes are thin, selective barriers used in energy applications to enhance efficiency and safety. They enhance ion transport in batteries, boost energy conversion in fuel cells, and enable efficient water treatment. Innovations in membranes will facilitate better performance, faster charging, and environmentally friendly energy solutions.

Following recent initiatives from the EC to phase out per- and polyfluoroalkyl substances (PFAS)[25], that have been associated with many cases of persistent soil and water contamination (including drinking water), the development of non-perfluorinated membranes is key for the sustainability dimension of these components.

Process optimisation

Process optimisation involves refining material synthesis and manufacturing techniques to enhance efficiency, scalability, and performance of advanced materials large scale manufacturing. Special attention is given to AI-driven methods and advanced simulations that accelerate materials design, streamline production, reduce waste, and lower costs.

3D printing of electrode materials for energy and environmental engineering applications

3D printing of electrode materials leverages additive manufacturing to create precise, customisable electrode structures for batteries, electrolysers, fuel cells, and environmental sensors. Some of the innovations in the field include using materials like graphene and metal-organic frameworks (MOFs) to boost conductivity and performance.

Use of AI for the study of Materials

AI is revolutionising the study of materials by predicting material properties, streamlining synthesis, and enhancing performance. These wild cards are mostly represented in the top signals presented previously. The aim of this step is to list a specific set of topics, bearing the most novelty and disruptiveness potential.

The full list of items that received votes, as well as the signals that were selected to support each topic, are listed in Annex 1.

More details on the full set of signals that were collected and considered for this process, can be found in Annex 2.

2.4 Drivers, enablers and barriers

Participants were invited to identify drivers, enablers and barriers that could affect the development and take-up of technologies and innovations in advanced materials for energy, with a particular focus on those selected in the previous step.

Some of these contextual factors can act in multiple ways. For example, standards can hinder through stifling innovation, or can enable by creating an environment for interoperability.

Regulations can also play multiple roles, namely acting as barriers for development of novel solutions, but on the other hand, driving and aligning those innovations with ethical and legal frameworks.

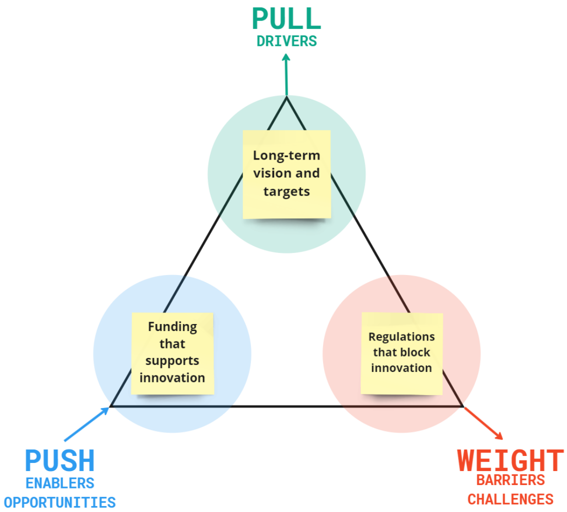
In that sense, emphasis was on identifying the factor rather than finding the ideal categorisation. These insights provide a complementary view regarding the main issues affecting the space sector and provide potential input for further discussion.

The contributions were mapped through an adapted version of the "Futures Triangle"

[25] https://environment.ec.europa.eu/strategy/chemicals-strategy/implementation_en / https://echa.europa.eu/hot-topics/perfluoroalkyl-chemicals-pfas

framework[26]. They are not intended to be an exhaustive list rather, indicate the issues raised by the participants.

Figure 3. Visual representation of the adapted version of the "Futures Triangle" framework used in the workshop, including some examples given to the participants.



Source: Authors.

The main elements highlighted by the participants are listed below.

2.4.1 Drivers

Drivers are considered as guiding forces, elements that pull new developments.

Governance and Compliance

Governance and compliance can foster the advancement and adoption of advanced materials. Environmental regulations push industries towards sustainable practices, incentivising innovations that reduce environmental impact.

EU policy mandates a "safe and sustainable by design" approach, ensuring new materials meet rigorous safety and environmental standards from their development phase. Tax incentives for Carbon Capture, Utilisation, and Storage (CCUS) encourage investment in these technologies by offsetting initial costs.

A risk-taking mindset within governance supports innovation by promoting the exploration and fast adoption of advanced materials, driving forward technological progress and regulatory compliance.

Funding

Funding plays a crucial role as a driver in the development of advanced materials by providing essential financial resources. Grant funding for scale-ups facilitates the transition from experimental prototypes to market-ready products, enabling companies to overcome the 'valley of death' in technology development.

Private capital introduces vital investment, often bringing not just money but also business expertise and market connections. New research calls can focus funding on cutting-edge topics, stimulating innovation and encouraging the scientific community to address emerging challenges and opportunities. This combination of public and private funding sources drives forward significant advancements and commercialisation in the sector.

Collaboration and Knowledge Exchange

Collaborating and exchanging knowledge can drive the adoption and innovation of advanced materials. Integrating new materials with existing manufacturing processes ensures a smoother transition and faster adoption in industrial settings, mitigating resistance from entrenched systems.

A dedicated platform for collaboration enhances opportunities by connecting diverse stakeholders, including researchers, industry

[26] Inayatullah, S. (2023). *The Futures Triangle: Origins and Iterations*. World Futures Review, 15(2-4), 112-121. https://doi.org/10.1177/19467567231203162

experts, and regulators. This not only fosters mutual learning and innovation but also accelerates the development of tailored solutions that meet specific industry needs, creating a synergistic effect that propels the entire field forward.

Industry and Market Dynamics

Industry and Market Dynamics are powerful drivers in the development and adoption of advanced materials. Market-driven performance requirements ensure that innovations align with consumer expectations and regulatory standards, promoting materials that meet specific efficiency, durability, and environmental criteria. Opportunities and demands arising from industry needs catalyse the development of new materials to address specific challenges or gaps in the market. This responsiveness to market signals not only fuels competitive advantage but also ensures that the advancements in materials are practical, sustainable, and aligned with real-world applications.

Sustainable and Efficient Development

Sustainable and efficient development drives the evolution of advanced materials with a focus on environmental and economic sustainability. Cost-effectiveness of production is crucial, encouraging the development of materials that are affordable to produce at scale while maintaining quality and performance. Embracing a circular economy model addresses environmental impacts by promoting the reuse and recycling of materials, reducing waste, and conserving resources. One example is the push for more energy-efficient water treatment technologies supporting decentralisation and allowing for local processing and reducing the ecological footprint associated with large centralised systems. This holistic approach ensures that material innovations are both economically viable and environmentally responsible.

Infrastructure and Technologies

The development of EU infrastructure dedicated to the scale-up of advanced material manufacturing is crucial for driving innovation in the field. This includes creating specialised facilities and technology hubs that provide the necessary equipment and technological support to transition from lab-scale prototypes to industrial-scale production. Such infrastructure not only enhances the capacity for innovation but also reduces the time to market for new materials, aligning with broader economic and sustainability goals by fostering a robust ecosystem for advanced material development within the EU. By rapidly producing and testing a large number of advanced materials for energy applications (High throughput testing), researchers can identify promising candidates and optimise their properties more quickly.

2.4.2 Enablers

Enablers provide opportunities for further development and give a push to the technologies.

Industry and Market Dynamics

Corporate sustainability, which encompasses environmental, social, and economic aspects, is a key element of industry and market dynamics as an enabler of innovation in advanced materials. Adopting sustainable practices encourages companies to develop advanced materials and production methods that minimise resource consumption, waste, and environmental impact. This fosters innovation, creating new market opportunities and competitive advantages for businesses, while addressing global challenges such as climate change and resource scarcity. Additionally, sustainable practices can improve a company's reputation and brand image, attracting socially conscious customers and investors, ultimately leading to increased market share.

Collaboration and Knowledge Exchange

Workshop participants highlighted the importance of knowledge transfer programs and interdisciplinary collaboration between material scientists and engineers as key enablers, as well as drivers, for technology development and uptake in the field of advanced materials for energy. Additionally, fostering multidisciplinary connections and synergies among industry researchers, entrepreneurs, investors and scientists across the European Union was identified as crucial for promoting innovation and driving progress. By facilitating these collaborations and knowledge sharing, barriers to technology development and adoption can be overcome, ultimately accelerating the deployment of advanced materials for energy applications. Sustainability and techno-economic assessment evaluates the environmental, social, and economic impacts of advanced materials for energy, ensuring that they contribute to a sustainable future while remaining cost-effective and competitive. This is crucial for identifying the most promising solutions and guiding the development of the energy sector.

Talent Development

Boosting Europe's AI talent and implementing entrepreneurial training programs for young researchers were identified as key enablers for technology development and uptake in the sector. By investing in the training and development of AI specialists and young researchers with an entrepreneurial mindset, Europe can nurture a skilled workforce capable of driving innovation and addressing complex challenges in the energy field. This, in turn, can contribute to overcoming barriers to technology adoption and fostering a culture of collaboration and progress.

Tools and methods

Advanced methods, equipment, and techniques that can rapidly and accurately measure the performance and efficiency of energy devices, such as batteries, fuel cells, and solar cells enable researchers to evaluate materials and designs more quickly. This in turn accelerates the development and optimisation of advanced materials for energy applications. By reducing the time and resources required for testing, this approach promotes innovation and allows for faster technology deployment, contributing to a more sustainable and energy-efficient future.

2.4.3 Barriers

Barriers are factors that do (or could) hinder technological advances.

Governance and Compliance

Environmental concerns related to manufacturing processes can lead to increased scrutiny and potential restrictions, discouraging investment and innovation. Standardisation difficulties can create inconsistencies and hinder collaboration, slowing down progress. Finally, stringent certifications can prolong the time and resources required for technology validation, making it more difficult for innovative solutions to reach the market and gain acceptance.

Supply Chain and Raw Materials

Limited access to critical raw materials can hinder research, development, and production of advanced energy technologies, while the abundance of low-cost imported materials can disincentivise the creation of more sustainable, locally-sourced alternatives. These challenges can hinder EU strategic autonomy and create reliance on foreign markets and impede the growth of a robust domestic industry, ultimately slowing down innovation.

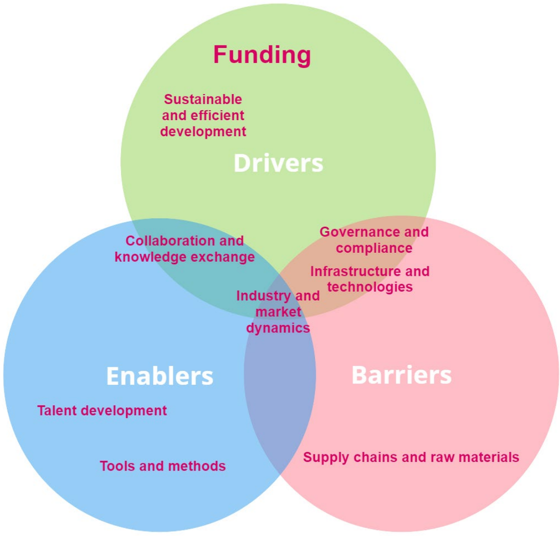
Infrastructure and Technologies

The field of advanced materials for energy faces several barriers to innovation, including process scalability, reproducibility, and standardisation. There is also a lack of infrastructure for collaboration and manufacturing, and challenges in moving from the lab to the demonstration stage. These barriers can hinder the development and commercialisation of advanced materials and technologies by making it difficult to scale up production, ensure consistent results, and establish collaborations among researchers, manufacturers, and investors. Additionally, the energy consumption required to produce advanced materials can pose challenges in terms of sustainability and cost-effectiveness.

Industry and Market Dynamics

Limited funding in the EU, compared with the US or China hinders research and development, as well as the commercialisation of advanced materials for energy, making it difficult for European innovators to compete globally. Additionally, the energy industry may be hesitant to adopt new materials due to concerns about reliability, performance, and integration with existing infrastructure, and does not always engage with researchers, resulting in a lack of understanding of their needs. Lengthy development cycles can make it difficult for innovative solutions to reach the market in a timely manner, reducing their potential impact on the energy sector. High costs and poor scalability can make it difficult for advanced materials to achieve cost-competitiveness and therefore widespread adoption.

Figure 4. Analysis of identified contextual factors to highlight potential overlaps.



Source: Authors.

3 Conclusions

The results presented earlier, will support the strategic intelligence activities of the EIC and may be used to inform future funding topics for EIC Challenges and other EC calls.

Further to these, the following conclusions have been drawn by the authors from the various exercises throughout the workshop and experts' discussions, across three main areas: policy, technology enablers and the business and innovation ecosystem. These can provide complementary insights for policy-makers and the EIC in their mission to support the field of Advanced Materials for Energy, including potential additional policy actions in this domain.

These conclusions should be considered in the context of the five strategic pillars identified by the European Commission in its communication on Advanced Materials for industrial Leadership[27]:

- Pillar 1- European R&I
- Pillar 2- Lab to Fab
- Pillar 3 Capital Investment & Finance
- Pillar 4.- Production & Use
- Pillar 5- Governance

In this Communication, the Commission outlines a European strategy aimed at achieving industrial leadership in advanced materials. Advanced materials play a significant role in the competitiveness of European industries and are essential components of the EU's resilience and open strategic autonomy. They are also part of the 10 critical technology areas vital for the Union's economic security[28].

As mentioned in the introduction, energy is identified as a priority for advanced materials R&I, alongside mobility, construction and electronics, in the EC's communication on Advanced Materials for industrial Leadership. However, energy is itself an enabler for the other 3 priorities, namely though new solutions to power electronic devices, vehicles and the built environment.

3.1 Policy

Two main policy aspects were discussed during the workshop. The importance of adopting a circularity mindset was emphasised. This involves progressing from traditional recycling approaches to implementing the Safe and Sustainable by Design (SSbD) framework. By prioritising SSbD principles, the reliance on recycling can be reduced, thereby lowering associated costs and promoting sustainable practices from the outset.

Furthermore, the issue of fluorine chemistry in advanced materials for energy was addressed, noting the significant challenges posed by recent regulatory changes in Europe. These regulations are tightening the use of fluorine due to its toxicity, posing substantial challenges for electrolysers that rely on fluorine-containing compounds for high efficiency and durability. The development of safer alternatives or advanced mitigation strategies is necessary to ensure compliance with new standards while maintaining performance.

3.2 Technology Enablers

Technology Enablers of Advance Materials

In the realm of advanced materials for energy, several technology enablers are driving

[27] https://op.europa.eu/en/publication-detail/-/publication/38970bfd-d61e-11ee-b9d9-01aa75ed71a1/language-en/format-PDF/source-search

[28] https://defence-industry-space.ec.europa.eu/commission-recommendation-03-october-2023-critical-technology-areas-eus-economic-security-further_en

innovation and efficiency. Two were highlighted specifically.

AI and computational materials science play a pivotal role in data harvesting, studying materials, designing new materials, and exploring their applications. These technologies accelerate discovery and optimisation processes, enabling faster development cycles. This is especially relevant as the future of advanced materials for energy is increasingly influenced by geopolitical challenges, such as supply chain disruptions and resource scarcity.

To address these issues and accelerate the development of new materials, the integration of AI is becoming essential. This speed is crucial for maintaining energy security and technological leadership amidst global uncertainties. By enhancing the pace of innovation, AI supports the swift development and deployment of advanced energy materials.

Advances in membranes and separators were identified as crucial, as separation science significantly enhances the performance and efficiency of energy systems.

Advanced materials as an enabling technology

It is important to note the potential of the field of advanced materials, specifically, 2D materials[29], to be transformative across many sectors, from agriculture to space. Questions arose regarding the relative disregard of this topic during the workshop despite its evident impact. It was widely agreed that identifying and involving specialists proficient in 2D materials in the future would be crucial for advancements in other domains.

3.3 Developing an Advanced Materials Ecosystem

The sector of advanced materials for energy faces a considerable challenge in bridging the gap between emergent technologies and industrial readiness. Academic research frequently concentrates on ideal conditions, often overlooking real-world engineering and device issues. For instance, in electrolysis, the production of electrodes and coatings at the scale required for future markets, projected to be in the hundreds of gigawatts by 2030, poses significant scalability challenges.

Here again, AI and computational tools are essential for rationally designing and accelerating the selection of materials suitable for large-scale production. Emphasising high-scale manufacturing processes is crucial for translating laboratory innovations into practical applications.

Some experts stressed the idea that it is important to find utility in the research. It can sometimes seem that research isn't that useful: projects might be scientifically valid but need to show tangible benefits or applications to be considered useful in a broader context.

In that sense, it is relevant to underscore the complementary but distinct roles of the European Research Council (ERC) and the European Innovation Council (EIC) within the European funding landscape. The primary focus of the ERC is the research of ideas, fostering groundbreaking scientific discoveries and theoretical advancements. In contrast, the EIC emphasises the application of research, supporting projects that translate scientific discoveries into real-world applications, thereby driving technological advancements and commercial viability. By maintaining this distinction, the ERC and EIC

[29] 2D materials offer unique electronic, mechanical, and thermal properties due to their atomic thinness. These properties enable advancements in electronics, sensors, energy storage, and optoelectronics. Their high surface area and reactivity also make them ideal for catalysis applications.

promote both fundamental research and its application, fostering a robust innovation ecosystem.

Investing in research and innovation is vital to sustainable progress, particularly in developing new talent for designing advanced materials, promoting interdisciplinarity (material scientists working with engineers) and creating connections & synergies between all the actors of the EU ecosystem of innovation (e.g. researchers, scientists, innovation managers, investors and policymakers).

3.4 Key role of public funding

The field of advanced materials involves long-term processes that are inherently risky and costly. Public funding can play a crucial role in reducing these risks. This funding, as expressed by the experts, should support not only the development of new materials but also the processes necessary for their implementation. Advanced materials are essential for the EU's strategic autonomy as they are critical to achieving digital and green transitions, ensuring progress towards sustainability and technological innovation, aligning with the EU's strategic objectives.

Nevertheless, and as previously mentioned, private capital introduces vital investment to accelerate the scale-up and market entry of advanced materials.

List of abbreviations and definitions

Abbreviations	Definitions
AI	Artificial intelligence
BIG-MAP	Battery Interface Genome – Materials Acceleration Platform
CCFOR	Competence Centre on Foresight
CCU	Carbon Capture and Utilisation
CCUS	Carbon Capture, Utilisation and Storage
DECODE	De-centralised cloud labs for the industrialisation of Energy materials
EC	European Commission
ETSI	European Telecommunications Standards Institute
CEN	The European Committee for Standardization
CENELEC	European Committee for Electrotechnical Standardization
CDI	Capacitive Deionization
EIC	European Innovation Council
EISMEA	European Innovation Council and SMEs Executive Agency
EMI	Electromagnetic Interference
EU	European Union
HS	Horizon scanning
ISO	International Organization for Standardization
JRC	Joint Research Centre (the scientific service of the European Commission)
MAP	Material Acceleration Platform
PEM	Proton Exchange Membrane
PM	Programme Manager
SSbD	Safe and Sustainable by Design
SAF	Sustainable Aviation Fuel
TIM	Tools for Innovation Monitoring
TRL	Technology Readiness Level
R&I	Research and Innovation
SMEs	Small and Midsize Enterprises
STEP	Strategic Technologies for Europe Platform
WP	Work package

List of figures

Annexes

Annex 1. Full list of topics (signals and clusters) that received votes in plenary

Topics in green were selected as the final list. Non-numbered topics (including both signals and clusters) were proposed by participants during the workshop. For more details on numbered signals see annex 2.

	Foundational Infrastructure - Accelerated Material Design / Synthesis • DeepMind discovers 2 millions new materials (135) • Material Acceleration Platforms - MAPs (712)	8 votes
	Biomaterials as part of the Circular Economy (SSbD)	6 votes
	Advanced materials allowing new applications • New 2D topological materials (918) • MXene (563) • Organic batteries for sustainable energy storage (713) • Double active membranes for CO2 capture and management (704) • Hybrid energy storage with aluminium (710)	6 votes
	Closed loop battery recycling (835)	5 votes
	Innovations in catalysis • Sustainable aviation fuel (838) • Heterojunction catalysts (857) • Ir-free catalysts for PEM Electrolysers • Biopolymer or greener membranes for electrolyser	5 votes
	Organic batteries for sustainable energy storage (713)	4 votes
	Design to performance batteries • Semi-solid and solid state batteries (150) • Silicon anodes (149) • Li-sulphur batteries (697)	3 votes
	Design to cost batteries • Next-Gen Batteries (62)	3 votes
	Electrochemical water treatment (e.g., capacitive de-ionization, electrocatalytic oxidation etc.)	3 votes
	Semi Solid and Solid-State Batteries (150)	2 votes
	Next-Gen Batteries (62)	2 votes
	Transparent perovskite solar cell (840)	2 votes
	Fuels	2 votes
	Material Acceleration Platforms - MAPs (712)	2 votes
	Self-healing ionogel (866)	1 vote

Annex 2. Full list of signals sent to participants before the workshop.

For more information on the signal collection, please see section 2.1

NUMBER | TITLE
46 | Paper-thin solar cells that are easily integrated into other materials
UNDERLYING TECHNOLOGY OR INNOVATION
Flexible solar cells
SUGGESTED MATURITY
Novel (TRL 1-3)
SUMMARY DESCRIPTION
Researchers develop a scalable fabrication technique to produce ultrathin, lightweight solar cells that can be seamlessly added to any surface. These durable, flexible solar cells, which are much thinner than a human hair, are glued to a strong, lightweight fabric, making them easy to install on a fixed surface. They can provide energy on the go as a wearable power fabric or be transported and rapidly deployed in remote locations for assistance in emergencies. They are one-hundredth the weight of conventional solar panels, generate 18 times more power-per-kilogram, and are made from semiconducting inks using printing processes that can be scaled in the future to large-area manufacturing.
SOURCE
MIT News https://news.mit.edu/2022/ultrathin-solar-cells-1209

(CCFOR)

NUMBER | TITLE
62 | Next-Gen Batteries
UNDERLYING TECHNOLOGY OR INNOVATION
Lithium ion batteries
SUGGESTED MATURITY
Emerging (TRL 4-6)
SUMMARY DESCRIPTION
Next-Gen Batteries refer to the developments in battery technology that offer benefits like greater sustainability, energy efficiency, and lower costs. Factors driving battery innovation include the increased demand for sustainable and lightweight rechargeable batteries used in electric vehicles (EVs) and consumer electronics and a growing shortage of rare metals like cobalt and lithium used in current batteries. New battery technology, including sodium-ion, aqueous, lithium-sulfur, and metal-air batteries, have rising expectations but require further research and development (R&D). Solid-state battery technology also is under development which promises faster charging, better safety and higher energy density.
SOURCE
ITONICS https://www.itonics-innovation.com/blog/trends-and-technologies-in-automotive-industry

(CCFOR)

NUMBER | TITLE
77 | Solid state battery recycling
UNDERLYING TECHNOLOGY OR INNOVATION
solid state batteries
SUGGESTED MATURITY
Novel (TRL 1-3)
SUMMARY DESCRIPTION
Since solid state batteries (SSBs) have such new manufacturing processes, they have not yet reached their pinnacle; thus more scrap is expected to be generated in the ramp up of SSB factories. There are some innovations in the recycling of SSBs such as supramolecular electrolytes which enable high qulaity recycling but this is still at early stage. This is important as there is a potential for a much larger lithium (Li) content to be returned via recycling as the anode is typically made of Li metal. Lithium is listed as highly critical on the EU's critical raw materials list.
SOURCE
MIT Technology Review https://www.technologyreview.com/2023/01/09/1066394/10-breakthrough-technologies-2023/#battery-recycling

(CCFOR)

NUMBER | TITLE
91 | Accelerating the shift from thermal energy to electrical energy to produce lower emission fuels
UNDERLYING TECHNOLOGY OR INNOVATION
Haber-Bosch process / carbon neutral fuels
SUGGESTED MATURITY
Close to market (TRL 7-9)
SUMMARY DESCRIPTION
The move from thermal energy in ammonia synthesis to electric energy is seen in the chemical industry and is done via a reverse water-gas shift process. The move from thermal energy in ammonia synthesis to electric energy is seen in the chemical industry and is done via new routes today such as electrochemical synehthsis of ammonia, plasma technology, or other novel electrochemical synthesis routes (such as hydrogen permeable membranes or electrocatalytic nitrogen reduction). This represents a paradigm shift, of obtaining carbon neutral fuels from electrochemcial processes instead of thermochemical processes.
SOURCE
International Energy Agency https://iea.blob.core.windows.net/assets/a86b480e-2b03-4e25-bae1-da1395e0b620/EnergyTechnologyPerspectives2023.pdf

(CCFOR)

NUMBER | TITLE
92 | Alternative fuel production
UNDERLYING TECHNOLOGY OR INNOVATION
Carbon capture
SUGGESTED MATURITY
Close to market (TRL 7-9)
SUMMARY DESCRIPTION
The Intergovernmental Panel on Climate Change (IPCC) highlighted the importance of deliberate carbon dioxide removal (CDR) for achieving net-zero or net negative CO_2 emissions. Carbon Capture and Storage (CCS) is pivotal in this transition, bridging the gap until more advanced carbon-neutral or negative technologies are developed. Utilizing captured CO_2, rather than just storing it, enhances the economic feasibility of CCS. This captured CO_2 can be transformed into synthetic fuels, plastics, concrete, and chemical reactants, offsetting capture costs. A US-based startup is currently retrofitting building cooling towers for atmospheric CO_2 capture, selling the CO_2 and sharing profits to reduce operational expenses. Concurrently, the shift towards a hydrogen economy, powered by green hydrogen, is crucial for decarbonizing industries like chemical production and transportation. While technologies like CCS and Pollution Capturing Devices are essential in the energy transition and in repurposing carbon, they are not ultimate solutions. The primary goal remains decarbonization.
SOURCE
ITONICS https://www.itonics-innovation.com/blog/accelerating-energy-transition-through-foresight

(CCFOR)

NUMBER | TITLE
103 | Material with beetle nanostructure for efficient solar reflectivity
UNDERLYING TECHNOLOGY OR INNOVATION
Cooling ceramic
SUGGESTED MATURITY
Novel (TRL 1-3)
SUMMARY DESCRIPTION
Scientists at City University of Hong Kong (CityU) have developed a new cooling ceramic material with a solar reflectivity of 99.6%, which is a record high, along with an infrared thermal emission of 96.5%. The alumina structure is inspired by the Cyphochilus beetle. The nano(aluminia)structrure allows for higher reflectivity which makes the distribution of the sunlight better. The application discussed in this article are buildings.
SOURCE
New Atlas https://newatlas.com/materials/ultra-white-ceramic-cools-buildings-record-high-reflectivity/

(CCFOR)

NUMBER | TITLE
106 | Multivalent batteries for lower cost chemistries
UNDERLYING TECHNOLOGY OR INNOVATION
Lithium-ion batteries
SUGGESTED MATURITY
Emerging (TRL 4-6)
SUMMARY DESCRIPTION
A multivalent battery is a rechargeable battery that uses ions with multiple charge states, such as magnesium or aluminum, during charging and discharging. This allows for higher energy density and lower production costs compared to traditional lithium-ion batteries. Multivalent batteries also have potential safety advantages. However, they face challenges in terms of ion movement, efficiency, and suitable electrode materials. Despite these challenges, multivalent batteries are being actively researched for their potential to improve energy storage in applications like electric vehicles and grid storage.
SOURCE
Tech Xplore https://techxplore.com/news/2023-11-blueprint-high-performance-batteries.html

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NUMBER | TITLE
113 | Low iridium electrolyzer
UNDERLYING TECHNOLOGY OR INNOVATION
Electrolysis
SUGGESTED MATURITY
Emerging (TRL 4-6)
SUMMARY DESCRIPTION
Proton exchange membrane (PEM) electrolyzers use catalyts which contain iridium which is a highly scarce material. Researchers at TNO have been the first to develop a method that will require 200 times less iridium while maintaing a performance of 25% - 46% of current state of the art. A patent application has been made for this method which includes application of spatial atomic layer deposition which allows you to apply a thin layer of material to a large surface area.
SOURCE
TNO https://www.tno.nl/en/newsroom/2022/10/breakthrough-electrolyser-development/

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NUMBER | TITLE
127 | Tuning the 'charge density' knob so super-conductors can operate at room temperature
UNDERLYING TECHNOLOGY OR INNOVATION
Superconductors
SUGGESTED MATURITY
Novel (TRL 1-3)
SUMMARY DESCRIPTION
Right now, superconductors can operate only at very cold temperatures. So, finding one that could work at room temperature without needing to be kept in a cold chamber could revolutionize power electronics. Scientists have discovered a new link between superconductivity and charge density waves, which could help in the search for room-temperature superconductors. The majority of superconducting materials currently operate at extremely cold temperatures, making them impractical for widespread use. The researchers found that the superconductivity of a material called yttrium barium copper oxide (YBCO) was connected to the density of electrons in the material. By altering the superconductivity, they were able to manipulate the charge density waves.
SOURCE
Yale News https://news.yale.edu/2022/05/19/new-step-search-room-temperature-superconductors

(CCFOR)

NUMBER | TITLE
135 | DeepMind discovers 2m new materials
UNDERLYING TECHNOLOGY OR INNOVATION
Artificial intelligence
SUGGESTED MATURITY
Novel (TRL 1-3)
SUMMARY DESCRIPTION
Researchers at Google DeepMind have used artificial intelligence (AI) to discover 2.2 million crystal structures, opening up possibilities in renewable energy and advanced computation. The team used an AI tool called GNoME to identify theoretically stable combinations that have not yet been experimentally realised. This trove of structures is 45 times larger than the number of known substances in the history of science. The researchers plan to make 381,000 of the most promising structures available to other scientists for testing in fields such as solar cells and superconductors. The use of AI in this way can accelerate the discovery of new materials and improve products and processes.
SOURCE
Financial Times https://www.ft.com/content/f841e9e0-c9c6-49ab-b91c-6d7bea2a3940

(CCFOR)

NUMBER | TITLE
148 | Low cost stationary energy storage
UNDERLYING TECHNOLOGY OR INNOVATION
Pumped hydro
SUGGESTED MATURITY
Emerging (TRL 4-6)
SUMMARY DESCRIPTION
Well-established energy storage technologies exist and can be used for grid balancing. However, more technlogies and innovation is needed to reduce cost of manufacturing. McKinsey imagines lower-cost and higher-performing materials such as sulfur and silicon to improve stationary batteries.
SOURCE
McKinsey https://www.mckinsey.com/capabilities/sustainability/our-insights/what-would-it-take-to-scale-critical-climate-technologies

(CCFOR)

NUMBER | TITLE
149 | Silicon anodes
UNDERLYING TECHNOLOGY OR INNOVATION
Graphite anodes; Lithium ion
SUGGESTED MATURITY
Emerging (TRL 4-6)
SUMMARY DESCRIPTION
Replacing some share of graphite in the anode with silicon nanostructures helps increase energy density of lithium ion batteries. This is important as it can help scale and reduce costs association with the electification transition for vehicles.
SOURCE
McKinsey https://www.mckinsey.com/capabilities/sustainability/our-insights/what-would-it-take-to-scale-critical-climate-technologies

(CCFOR)

NUMBER | TITLE
150 | Semi solid and solid state batteries
UNDERLYING TECHNOLOGY OR INNOVATION
Lithium-ion batteries
SUGGESTED MATURITY
Emerging (TRL 4-6)
SUMMARY DESCRIPTION
Switching the traditionally liquid electrolyte in the lithium ion battery to semi-solid-state and solid-state to store more energy per kilogram of battery weight leads to advances in fast charging and energy density. This is important as it can help scale and reduce costs association with the electification transition for vehicles.
SOURCE
McKinsey https://www.mckinsey.com/capabilities/sustainability/our-insights/what-would-it-take-to-scale-critical-climate-technologies

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NUMBER | TITLE
169 | Hafnium oxide thin films
UNDERLYING TECHNOLOGY OR INNOVATION
Metals deposition
SUGGESTED MATURITY
Novel (TRL 1-3)
SUMMARY DESCRIPTION
Hafnium oxides thin films have a wide range of potential applications in various high-tech fields, including optics, integrated circuits, and flexible and wearable electronics. The films exhibit excellent mechanical, thermal, and chemical stability, which makes them ideal for use in harsh environments. They also have desirable properties such as high dielectric constant, thermal stability, and good adhesion to neighboring layers, making them a promising material for future generations of ultra-large scale integrated circuits (ULSI). Recent studies have focused on optimizing the properties of hafnium oxide thin films through various techniques such as thermal annealing, plasma-enhanced atomic layer deposition (PEALD), and chemical bath deposition. The resulting films have shown improved mechanical, electrical, and thermal properties, as well as promising ferroelectric behavior. These advancements have led to the development of new applications such as resistive switching memories, ferroelectric field-effect transistors, and microelectronic cooling and solid-state refrigeration. Overall, hafnium oxide thin films have the potential to contribute significantly to energy savings and the development of more efficient and reliable electronic devices.
SOURCE
TIM signals. Sources used in the signal's detection and description include, but are not limited to: http://doi.org/10.1016/j.jnoncrysol.2006.10.041 ; http://doi.org/10.1149/1.3456551 ; http://doi.org/10.1039/c6nr08687j ; http://doi.org/10.1016/j.jallcom.2019.152552 ; http://doi.org/10.4028/www.scientific.net/KEM.784.135

(TIM)

NUMBER | TITLE
197 | Meta-crystalline materials for smart materials
UNDERLYING TECHNOLOGY OR INNOVATION
n/a
SUGGESTED MATURITY
Emerging (TRL 4-6)
SUMMARY DESCRIPTION
By replicating the strength-providing structure of metallic crystals in 3D-printed structures, lightweight meta-crystalline materials could have with tailored strength. Manipulating the arrangement of building blocks allows for the creation of smart materials capable of specific responses to stress, such as directing impact forces away from certain areas. This approach enables intentional material designs that can, for example, protect embedded sensors. This work has application in fields from car design to nanotechnology
SOURCE
Imperial College London https://imperialtechforesight.com/20-futures/tf2040/

(CCFOR)

NUMBER | TITLE
225 | 4D printing to self-repair
UNDERLYING TECHNOLOGY OR INNOVATION
n/a
SUGGESTED MATURITY
Emerging (TRL 4-6)
SUMMARY DESCRIPTION
4D printing is similar to 3D printing but uses programmable "smart" materials and designs to create products that can respond to stimuli over time. This adds a fourth dimension to the printing process. 4D printed materials can self-assemble, self-repair, adapt to their environment, or transform in response to specific triggers. By combining different "smart" materials that respond to stimuli, complex structures and behaviors can be achieved. Shape-memory alloys, for example, can be deformed and then return to their original shape when heated. Overall, 4D printing allows for the creation of dynamic, responsive products with a wide range of potential applications.
SOURCE
Government Office for Science – United Kingdom https://assets.publishing.service.gov.uk/media/64219412ba5ac9000cb1a9ce/Summary_Report_-_4D_Printing.pdf

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NUMBER | TITLE
238 | Metamaterials
UNDERLYING TECHNOLOGY OR INNOVATION
Electromagnetism
SUGGESTED MATURITY
Emerging (TRL 4-6)
SUMMARY DESCRIPTION
This technology refers to engineered materials designed to interact with electromagnetic radiation. These structures are very small, which is why they are called meta-atoms. They can interact with the electric and magnetic components of light in a way that natural atoms do not, and could even make substances with which they interact invisible.
SOURCE
Innovate UK https://www.ukri.org/wp-content/uploads/2023/12/IUK-05122023-INO0617_Emerging-Tech-Report_AW2-final.pdf

(CCFOR)

NUMBER | TITLE
270 | Edge computing with stacks of 2D memristive materials
UNDERLYING TECHNOLOGY OR INNOVATION
;#2D Memristors;#
SUGGESTED MATURITY
Emerging (TRL 4-6)
SUMMARY DESCRIPTION
As 2D materials are atomically thin, memristors made of 2D layered materials have exhibited the lowest energy consumption per state transition ever reported for any type of memristor, which may be an important advantage for low-power computation. Due to the atomically thin nature of 2D materials, these possess intrinsically extremely low stiffness and almost zero internal stress. Accordingly, the physical constraints of 3D integration imposed by conventional rigid 3D materials can be completely overcome.
SOURCE
Kang, JH., Shin, H., Kim, K.S. et al. https://doi.org/10.1038/s41563-023-01704-z

(External experts)

NUMBER | TITLE
282 | Strange metals as superconductors
UNDERLYING TECHNOLOGY OR INNOVATION
Superconductors
SUGGESTED MATURITY
Novel (TRL 1-3)
SUMMARY DESCRIPTION
Strange metals are a type of quantum material that exhibit an electrical resistivity at normal temperature. These types of materials have included andpnictide superconductors, ruthenates, heavy fermion metals, and twisted bilayer graphene. Electricty is delivered via these materials in an out of step manner and in a liquid way and hints at the possibility of strange metals becoming superconductors which can operate at normal temps.
SOURCE
Liyang Chen et al. https://www.science.org/doi/10.1126/science.abq6100

(External experts)

NUMBER | TITLE
284 | synthesis of 2D quantum dot materials
UNDERLYING TECHNOLOGY OR INNOVATION
Nanotechnology
SUGGESTED MATURITY
Novel (TRL 1-3)
SUMMARY DESCRIPTION
The innovation here is not the 2D quantum dot materials themselves which are ultra thin dots 1 atom thick. But the novelty is the synthesizing of quantum dot materials of different sizes to achieve continuously tunable band gaps, thereby offering potential for diverse colored light emission, especially for blue light emission. For example, perovskite dots, and carbon dots as representatives of quantum dots, demonstrate the advantages of high color purity, wide color gamut, and continuously tunable emission peak wavelength.
SOURCE
Xu, H., Liu, J., Wei, S. et al. https://doi.org/10.1038/s41377-023-01327-8

(External experts)

NUMBER | TITLE
286 | Harvesting energy from the ambient sources to power nanoelectronics
UNDERLYING TECHNOLOGY OR INNOVATION
Nanotechnology
SUGGESTED MATURITY
Novel (TRL 1-3)
SUMMARY DESCRIPTION
One potential way to bring power to nanoelectronics is to use radiofrequencies where you can have inductive coupling for small chips, to link to the transmitter. Reducing dimensions further into the micrometer and nanometer scale, while also maintaining suitable efficiency, will require corresponding increases in frequency and/or novel approaches for deep subwavelength antennas. The use of metamaterials may be used to achieve high efficiency at subwavelength dimensions.
SOURCE
Phillips, J.D. https://www.frontiersin.org/articles/10.3389/fnano.2021.633931/full

(External experts)

NUMBER | TITLE
288 | Phononic thermal conduction in ScAgC half-Heusler
UNDERLYING TECHNOLOGY OR INNOVATION
Photons
SUGGESTED MATURITY
Novel (TRL 1-3)
SUMMARY DESCRIPTION
This research could be important for enhancing the properties of ScAgC regarding thermoelectric and photovoltaic applications. Basically, the knowledge of phonons is very critical in accounting for many physical properties and behaviours of crystals, such as thermal transport properties, thermal expansion, phase transition, mechanical properties, and certain electrical properties (superconductivity).
SOURCE
Solet, V.K., Pandey, S.K. https://doi.org/10.1140/epjb/s10051-023-00524-z

(External experts)

NUMBER | TITLE
303 | Electrical control of quantum anomalous Hall insulators
UNDERLYING TECHNOLOGY OR INNOVATION
Quantum
SUGGESTED MATURITY
Novel (TRL 1-3)
SUMMARY DESCRIPTION
A quantum anomalous Hall (QAH) insulator is a special material that conducts electricity only along its edges, with the current flowing in a specific direction determined by the material's magnetization. This unique property allows for a highly efficient flow of electricity with no resistance. In a recent study, researchers successfully manipulated the direction of this edge current using a method called thermally assisted spin-orbit torque (SOT). This breakthrough opens up new possibilities for quickly and easily controlling the flow of electricity in these materials, which could have important implications for future electronic devices.
SOURCE
Yuan, W., Zhou, LJ., Yang, K. et al. https://www.nature.com/articles/s41563-023-01694-y

(CCFOR)

NUMBER | TITLE
372 | Green synthesis of nanoparticles
UNDERLYING TECHNOLOGY OR INNOVATION
Nanotechnology
SUGGESTED MATURITY
Emerging (TRL 4-6)
SUMMARY DESCRIPTION
Green synthesis of nanoparticles, using biomolecules from plants, bacteria, fungus, and algae, reduces reliance on hazardous chemicals and promotes eco-friendly and cost-effective processes. These nanoparticles, like MgO, Ag, Au, Se, Fe, Cu, ZnO, and CuO, have diverse applications in biochemical, environmental remediation, catalysis, and energy production. In agriculture, they serve as antimicrobial agents, adsorbents, and sensors, offering safer alternatives to traditional pesticides and enhancing crop growth, yield, and nutritional status. Their potential extends to industries like medicine, food processing, textiles, and packaging. Green synthesis is recognized as a sustainable route for nanoparticle production, with reduced toxicity towards living organisms and the environment.
SOURCE
TIM signals. Sources used in the signal's detection and description include, but are not limited to: http://doi.org/10.1186/s12951-018-0334-5 ; http://doi.org/10.1186/s40643-014-0003 ; http://doi.org/10.1007/s12011-020-02138-3 ; http://doi.org/10.1039/d1nr08144f ; http://doi.org/10.1016/B978-0-12-822401-4.00022-2

(TIM)

NUMBER | TITLE
417 | Battery-powered electric aircraft
UNDERLYING TECHNOLOGY OR INNOVATION
Lithium ion batteries
SUGGESTED MATURITY
Novel (TRL 1-3)
SUMMARY DESCRIPTION
Electric batteries are used to power electric motors that spin propellers or ducted fans to generate thrust. This is signifncant because it will reduce environmental impacts to 0 but will be limited in terms of range inless improvements of battery technologies on the energy density side arrive. There's also issues with accessing massive amount of renewable energy to power these batteries.
SOURCE
Deloitte https://www2.deloitte.com/nl/nl/pages/consumer/articles/europe-aviation-landscape-in-2040.html

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NUMBER | TITLE
467 | High performance glass such as low-emissivity and thermochromic glass
UNDERLYING TECHNOLOGY OR INNOVATION
High performance glass
SUGGESTED MATURITY
Close to market (TRL 7-9)
SUMMARY DESCRIPTION
This tech has the chance to significantly impact building energy consumption. Key features and advantages of high-performance glass include: – Low-E glass reduces heat transfer, minimizing energy loss. – Thermochromic glass changes its tint dynamically, controlling solar heat gain. – Provides ample natural lighting, reducing the need for artificial lighting during the day. – Reduces HVAC system loads and enhances occupant comfort.
SOURCE
Utilities One https://utilitiesone.com

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NUMBER | TITLE
473 | Light from plants
UNDERLYING TECHNOLOGY OR INNOVATION
optoelectronics
SUGGESTED MATURITY
Novel (TRL 1-3)
SUMMARY DESCRIPTION
Advanced materials built from natural resources are demonstrating large potential in optoelectronics due to the potential low cost, while meeting demands in performance.
SOURCE
J. J. Kaschuk, Y. AlHaj, O. J. Rojas, K. Miettunen, T. Abitbol, J. Vapaavuori, https://onlinelibrary.wiley.com/doi/10.1002/adma.202104473

(External experts)

NUMBER | TITLE
474 | 2Ds go integrated
UNDERLYING TECHNOLOGY OR INNOVATION
2D materials for electronics
SUGGESTED MATURITY
Emerging (TRL 4-6)
SUMMARY DESCRIPTION
2D material research is now mature enough to be able to benefit from standard microelectronic research approaches, and to achieve large-scale circuit integrations. With reliable device and material models, engineers can safely scale down transistors, and anticipate and optimize the device performance without doing extra rounds of fabrication, measurements and optimization. The use of design technology co-optimization should accelerate the development of high-speed, high-density front-end-of-line and back-end-of-line circuits based on 2D materials.
SOURCE
Zhu, J., Palacios, T. https://www.nature.com/articles/s41928-023-01072-1

(External experts)

NUMBER | TITLE
488 | Next-gen, low-energy atmospheric water harvesting
UNDERLYING TECHNOLOGY OR INNOVATION
Polymers and material science
SUGGESTED MATURITY
Emerging (TRL 4-6)
SUMMARY DESCRIPTION
Innovative hydrogels or nanomaterials applied to atmospheric water harvesting while operating on minimal energy, such as solar power alone, hold great promise for water security and low-cost irrigation in arid regions. Many technologies exist for passive air water harvesting, but the past few years have seen many developments in improved technologies to enhance the capacity of such materials, but also to reduce drastically their energy needs.
SOURCE
Spectrum https://spectrum.ieee.org/atmospheric-water-harvesting Li, T., Yan, T., Wang, P. et al. https://www.nature.com/articles/s44221-023-00150-0

(External experts)

NUMBER | TITLE
535 | Catalytic combo converts CO_2 to solid carbon nanofibers while offsetting emissions
UNDERLYING TECHNOLOGY OR INNOVATION
SUGGESTED MATURITY
Novel (TRL 1-3)
SUMMARY DESCRIPTION
Scientists at the U.S. Department of Energy's (DOE) Brookhaven National Laboratory and Columbia University have developed a way to convert carbon dioxide (CO2), a potent greenhouse gas, into carbon nanofibers, materials with a wide range of unique properties and many potential long-term uses. Their strategy uses tandem electrochemical and thermochemical reactions run at relatively low temperatures and ambient pressure.
SOURCE
Techxplore https://techxplore.com/news/2024-01-catalytic-combo-solid-carbon-nanofibers.html

(CCFOR)

NUMBER | TITLE
563 | MXene
UNDERLYING TECHNOLOGY OR INNOVATION
n/a
SUGGESTED MATURITY
Novel (TRL 1-3)
SUMMARY DESCRIPTION
MXene is a two-dimensional material that exhibits unique properties and has been gaining attention in the field of space science. Characterized by its low shear resistance, easy-to-modify ability, and a unique structure, MXene possesses exceptional potential for various applications. MXene's distinctive properties make it a promising candidate for creating lightweight electromagnetic interference (EMI) shielding materials that are essential for spacecraft, aircraft, and smart electronics. Recent developments have seen it integrated into superelastic and superhydrophobic hybrid sponges that exhibit a high EMI shielding effectiveness. These sponges are also scalable, offering the potential for large-scale production.
SOURCE
TIM Signals. Sources used in the signal's detection and description include, but are not limited to: http://doi.org/10.1016/j.jelechem.2021.115973 ; http://doi.org/10.1039/d2tc00516f ; http://doi.org/10.1016/j.ijleo.2022.168959 ; http://doi.org/10.1016/j.cej.2022.136527 ; http://doi.org/10.1016/j.apmate.2022.100092

(TIM)

NUMBER | TITLE
566 | Graphene thermal interface material
UNDERLYING TECHNOLOGY OR INNOVATION
n/a
SUGGESTED MATURITY
Novel (TRL 1-3)
SUMMARY DESCRIPTION
Graphene thermal interface materials (TIMs) present an exciting frontier in space science, offering innovative solutions for thermal management, electromagnetic protection, and energy storage in aerospace applications. Based on a blend of graphene nanoplatelets and carbon nanotubes, these materials provide superior thermal and electrical properties, outperforming traditional composite materials in both in-plane and through-plane thermal conductivity. Moreover, they are cost-effective and easy to integrate into existing manufacturing processes. Recent advances include the fabrication of graphene/carbon nanotube thick films that demonstrate high heat flux, crucial for advanced spacecraft. Similarly, the development of polyethylene/poly(ethylene oxide)/graphene films has shown remarkable thermal management capability, energy storage density, and robust shape stability, making it suitable for energy harvesting in harsh environments. Lastly, graphene aerogels, despite their mechanical limitations, offer promising avenues for thermal insulation and electromagnetic protection, with recent developments enhancing their compressibility, thermal conductivity, and microwave absorption performance.
SOURCE
TIM Signals. Sources used in the signal's detection and description include, but are not limited to: http://doi.org/10.1021/acs.nanolett.8b01746 ; http://doi.org/10.1016/j.carbon.2020.09.017 ; http://doi.org/10.1117/12.2594375 ; http://doi.org/10.1021/acsnano.2c00720 ; http://doi.org/10.1021/acsnano.2c06065

(TIM)

NUMBER | TITLE
569 | Phase change materials thermal management
UNDERLYING TECHNOLOGY OR INNOVATION
n/a
SUGGESTED MATURITY
Emerging (TRL 4-6)
SUMMARY DESCRIPTION
Phase change materials (PCMs) thermal management technology has the potential to revolutionize thermal regulation in the field of space science. PCMs are materials that absorb or release heat during phase transition, thereby effectively managing thermal changes. This makes them ideal for applications where significant temperature variations can occur, such as space exploration. However, traditional PCMs often suffer from issues such as high rigidity, lack of breathability, and easy leakage and abrasion. Recent advancements have addressed these issues, creating more durable, breathable, and efficient PCMs. In satellites, PCMs have been used in thermal storage panels to improve thermal control performance in the variable thermal environment of low earth orbit. This technology has also been implemented in thermal control devices for managing small satellite subsystems under zero gravity conditions, with the addition of pin fins of different geometries to enhance the thermal conductivity of the PCM.
SOURCE
TIM Signals. Sources used in the signal's detection and description include, but are not limited to: http://doi.org/10.1149/1.1393888 ; http://doi.org/10.1016/j.rser.2010.08.007 ; http://doi.org/10.1016/j.ensm.2021.05.018 ; http://doi.org/10.1016/j.tsep.2022.101601 ; http://doi.org/10.1016/j.est.2022.106531

(TIM)

NUMBER | TITLE
696 | Ultra-high density hydrogen storage holds twice as much as liquid H2
UNDERLYING TECHNOLOGY OR INNOVATION
Liquid hydrogen
SUGGESTED MATURITY
Novel (TRL 1-3)
SUMMARY DESCRIPTION
A novel hydrogen storage system developed by a team of researchers in Australia. The system utilizes a new material called "pentinitride" to store hydrogen at significantly higher densities compared to conventional storage methods. The novel aspect lies in the material's ability to hold hydrogen at a high density under ambient conditions, bypassing the need for extreme pressures or temperatures. This breakthrough could potentially revolutionize hydrogen storage, making it safer, more efficient, and economically viable for various applications, including fuel cells and energy storage.
SOURCE
New Atlas https://newatlas.com/energy/high-density-hydrogen-storage/

(CCFOR)

NUMBER | TITLE
697 | Li-sulfur batteries
UNDERLYING TECHNOLOGY OR INNOVATION
Lithium ion batteries
SUGGESTED MATURITY
Novel (TRL 1-3)
SUMMARY DESCRIPTION
Li-metal anode combined with sulfur on cathode to produce batteries which are longer lasting and relying less on conventional critical materials. It is still early stage as only 100s of cycles have been experimented but it holds promise for reducing range anxiety of EVs.
SOURCE
MIT Technology Review https://www.technologyreview.com/2024/02/14/1088177/sulfur-cheaper-better-batteries/

(CCFOR)

NUMBER | TITLE
700 | Microwave technology for critical raw materials recovery
UNDERLYING TECHNOLOGY OR INNOVATION
microwave treatment
SUGGESTED MATURITY
Novel (TRL 1-3)
SUMMARY DESCRIPTION
Recycling processes typically start with the discharge of batteries to reduce their hazard level by mitigating the risk of residual stored energy causing further reactions and overheating. Subsequent steps involve mechanical, pyrometallurgical, and/or hydrometallurgical treatments. However, drawbacks are associated with these processes, particularly the environmental impact of chemicals used in hydrometallurgical methods and the energy required for high-temperature pyrometallurgical processes. Recent research suggests that improving overall lithium recovery efficiency can be achieved by extracting lithium before recovering other metals. This involves a reduction reaction followed by water leaching to recover Li-ions.rStudies indicate that microwaves (MW) can significantly decrease the energy required for heating compared to conventional heating. This is due to the ability of MW to generate thermal energy, based on their interactions with some materials. In this context, we proposed a novel technology to replace conventional pyrometallurgical processes, providing a stable contribution to securing strategic metals from spent Lithium-ion Batteries (LIB).aOur work proposes a treatment for spent LIB materials, employing carbothermic reduction with short treatment times (a few minutes) and without requiring external additives or an inert atmosphere (carbon, for reaction, is present in the graphite phase, in the black mass). This is achieved through a synergistic combination of a graphite-based MW absorber with a dedicated chamber, significantly enhancing the overall efficiency of the carbothermal treatment. In particular, the interaction of microwaves with the materials enhances the energy efficiency of the thermal process, as heating begins from the inner parts of the materials.r
SOURCE
Fahimi, A. et al. https://www.sciencedirect.com/science/article/pii/S0921344923001258

(External experts)

NUMBER | TITLE
701 | Advanced Functional Materials for sustainable Electronics and Energy Harvesters
UNDERLYING TECHNOLOGY OR INNOVATION
Green sustainable technologies such as one step Laser Induced Processes
SUGGESTED MATURITY
Emerging (TRL 4-6)
SUMMARY DESCRIPTION
In the current digital era, as the world is growing up with smart technology, on the same time our planet is drowning with huge number of unrecycled waste and environmental pollution. World is facing off the challenges against rapid climate changes and continuous ecological disturbances, caused by the revolutionary growth in socio-economic developments with fastest growing trend in smart electronics, plastic-based products and the continuous dependence on non-recyclable raw materials. On the other hand, a huge significant progress in IoT and wearable smart electronics system is demanding unremittingly portable power source. Though, there remains a lot of challenges like endless energy supply, stability, functionality and obviously biocompatibility that will promote the applications from lab scale research to industrial scale. Therefore, collectively the eco-design strategies has to ensure technological breakthroughs on multiple levels: sustainable materials design with maximum recyclable approach, electronics schemes beyond silicon, low-cost-energy efficient manufacturing methods, green energy sources and integration of energy harvester into low-powered electronic platform.
SOURCE
Universidade Nova de Lisboa https://cordis.europa.eu/project/id/787410

(External experts)

NUMBER | TITLE
703 | Advanced Organic Electrode Materials for Electrochemical Energy Storage
UNDERLYING TECHNOLOGY OR INNOVATION
Organic synthesis, electrochemistry, AI, machine learning
SUGGESTED MATURITY
Novel (TRL 1-3)
SUMMARY DESCRIPTION
Organic battery materials per se are not that novel, but there has been extensive progress in the past few years to push this technology forward. In fact, one issue has been the introduction of the charge carrier ions in order to go for fully organic batteries. This has been recently achieved by two groups in France and Belgium. Additionally, the field of organic electrode materials is much more prone to benefit from further improvements based on AI and machine learning, as these materials can rather easily be chemically modified to optimize the redox potential, crystal structure etc. - which is different from commonly used inorganic electrode materials. A group in Sweden, for instance, has been carrying out excellent (preliminary) work in this regard already (not published, yet). Accordingly, organic batteries may (i) pave the way for meaningfully combining AI/machine learning and experimental research much faster than for inorganic materials and (ii) enable the development of truly sustainable rechargeable batteries - a field in which Europe is currently leading worldwide (far ahead of, e.g., China, Korea, Japan or the US).
SOURCE
Wang, J., Lakraychi, A.E., Liu, X. et al. https://www.nature.com/articles/s41563-020-00869-1

(External experts)

NUMBER | TITLE
704 | Double active membranes for CO2 capture and management
UNDERLYING TECHNOLOGY OR INNOVATION
Membrane technology
SUGGESTED MATURITY
Novel (TRL 1-3)
SUMMARY DESCRIPTION
The idea of this signal is the use of the same membrane or membrane module for the capture CO2 and its conversion in Renewable Fuels of Not Biological Origin. This will include materials development such as Polymers with High free volume, MOFs, bi-functional catalyst and everything will be used in the same device.
SOURCE
Project “Double-Active Membranes for a sustainable CO_2 cycle” http://www.dam4co2.eu

(External experts)

NUMBER | TITLE
705 | Revolutionizing IoT with High-Efficiency Indoor Photovoltaics and AI-Powered Energy Management
UNDERLYING TECHNOLOGY OR INNOVATION
advanced photovoltaics, Long Short-Term Memory (LSTM) neural networks
SUGGESTED MATURITY
Emerging (TRL 4-6)
SUMMARY DESCRIPTION
Innovative strides in indoor photovoltaics, IoT, and AI technologies are spearheaded by significant contributions from Exeger, Ambient Photonics, and the research led by Prof Freitag at Newcastle University. These entities are at the forefront of developing high-efficiency, environmentally-friendly photovoltaic cells capable of harnessing ambient light to power IoT devices. Exeger's advancements in dye-sensitized solar cells (DSSCs) have resulted in a 20% increase in efficiency for their Powerfoyle Indoor solar cells, showcasing the practical application of these technologies in everyday devices. Ambient Photonics, on the other hand, is pioneering the use of ambient-light-harvesting photovoltaics aimed at making disposable batteries obsolete, promising a sustainable future for electronics. Freitag's team has created non-toxic, sustainable photovoltaic cells based on a copper(II/I) electrolyte, achieving an unprecedented power conversion efficiency of 38% at 1,000 lux. A distinguishing feature of these developments is their focus on non-toxic, sustainable, and efficient advanced materials, underpinning the potential for wide-scale adoption in various industries. The integration of AI, specifically through LSTM neural networks, into this ecosystem marks a significant leap towards intelligent energy management. This combination not only enhances the operational efficiency of IoT devices by adapting to changing environmental conditions but also aligns with global sustainability goals by reducing dependency on traditional energy sources and promoting clean, renewable energy solutions. The collaborative efforts of these researchers and companies underscore the importance of sustainable and efficient technologies in driving the next generation of electronic devices, paving the way for a multitude of applications in sectors ranging from healthcare to smart city development.d
SOURCE
Michaels, H., Rinderle, M., Benesperi, I., Freitag, R., Gagliardi, A., Freitag, M. https://pubs.rsc.org/en/content/articlelanding/2023/sc/d3sc00659j

(External experts)

NUMBER | TITLE
706 | Organic solvents being used to improve interfaces in electrochemical applications
UNDERLYING TECHNOLOGY OR INNOVATION
n/a
SUGGESTED MATURITY
Novel (TRL 1-3)
SUMMARY DESCRIPTION
In the paper titled “Novel Organic Solvents for Electrochemistry at the Liquid/Liquid Interface”, the authors explore the use of organic solvents in the context of liquid/liquid interfaces for electrochemical applications. The researchers carried out two-phase voltammetry using a reverse cell configuration, where the lower density organic solvent is on top of the aqueous solution. The organic solvents used in this study contain either nitrile or ketone functional groups. Liquid/liquid interfaces offer advantages over traditional solid/liquid interfaces. They can be considered defect-free, allowing reactants to be separated to avoid direct interactions. The choice of solvent significantly impacts the reactivity and stability of electrochemical processes. In summary, the study contributes to the field of electrochemistry by exploring innovative solvent systems and their impact on liquid/liquid interfaces, ultimately addressing challenges in electrocatalysis and interface engineering.
SOURCE
Toth, P., Dryfe, R. https://pubs.rsc.org/en/content/articlepdf/2015/an/c4an02250e

(CCFOR)

NUMBER | TITLE
710 | Hybrid energy storage with aluminium
UNDERLYING TECHNOLOGY OR INNOVATION
Material research on inert anodes and wet combustion of aluminium
SUGGESTED MATURITY
Emerging (TRL 4-6)
SUMMARY DESCRIPTION
The latest technologies for aluminium oxid reduction in a smelter produce aluminium without CO2 emissions and are associated with a significant reduction in costs. As a result, aluminium can be used as a hybrid energy store. The use of steam at 900 degrees Celsius enables the oxidation of aluminium, which produces hydrogen, pressure and heat. One m^3 of aluminium provides approx. 330 kg of hydrogen, electricity and heat. The costs for the production and long-term storage of hydrogen would amount to about 4-6 €/kg hydrogen. The waste is aluminum oxid, which will be reused. The process supports by 100% the circulur economy. There are no geographical restrictions on its use, the storage capacity is virtually unlimited, no further critical raw materials are used and no poisonous materials are used. Aluminium is the third most abundant element in the earth's crust.
SOURCE
Light Metal Age https://www.elysis.com/sites/default/files/newsfiles/lmaelysisfeb2022.pdf Barelli, L., Baumann, M., Bidini, G., Ottaviano, P.A., Schneider, R.V., Passerini, S. and Trombetti, L. https://onlinelibrary.wiley.com/doi/10.1002/ente.202000233

(External experts)

NUMBER | TITLE
711 | Spin and magnetic enhancement of catalysis
UNDERLYING TECHNOLOGY OR INNOVATION
Computational chemistry; materials science
SUGGESTED MATURITY
Novel (TRL 1-3)
SUMMARY DESCRIPTION
Spin polarization, spin flips, and responses to magnetic fields in catalytic materials and molecules have been known for a long time. Recently it is becoming increasingly clear that this phenomenon can be utilized to enhance catalytic efficiency. Previously not well understood, spin enhancement, or magnetic enhancement, is modelled leading to a more complete and systematic understanding of catalysis in general, and the possibility of designing materials to be more efficient catalysts in particular. The signal is of importance for renewable energy and green electrosynthesis, where catalyst specificity, efficiency, and durability are major bottlenecks.
SOURCE
Do, V., Lee, J. https://pubs.acs.org/doi/10.1021/acsnano.2c08919

(External experts)

NUMBER | TITLE
712 | Material Acceleration Platforms (MAPs)
UNDERLYING TECHNOLOGY OR INNOVATION
AI, robotics, data bases, exchange of information, automazation
SUGGESTED MATURITY
Emerging (TRL 4-6)
SUMMARY DESCRIPTION
The MAP concept robotically couples materials synthesis and characterization in a closed loop that is accelerated by AI driven algorithms and advanced simulation techniques to realize materials and device development at least 10 times faster than conventional science methods and at a fraction of the cost. The ability to rapidly seek out Advanced Materials solutions tailored to geopolitical and supply chain realities offers opportunities for technological sovereignty and broader sustainability. The next step is to integrate AI and modelling tools to build and construct new devices with new materials faster. The implementation of new materials in new devices takes typically 10-20 years. The target is to reduce the implementation time also by a factor of 5-10. First framework projects are already ongoing in the areas of batteries (BIGMAP) and electrolysers (DECODE).
SOURCE
Zhang, J. et al. https://pubs.acs.org/doi/10.1021/acsenergylett.3c01508 Royal Society of Chemistry https://pubs.rsc.org/en/content/articlepdf/2022/dd/d2dd00046f University of Toronto https://acceleration.utoronto.ca/maps

(External experts)

NUMBER | TITLE
713 | Organic batteries for sustainable energy storage
UNDERLYING TECHNOLOGY OR INNOVATION
electrochemical devices
SUGGESTED MATURITY
Emerging (TRL 4-6)
SUMMARY DESCRIPTION
In 2019, the European Union proposed the ambitious vision of a fossil-fuel-free society by 2050. Achieving this goal will require a massive use of batteries for electric mobility and energy storage from renewable sources. Although rechargeable batteries have several desirable characteristics, the rapid expansion of their market have raised concerns about the availability of the raw materials used, particularly Lithium, Nickel, Manganese, with projections predicting a shortage of critical raw materials in less than ten years. Therefore, the conventional battery electrode, based on the insertion of Li, should be revolutionized and a new type of device should be developed, in which organic molecules with redox functionality can be the active part of the battery and are able to reversibly and efficiently absorb and release electrons. This will contribute to technology advance, addressing the problems of safety and sustainability of conventional energy storage systems.
SOURCE
Kim, J., Kim, Y., Yoo, J. et al. https://www.nature.com/articles/s41578-022-00478-1

(External experts)

NUMBER | TITLE
717 | Smart dust
UNDERLYING TECHNOLOGY OR INNOVATION
sensors, artifical intelligence, chips, nanobattery
SUGGESTED MATURITY
Emerging (TRL 4-6)
SUMMARY DESCRIPTION
Smart dust is a system of tiny electromechanical sensors that detect and wirelessly transmit real-time data from their environment. Measured at one cubic millimeter or less, these devices are dispersed in large quantities as a networked cluster suspended in mid-air or on the ground, or in the brain (neurograins).
SOURCE
EPIC Semiconductors, Inc. https://www.linkedin.com/pulse/smart-dust-revolutionizing-aiot-landscape-epic-semiconductors/

(External experts)

NUMBER | TITLE
718 | Quantum Materials for information and energy storage
UNDERLYING TECHNOLOGY OR INNOVATION
quantum materials
SUGGESTED MATURITY
Novel (TRL 1-3)
SUMMARY DESCRIPTION
The interaction between quantum light and quantum materials allow to control the energy transfer at a rate that is far beyond what can be achieved in classical technologies. Examples are collective superradiant phenomena and quantum batteries.
SOURCE
Broholm, C., Ian, F. et al. https://www.osti.gov/servlets/purl/1616509

(External experts)

NUMBER | TITLE
814 | Protonic Ceramic Cells
UNDERLYING TECHNOLOGY OR INNOVATION
ceramic materials
SUGGESTED MATURITY
Novel (TRL 1-3)
SUMMARY DESCRIPTION
Protonic Ceramic Cells (PCCs) are versatile energy devices with the ability to efficiently produce high-quality fuels and generate electricity. Their lower operating temperatures, compared to solid oxide fuel cells, grant PCCs greater flexibility in handling less pure fuels and a wider range of fuel types. Additionally, they offer higher efficiency than PEM fuel cells. PCCs deliver dry hydrogen in H2 production and can be pressurized for high-quality ammonia production. Recent advancements in electrolyte and materials development (including exsolution materials, nanocomposites, and ferrites) position this technology as a potential game-changer for future energy systems.
SOURCE
Wang, Z., Wang, Y., Wang, J. et al. https://doi.org/10.1038/s41929-022-00829-9 Liu, Z., Song, Y., Xiong, X. et al. https://doi.org/10.1038/s41467-023-43725-x Liu, F., Deng, H., Diercks, D. et al. https://doi.org/10.1038/s41560-023-01350-4

(External experts)

NUMBER | TITLE
815 | New Battery Diagnostics of Batteries and Beyond
UNDERLYING TECHNOLOGY OR INNOVATION
AI, Machine Learning, Diagnostics
SUGGESTED MATURITY
Novel (TRL 1-3)
SUMMARY DESCRIPTION
Integrating timescale characterization with the distribution of relaxation times (DRT) analysis represents a major breakthrough in electrolysis and battery technologies. This approach enables a deeper understanding and optimization of the kinetic processes critical for energy storage and conversion. This method provides a precise diagnosis of phenomena such as ion transport and charge transfer mechanisms within these systems. Using non-destructive impedance characterizations allows for real-time monitoring, ultimately leading to the development of more efficient, durable, and faster-charging batteries and electrolyzers. Furthermore, it can be used to accelerate experimentation potentially integrating with high-throughput experiments. This emerging technology has the potential to disrupt current practices in energy storage and conversion. Particularly in electrolysis, applying timescale characterization could revolutionize hydrogen production efficiency and overall energy system performance, supporting sustainability goals. This signals a shift towards data-driven techniques in materials science and energy technology, promising to shape the future of the industry and open new avenues for research and development.
SOURCE
Lu, Y., Zhao, C., Huang, J., Zhang, Q., https://doi.org/10.1016/j.joule.2022.05.005

(External experts)

NUMBER | TITLE
823 | Solar cell that reaches 190% level for external quantum efficiency
UNDERLYING TECHNOLOGY OR INNOVATION
Solar cells
SUGGESTED MATURITY
Novel (TRL 1-3)
SUMMARY DESCRIPTION
A team at Pennsylvania University have developed the proof of concept for a new solar cell that captures energy from reflected light and heat, as well as direct sunlight, to get to the 190% level for external quantum efficiency
SOURCE
Cleantechnica https://cleantechnica.com/2024/04/11/a-new-dawn-for-solar-cells-190-quantum-efficiency-is-possible/?utm_source=flipboard&utm_content=topic%2Fclimatechange

(CCFOR)

NUMBER | TITLE
825 | Kagome superconductors
UNDERLYING TECHNOLOGY OR INNOVATION
n/a
SUGGESTED MATURITY
Novel (TRL 1-3)
SUMMARY DESCRIPTION
Kagome superconductors are a category of advanced materials with unique electrical properties. They derive their name from the Kagome lattice structure, a pattern reminiscent of Japanese basket-weaving, upon which the atoms are arranged. These materials exhibit superconductivity - the ability to conduct electric current without resistance - under certain conditions. The unique Kagome lattice structure results in unusual electronic behaviors, such as flat bands and Dirac cones, which are of interest for understanding the fundamental physics of superconductivity and potential technological applications. The novelty of Kagome superconductors lies in their distinctive atomic structure, which gives rise to unique electronic behaviors and superconducting properties that differ from those of conventional superconductors. Recent advances have been made in the synthesis and characterization of these materials, which have potential applications in the development of superconducting devices, quantum computing, and energy technologies. The ongoing exploration of the properties and potential uses of Kagome superconductors is contributing to the advancement of materials science and condensed matter physics.
SOURCE
TIM signals. Sources used in the signal's detection and description include, but are not limited to: http://doi.org/10.1038/s41563-021-01034-y; http://doi.org/10.1103/PhysRevB.104.L041103; http://doi.org/10.1038/s41586-021-03983-5; http://doi.org/10.1038/s41467-021-27946-6; http://doi.org/10.1038/s41567-021-01451-5

(TIM)

NUMBER | TITLE
826 | Electrically rechargeable liquid fuel
UNDERLYING TECHNOLOGY OR INNOVATION
n/a
SUGGESTED MATURITY
Emerging (TRL 4-6)
SUMMARY DESCRIPTION
Electrically rechargeable liquid fuel is an advanced material technology that employs electricity to regenerate spent fuel for re-use. This technology uses the electrical power to trigger chemical reactions that convert waste products back into usable fuel, thus enabling a circular energy system. It has the potential to significantly improve energy efficiency as well as environmental sustainability by reducing the need for the extraction and refining of new fuels. The novelty of the electrically rechargeable liquid fuel lies in its capability to transform our energy systems by creating a sustainable and closed-loop fuel cycle. Instead of continuously extracting and burning fuels, this technology allows us to reuse the same fuel multiple times, reducing environmental damage and resource depletion. Recent developments show a promising future for this technology, with potential applications in various sectors such as transportation and power generation. However, further research and development are required to overcome current limitations and to bring this innovative technology to commercial reality.
SOURCE
TIM signals. Sources used in the signal's detection and description include, but are not limited to: http://doi.org/10.1016/j.scib.2019.01.014; http://doi.org/10.1016/j.xcrp.2020.100102; http://doi.org/10.1016/j.jpowsour.2021.230023; http://doi.org/10.1016/j.apenergy.2021.117145; http://doi.org/10.1016/j.jpowsour.2021.230198

(TIM)

NUMBER | TITLE
827 | Polyetherimide for energy storage
UNDERLYING TECHNOLOGY OR INNOVATION
n/a
SUGGESTED MATURITY
Emerging (TRL 4-6)
SUMMARY DESCRIPTION
Polyetherimide for energy storage is a technology that utilizes polyetherimide (PEI), a type of high-performance thermoplastic, for the purpose of energy storage. PEI's exceptional thermal, mechanical, and electrical properties, along with its inherent flame resistance, make it an ideal material for use in advanced energy storage systems. This technology is particularly relevant in the development of high-performance capacitors, batteries, and other energy storage devices. The novelty of this technology lies in the application of PEI in the field of energy storage, which is a relatively recent development. While PEI has been used extensively in various industries due to its durability and resistance to heat and chemicals, its potential for energy storage applications is a burgeoning area of research. The high thermal and electrical performance of PEI, coupled with its flame resistance, introduces new possibilities for the design and manufacture of advanced energy storage systems. However, further research is required to fully understand and optimize the potential of PEI in this context.
SOURCE
TIM signals. Sources used in the signal's detection and description include, but are not limited to: http://doi.org/10.1016/j.compscitech.2020.108528; http://doi.org/10.1016/j.nanoen.2022.107215; http://doi.org/10.1002/adfm.202210050; http://doi.org/10.1002/aenm.202203925; http://doi.org/10.1039/d2ta09658g

(TIM)

NUMBER | TITLE
828 | Sustainable Ammonia fuel
UNDERLYING TECHNOLOGY OR INNOVATION
n/a
SUGGESTED MATURITY
Emerging (TRL 4-6)
SUMMARY DESCRIPTION
Sustainable Ammonia fuel refers to the use of ammonia as a carbon-free alternative to fossil fuels. It involves the production of ammonia using sustainable methods, such as electrochemical synthesis, and harnessing it as a source of hydrogen for fuel cells. This technology seeks to address the global need for clean, renewable energy sources and reduce carbon emissions. The novelty of Sustainable Ammonia fuel lies in its potential to serve as a carbon-free, renewable energy source. Unlike traditional fuels, the combustion of ammonia does not release carbon dioxide, making it environmentally friendly. Recent developments have focused on improving the efficiency and scalability of sustainable ammonia production. Potential applications span across various industries, notably in power generation and transportation, where it can be used in fuel cells for electric vehicles. However, challenges remain in the safe storage and transportation of ammonia.
SOURCE
TIM signals. Sources used in the signal's detection and description include, but are not limited to: http://doi.org/10.1039/c9ee02873k; http://doi.org/10.1002/eem2.12268; http://doi.org/10.1038/s41586-022-05409-2; http://doi.org/10.1039/d2ee04095f; http://doi.org/10.1007/978-3-031-32041-5_12

(TIM)

NUMBER | TITLE
829 | Battery pyrometallurgy recycling
UNDERLYING TECHNOLOGY OR INNOVATION
n/a
SUGGESTED MATURITY
Emerging (TRL 4-6)
SUMMARY DESCRIPTION
Battery pyrometallurgy recycling is a technology that utilizes heat and chemical reactions in high-temperature environments to recycle spent batteries. This method aids in the recovery of valuable metals like lithium, cobalt, and nickel, which are commonly found in batteries. The process involves first mechanically processing the batteries, followed by smelting to extract the metals. The extracted metals can then be reused to manufacture new batteries or other products. The novelty of battery pyrometallurgy recycling lies in its ability to efficiently reclaim valuable metals from spent batteries, reducing the need for mining new materials and contributing to sustainable practices. Despite being a well-established process, its application in battery recycling is relatively recent. The technology has been improved by incorporating more efficient processes and technologies to increase recovery rates and minimize environmental impacts. However, further research is required to address challenges such as energy consumption and the management of hazardous by-products.
SOURCE
TIM signals. Sources used in the signal's detection and description include, but are not limited to: http://doi.org/10.1016/j.joule.2019.09.014 ; http://doi.org/10.1021/acssuschemeng.1c04938 ; http://doi.org/10.1016/j.wasman.2021.11.038 ; http://doi.org/10.1016/j.cej.2021.133993 ; http://doi.org/10.1002/eem2.12271

(TIM)

NUMBER | TITLE
830 | Argyrodite electrolyte
UNDERLYING TECHNOLOGY OR INNOVATION
n/a
SUGGESTED MATURITY
Emerging (TRL 4-6)
SUMMARY DESCRIPTION
Argyrodite electrolyte is a class of advanced materials primarily used in solid-state lithium-ion batteries. These electrolytes are characterised by their high lithium-ion conductivity, which contributes to the performance and safety of the batteries. Based on an inorganic crystal structure, argyrodite electrolytes are more stable and less flammable than their organic counterparts, thus affording higher energy density and better safety features for lithium-ion batteries. The novelty of Argyrodite electrolytes lies in their potential to revolutionize the performance and safety profile of lithium-ion batteries. Their exceptional ionic conductivity and thermal stability have been recently explored, and advancements in synthesizing these materials have been made. However, challenges remain in optimizing their integration into battery systems. Despite these, Argyrodite electrolytes mark a promising step forward in the development of next-generation battery technologies.
SOURCE
TIM signals. S Sources used in the signal's detection and description include, but are not limited to: http://doi.org/10.1016/j.ssi.2017.07.005 ; http://doi.org/10.1038/s41467-017-01187-y ; http://doi.org/10.1002/aenm.201903422 ; http://doi.org/10.1021/acs.accounts.0c00874 ; http://doi.org/10.1021/acsenergylett.1c02428

(TIM)

NUMBER | TITLE
831 | Dibenzyl Toluene for Hydrogen transport
UNDERLYING TECHNOLOGY OR INNOVATION
n/a
SUGGESTED MATURITY
Close to market (TRL 7-9)
SUMMARY DESCRIPTION
Dibenzyl Toluene for Hydrogen Transport is a method of transporting hydrogen efficiently and safely. The technology involves using dibenzyl toluene, a complex organic compound, as a liquid organic hydrogen carrier (LOHC). Hydrogen gas is chemically bonded to the dibenzyl toluene, converting it into a safe, non-explosive liquid that can be transported using existing infrastructure. The hydrogen can then be released on-demand at the destination. The novelty of this technology lies in its ability to overcome the significant challenges associated with hydrogen transport. Traditional methods of transporting hydrogen, such as high-pressure tanks or cryogenic liquids, have inherent risks and require specialised infrastructure. Using dibenzyl toluene as a LOHC offers a safe, efficient, and scalable solution. This technology is a significant development in the field of advanced materials and is likely to play a crucial role in the future hydrogen economy.
SOURCE
TIM signals. Sources used in the signal's detection and description include, but are not limited to: http://doi.org/10.1021/acs.iecr.5b01840 ; http://doi.org/10.1016/j.ijhydene.2016.09.196 ; http://doi.org/10.1016/j.jpowsour.2018.04.011 ; http://doi.org/10.1039/c9cc09715e ; http://doi.org/10.3390/ma13020277

(TIM)

NUMBER | TITLE
832 | Battery hydrometallurgy recycling
UNDERLYING TECHNOLOGY OR INNOVATION
n/a
SUGGESTED MATURITY
Emerging (TRL 4-6)
SUMMARY DESCRIPTION
Battery Hydrometallurgy Recycling is a technological process in the field of advanced materials, which involves the recovery of valuable metals from waste batteries using a combination of chemical and physical methods. It typically involves initial mechanical processing, followed by hydrometallurgical steps including leaching, solvent extraction, and precipitation to extract metals such as lithium, cobalt, nickel, and manganese. While the concept of metal recycling is not new, the application of hydrometallurgy to battery recycling represents a novel approach. This technology offers a more sustainable and economically viable method of dealing with the ever-increasing problem of battery waste. Recent developments have focused on improving efficiency and reducing environmental impact, but further research is needed to optimize the process and address challenges such as the handling of hazardous waste. Potential applications extend beyond waste management, into areas like raw material supply for battery manufacturing, contributing to circular economy models.
SOURCE
TIM signals. Sources used in the signal's detection and description include, but are not limited to: http://doi.org/10.1016/j.jclepro.2022.133342 ; http://doi.org/10.1016/j.seppur.2022.122966 ; http://doi.org/10.1039/d2ee03910a ; http://doi.org/10.1109/ITEC55900.2023.10187051

(TIM)

NUMBER | TITLE
833 | Covalent organic framework in batteries
UNDERLYING TECHNOLOGY OR INNOVATION
n/a
SUGGESTED MATURITY
Emerging (TRL 4-6)
SUMMARY DESCRIPTION
Covalent Organic Frameworks (COFs) in batteries are advanced materials that are structured to enhance energy storage. COFs are crystalline organic polymers with a predetermined structure, offering high thermal stability, large surface area, and adjustable chemical functionality. In the context of batteries, they can enhance energy density, power density, and cycle life, significantly improving battery performance and safety. The novelty of COFs in batteries lies in their unique properties, which include high porosity, low density, and structural designability. These characteristics allow for the design of energy storage materials with high specific capacity, excellent rate performance, and long cycle life. Recent developments indicate COFs have potential applications in advanced energy storage systems, such as lithium-ion batteries, sodium-ion batteries, and supercapacitors. However, challenges remain in improving their conductivity and structural stability during the charge/discharge process. The integration of COFs in batteries represents a promising avenue for the development of next-generation energy storage devices.
SOURCE
TIM signals. Sources used in the signal's detection and description (non-exhaustive list http://doi.org/10.1002/eem2.12345 ; http://doi.org/10.1002/anie.202214449 ; http://doi.org/10.1016/j.ccr.2022.214968 ; http://doi.org/10.1021/jacs.2c10509 ; http://doi.org/10.1002/batt.202200434

(TIM)

NUMBER | TITLE
834 | Oxymethylene ethers fuel
UNDERLYING TECHNOLOGY OR INNOVATION
n/a
SUGGESTED MATURITY
Emerging (TRL 4-6)
SUMMARY DESCRIPTION
Oxymethylene ethers (OMEs) fuel is an emerging technology in the field of advanced materials. OMEs are synthetic fuels composed of carbon, hydrogen, and oxygen. They have the potential to significantly reduce the emission of pollutants from combustion engines, particularly in the transportation sector. OMEs have a high oxygen content which promotes clean combustion, and their properties can be tailored to specific applications. The novelty of OME fuel technology lies in its potential to serve as an environmentally friendly alternative to conventional fossil fuels. Its high oxygen content facilitates complete combustion, reducing harmful emissions. It also offers versatility as its properties can be adjusted for specific uses. While the technology is promising, it is still in the development stage, with ongoing research exploring its production, potential applications, and environmental impact.
SOURCE
TIM signals. Sources used in the signal's detection and description include, but are not limited to: http://doi.org/10.1016/j.fuel.2015.03.012 ; http://doi.org/10.1039/c7ee01657c ; http://doi.org/10.1016/j.fuel.2019.116231 ; http://doi.org/10.4271/2020-01-0805 ; http://doi.org/10.4271/2021-01-1190

(TIM)

NUMBER | TITLE
835 | Closed loop battery recycling
UNDERLYING TECHNOLOGY OR INNOVATION
n/a
SUGGESTED MATURITY
Emerging (TRL 4-6)
SUMMARY DESCRIPTION
Closed loop battery recycling is a sustainable technology aimed at managing the lifecycle of batteries by extracting and reusing valuable materials. This technology addresses the environmental and health concerns associated with battery disposal, and is crucial in the context of growing demand for lithium-ion batteries in electric vehicles and renewable energy storage. Closed loop recycling involves several steps, including collection, sorting, mechanical treatment, hydrometallurgical or pyrometallurgical processes, and purification of the extracted materials for reuse in battery production. The novelty of closed loop battery recycling lies in its comprehensive approach to battery waste management. Unlike traditional recycling methods, which focus on extracting a few key materials and generally discard the rest, closed loop recycling aims to recover and reuse as many materials as possible, reducing waste and making the process more economically viable. This technology also aligns with the circular economy model, promoting sustainability and resource efficiency. Despite these advantages, challenges such as technical complexity and high initial investment costs must be addressed to enable wider adoption of this technology.
SOURCE
TIM signals. Sources used in the signal's detection and description include, but are not limited to: http://doi.org/10.1007/s10479-020-03888-y ; http://doi.org/10.1016/j.jhazmat.2021.127900 ; http://doi.org/10.1016/j.ensm.2021.12.013 ; http://doi.org/10.1038/s43246-020-00095-x ; http://doi.org/10.1016/j.cej.2022.139258

(TIM)

NUMBER | TITLE
836 | Germanene in batteries
UNDERLYING TECHNOLOGY OR INNOVATION
n/a
SUGGESTED MATURITY
Emerging (TRL 4-6)
SUMMARY DESCRIPTION
Germanene in batteries refers to the application of germanene - a single layer of germanium atoms arranged in a honeycomb pattern - in battery technology. This material has been identified for its superior electrical conductivity and charge capacity. Its unique two-dimensional structure allows for faster electron movement, and its large surface area can hold more lithium ions, enhancing the battery's overall storage capacity and charge-discharge efficiency. This makes germanene a promising candidate for next-generation lithium-ion batteries. The use of germanene in batteries is a novel technology that could revolutionize the energy storage field. While similar materials like graphene have been explored extensively, germanene's potential in battery technology is a relatively new area of research. Recent developments indicate that germanene-based batteries not only have a higher energy capacity but also display excellent stability and durability. This breakthrough underscores the potential of germanene in developing more efficient, high-performance batteries, thereby opening up new avenues in the realm of energy storage.
SOURCE
TIM signals. Sources used in the signal's detection and description include, but are not limited to: http://doi.org/10.1088/2053-1591/aaf2da ; http://doi.org/10.1021/acsanm.8b01751 ; http://doi.org/10.1016/j.jpowsour.2020.229318 ; http://doi.org/10.1016/j.nantod.2022.101501 ; http://doi.org/10.1007/978-981-16-8538-5_12

(TIM)

NUMBER | TITLE
837 | Batteries - stanene
UNDERLYING TECHNOLOGY OR INNOVATION
n/a
SUGGESTED MATURITY
Emerging (TRL 4-6)
SUMMARY DESCRIPTION
Technology Batteries - Stanene refers to the application of stanene, a two-dimensional (2D), tin-based material, in battery technology. Stanene's unique properties, including high electron mobility and robustness even at room temperature, make it a promising candidate for enhancing battery performance. Its potential applications span across the field of energy storage, particularly in the development of high-capacity, fast-charging, and durable batteries. The novelty of this technology lies in the innovative use of stanene, a relatively new material in the realm of 2D nanomaterials, for energy storage. Stanene's high electron mobility potentially allows for a quicker charge and discharge process, thereby improving the energy efficiency of batteries. Furthermore, its robustness at room temperature suggests a longer lifespan for the batteries. However, the full potential of stanene in batteries is yet to be explored. Its applicability and effectiveness in real-world scenarios, as well as its commercial viability, remain subjects of ongoing research.
SOURCE
TIM signals. Sources used in the signal's detection and description include, but are not limited to: http://doi.org/10.1016/j.electacta.2016.08.027 ; http://doi.org/10.1016/j.mtener.2018.02.003 ; http://doi.org/10.1039/c9cs00551j ; http://doi.org/10.1039/d2qm01293f ; http://doi.org/10.1039/c8ta01716f

(TIM)

NUMBER | TITLE
838 | Sustainable aviation fuel
UNDERLYING TECHNOLOGY OR INNOVATION
n/a
SUGGESTED MATURITY
Close to market (TRL 7-9)
SUMMARY DESCRIPTION
Sustainable aviation fuel (SAF) is a technology aiming to decrease the environmental impact of aviation by substituting conventional jet fuels with more environmentally friendly alternatives. SAFs are typically produced from renewable resources such as waste oils, agricultural residues, and non-food energy crops, and can significantly reduce greenhouse gas emissions compared to fossil-based jet fuels. The novelty of SAF technology resides in its potential to significantly reduce the carbon footprint of the aviation sector, traditionally a major contributor to global emissions. Recent advancements include improvements in fuel production processes, with an emphasis on optimizing efficiency and sustainability, and the development of new feedstocks, particularly those that do not compete with food production. However, despite these promising developments, the cost, scalability, and availability of SAFs remain ongoing challenges that need to be addressed to fully realize the potential of this technology.
SOURCE
TIM signals. Sources used in the signal's detection and description include, but are not limited to: http://doi.org/10.1016/j.fuel.2022.126294 ; http://doi.org/10.1038/s41893-022-01046-9 ; http://doi.org/10.1080/03036758.2023.2212174 ; http://doi.org/10.4271/2023-01-0263 ; http://doi.org/10.1016/j.fuel.2023.129557

(TIM)

NUMBER | TITLE
839 | 1D perovskite
UNDERLYING TECHNOLOGY OR INNOVATION
n/a
SUGGESTED MATURITY
Emerging (TRL 4-6)
SUMMARY DESCRIPTION
1D perovskite is a type of advanced material with unique properties. It is a dimensionally confined version of the traditionally 3D perovskite material, characterized by its one-dimensional structure. This structure enables enhanced photoluminescent properties and improved stability, making 1D perovskite a potent material in the field of optoelectronics, particularly in light-emitting diodes (LEDs) and solar cells. The novelty of 1D perovskite lies in its unique dimensional structure and the associated enhanced properties. Compared to their 3D counterparts, 1D perovskites exhibit superior stability and light-emitting properties. These characteristics have opened new possibilities for their use in high-efficiency solar cells and LEDs, which were previously unattainable. The recent developments in the fabrication and synthesis of 1D perovskites have further expanded the potential applications of this material, demonstrating its promising future in the advanced materials field.
SOURCE
TIM signals. Sources used in the signal's detection and description include, but are not limited to: http://doi.org/10.1002/adma.201805323 ; http://doi.org/10.1038/s41560-020-00692-7 ; http://doi.org/10.1002/adfm.202008404 ; http://doi.org/10.1021/acs.nanolett.5b00046 ; http://doi.org/10.1002/anie.202213240

(TIM)

NUMBER | TITLE
840 | Transparent perovskite solar cell
UNDERLYING TECHNOLOGY OR INNOVATION
n/a
SUGGESTED MATURITY
Emerging (TRL 4-6)
SUMMARY DESCRIPTION
Transparent perovskite solar cells are an emerging technology in the field of advanced materials. They utilize a unique family of materials known as perovskites for the conversion of sunlight into electricity. What sets these solar cells apart is their transparency, which allows them to be integrated into windows or other transparent surfaces, opening up a wide range of potential applications. The novelty of transparent perovskite solar cells lies in their combination of high efficiency, low production cost, and transparency. Traditional solar cells are opaque and cannot be used in applications where light transmission is required. Recent developments in the field have focused on improving the stability and performance of these cells, while maintaining their transparency. This technology is still in its developmental stages, but it holds great promise for the future of solar energy.
SOURCE
TIM signals. Sources used in the signal's detection and description include, but are not limited to: http://doi.org/10.1039/c7ee02627g ; http://doi.org/10.1002/solr.202200739 ; http://doi.org/10.1002/adma.202202447 ; http://doi.org/10.1007/s40820-022-00995-2 ; http://doi.org/10.1007/s12274-023-5975-5

(TIM)

NUMBER | TITLE
841 | Photothermal superhydrophobic coating
UNDERLYING TECHNOLOGY OR INNOVATION
n/a
SUGGESTED MATURITY
Emerging (TRL 4-6)
SUMMARY DESCRIPTION
Photothermal superhydrophobic coating is a novel technology in the field of advanced materials, which combines photothermal properties with superhydrophobicity. This technology utilizes solar energy to generate heat, while its superhydrophobic nature allows for extreme water repellency. As a result, it can be used for various applications such as self-cleaning, anti-icing, and water evaporation. The novelty of photothermal superhydrophobic coating lies in its dual-functionality. The integration of photothermal conversion and superhydrophobicity in a single coating is an innovative approach that offers unique advantages. The photothermal property allows the coating to generate heat under sunlight, which can be used for applications like deicing or water evaporation. On the other hand, its superhydrophobic nature ensures that the coated surface remains dry and clean. Therefore, this technology provides a multifunctional solution that can be useful in various sectors, including energy, environmental, and industrial applications. Recent developments have focused on improving the efficiency and durability of the coating, which could further expand its potential applications.
SOURCE
TIM signals. Sources used in the signal's detection and description include, but are not limited to: http://doi.org/10.1007/s42114-022-00549-5 ; http://doi.org/10.1016/j.mtphys.2022.100927 ; http://doi.org/10.1021/acsanm.3c01881 ; http://doi.org/10.1016/j.matlet.2023.135463 ; http://doi.org/10.1002/adma.202310312

(TIM)

NUMBER | TITLE
842 | Direct recycling of batteries
UNDERLYING TECHNOLOGY OR INNOVATION
n/a
SUGGESTED MATURITY
Emerging (TRL 4-6)
SUMMARY DESCRIPTION
Direct recycling of batteries is a technology in the field of advanced materials that focuses on recovering and reusing the active materials in spent batteries. This process involves disassembling the battery and directly reusing the recovered materials in new batteries. This method can potentially enhance the sustainability of battery production and reduce environmental impacts associated with battery disposal. The novelty of this technology lies in its departure from traditional recycling methods that involve energy-intensive smelting processes and harmful chemical treatments. Direct recycling of batteries allows for the preservation of the material's original structure, thereby reducing energy consumption and waste generation. Furthermore, this technology has the potential to address the growing demand for battery materials in a sustainable manner. However, it may pose challenges in terms of ensuring the quality and performance of the recycled materials. Recent developments have focused on addressing these issues and further optimizing the process for different types of batteries.
SOURCE
TIM signals. Sources used in the signal's detection and description include, but are not limited to: http://doi.org/10.1007/978-3-030-92563-5_49 ; http://doi.org/10.1002/cey2.231 ; http://doi.org/10.1002/gch2.202200212 ; http://doi.org/10.1021/acsnano.3c00270 ; http://doi.org/10.1016/j.esci.2023.100091 ; http://doi.org/10.1016/j.procir.2023.02.032 ; http://doi.org/10.1016/j.procir.2023.02.118

(TIM)

NUMBER | TITLE
844 | Black mass battery recycling
UNDERLYING TECHNOLOGY OR INNOVATION
n/a
SUGGESTED MATURITY
Emerging (TRL 4-6)
SUMMARY DESCRIPTION
Black mass battery recycling is a technology that concerns the recovery and reutilization of spent lithium-ion batteries. The process involves the extraction of valuable materials from the black mass - the residual substance left after initial recycling - typically containing lithium, cobalt, nickel, and other valuable metals. This technology is an environmentally-friendly and cost-effective solution to manage the escalating problem of battery waste. The novelty of black mass battery recycling lies in its potential to significantly reduce the environmental impact of battery disposal and to provide a sustainable source of valuable materials. This is especially relevant given the increasing demand for such materials in various industries, particularly in the production of new batteries. However, the technology is still evolving, with ongoing research to optimize the extraction process, improve efficiency, and broaden the range of recoverable materials.
SOURCE
TIM signals. Sources used in the signal's detection and description include, but are not limited to: http://doi.org/10.1002/aenm.202203093 ; http://doi.org/10.1021/jacs.2c13151 ; http://doi.org/10.3390/min12010072 ; http://doi.org/10.1016/j.jclepro.2022.135274 ; http://doi.org/10.1016/j.seppur.2023.123555

(TIM)

NUMBER | TITLE
847 | Biphenylene network
UNDERLYING TECHNOLOGY OR INNOVATION
n/a
SUGGESTED MATURITY
Emerging (TRL 4-6)
SUMMARY DESCRIPTION
The Biphenylene network is a class of advanced materials characterized by a two-dimensional (2D) carbon allotrope, which is a variant of carbon atoms linked in a distinct pattern. This framework exhibits an intriguing hybrid structure, integrating the properties of both graphitic carbon networks and diamond-like structures. The Biphenylene network's unique structure makes it ideal for various potential applications, particularly in electronics and photonics due to its thermal stability, mechanical strength, and exceptional electronic properties. The novelty of the Biphenylene network lies in its unique hybrid structure, which has not been observed in other 2D carbon allotropes. Its creation represents a significant breakthrough in materials science, opening up new avenues for the design of advanced materials with tailored properties. Recent developments have demonstrated the feasibility of synthesizing Biphenylene networks, marking a significant step forward in exploring its potential applications. However, further research is required to fully understand and harness the unique properties of this advanced material.
SOURCE
TIM signals. Sources used in the signal's detection and description (non-exhaustive list): http://doi.org/10.1126/science.abg4509 ; http://doi.org/10.1016/j.ijheatmasstransfer.2021.122060 ; http://doi.org/10.1088/1361-648X/ac2a7b ; http://doi.org/10.1002/jcc.26854 ; http://doi.org/10.1088/1361-6528/ac6f64

(TIM)

NUMBER | TITLE
849 | Eutectogel
UNDERLYING TECHNOLOGY OR INNOVATION
n/a
SUGGESTED MATURITY
Emerging (TRL 4-6)
SUMMARY DESCRIPTION
Eutectogel refers to a class of hybrid materials that combine the attributes of eutectic systems and gels, particularly in the context of advanced materials for energy storage and sensor applications. These materials exhibit properties such as high ionic conductivity, mechanical flexibility, stretchability, self-healing, and environmental adaptability, making them suitable for use in solid-state batteries, supercapacitors, strain sensors, and triboelectric nanogenerators. The novelty of eutectogel technology lies in its multifunctional capabilities, which address several challenges in the field of wearable devices and energy storage. Recent developments highlight eutectogels with high ionic transference numbers, superior electrochemical performance, and stable operation over a wide temperature range. Innovations include self-healing abilities, outstanding mechanical properties, and resistance to humidity, significantly enhancing the reliability and lifespan of devices. Additionally, the integration of eutectogels into various 3D architectures and their application in both visual and electronic strain sensing suggest a substantial advancement in the design of flexible and wearable technology. The combination of low-cost, non-flammable, and environmentally stable characteristics further underscores the potential of eutectogels to revolutionize next-generation electronic materials and devices.
SOURCE
TIM signals. Sources used in the signal's detection and description include, but are not limited to: http://doi.org/10.1016/j.nanoen.2022.107284 ; http://doi.org/10.1007/s12274-022-4759-7 ; http://doi.org/10.1016/j.cej.2022.139051 ; http://doi.org/10.1002/adma.202208392 ; http://doi.org/10.1039/d3mh00310h

(TIM)

NUMBER | TITLE
850 | High entropy carbides
UNDERLYING TECHNOLOGY OR INNOVATION
n/a
SUGGESTED MATURITY
Emerging (TRL 4-6)
SUMMARY DESCRIPTION
High entropy carbides (HECs) are a class of advanced materials that feature five or more principal elements distributed evenly. Characterized by high hardness, thermal stability, and resistance to wear and corrosion, these materials provide significant benefits in harsh conditions. Applications for HECs are diverse, ranging from coatings for cutting tools and wear parts to potential use in nuclear environments due to their impressive radiation tolerance. The novelty of high entropy carbides lies in the unique combination of properties that they offer. Unlike traditional materials, HECs are not limited to a single primary element, which allows for the creation of an almost endless array of compositions. This flexibility in design facilitates the optimization of material properties for specific applications. Recent developments have been focused on understanding the structure-property relationships in HECs to further enhance their performance. While the field is relatively new, HECs hold promise for the creation of next-generation materials with unparalleled performance characteristics.
SOURCE
TIM signals. Sources used in the signal's detection and description include, but are not limited to: http://doi.org/10.1016/j.compositesb.2022.110467 ; http://doi.org/10.1016/j.jeurceramsoc.2022.12.056 ; http://doi.org/10.1016/j.materresbull.2023.112212 ; http://doi.org/10.1016/j.actamat.2023.118856 ; http://doi.org/10.1038/s41586-023-06786-y

(TIM)

NUMBER | TITLE
851 | Mbene
UNDERLYING TECHNOLOGY OR INNOVATION
n/a
SUGGESTED MATURITY
Emerging (TRL 4-6)
SUMMARY DESCRIPTION
Mbene technology encompasses two-dimensional (2D) transition-metal borides with potential applications in energy storage, catalysis, and environmental remediation. These materials offer unique electronic structures and physicochemical properties, including high capacity for ion storage, catalytic activity for various reactions, and stability across different environments. The novelty of mbene technology is evident in its recent emergence as a promising candidate for multiple advanced material applications. Its exploration in high-loading lithium-sulfur batteries, water splitting, biomass upgrading, and nitrate reduction to ammonia underscores its versatility. The ability to stabilize single-atom catalysts for enhanced electrocatalytic performance and the development of new phases for rechargeable batteries highlight the innovative progress in mbene research. Furthermore, mbene's role in adsorption-reduction processes to remove environmental contaminants demonstrates its potential for addressing ecological challenges. As a nascent material with multifaceted applications, mbene stands at the frontier of material science, offering novel solutions for energy conversion, storage, and environmental sustainability.
SOURCE
TIM signals. Sources used in the signal's detection and description include, but are not limited to: http://doi.org/10.1002/adma.202108840 ; http://doi.org/10.1111/jace.18819 ; http://doi.org/10.1016/j.cej.2022.140318 ; http://doi.org/10.1007/s40820-022-00976-5 ; http://doi.org/10.1002/anie.202300054 ; http://doi.org/10.1016/j.commatsci.2023.112710

(TIM)

NUMBER | TITLE
852 | Ti3c2tx mxene
UNDERLYING TECHNOLOGY OR INNOVATION
n/a
SUGGESTED MATURITY
Emerging (TRL 4-6)
SUMMARY DESCRIPTION
Ti3C2Tx MXene is a two-dimensional (2D) transition metal carbide, which has garnered significant interest in the field of advanced materials due to its exceptional physicochemical properties. As a conductive, flexible and hydrophilic material, MXene exhibits superior electrochemical behavior, making it a promising candidate for various applications such as energy storage devices, electromagnetic interference shielding, sensors, and catalysis. The novelty of Ti3C2Tx MXene lies in its unique structure and multifunctional capabilities. Unlike other 2D materials, MXene's metallic conductivity and hydrophilic nature enable it to interact effectively with various substances. Its high electronic conductivity and large specific surface area also contribute to its excellent performance in energy storage and conversion. Recent developments have further expanded its potential use in advanced technological applications, including wearable devices and environmental remediation. However, the challenge remains to scale up its synthesis while maintaining its high quality and performance.
SOURCE
TIM signals. Sources used in the signal's detection and description include, but are not limited to: http://doi.org/10.1021/acsnano.1c08957 ; http://doi.org/10.1016/j.apcatb.2022.122245 ; http://doi.org/10.1021/acssensors.2c01748 ; http://doi.org/10.1007/s40820-023-01073-x ; http://doi.org/10.1016/j.ijhydene.2023.05.145

(TIM)

NUMBER | TITLE
853 | Janus monolayers
UNDERLYING TECHNOLOGY OR INNOVATION
n/a
SUGGESTED MATURITY
Novel (TRL 1-3)
SUMMARY DESCRIPTION
Janus monolayers are a type of two-dimensional (2D) material with distinct properties on each side due to a difference in composition or structure. This unique characteristic enables a wide array of physical and chemical interactions, making Janus monolayers suitable for a variety of applications in advanced material science. The novelty of Janus monolayers lies in their asymmetric property distribution, which provides an unprecedented platform for material engineering. This technology allows for the creation of materials with highly specific and customizable properties, expanding the potential applications in fields like electronics, optics, catalysis, and biosensing. Recent developments have revealed new methods for synthesizing Janus monolayers, improving their quality and control over their properties, while potential applications continue to be explored and expanded.
SOURCE
TIM signals. Sources used in the signal's detection and description include, but are not limited to: http://doi.org/10.1021/acs.nanolett.8b05050 ; http://doi.org/10.1103/PhysRevB.101.184401 ; http://doi.org/10.1088/2053-1583/ac1059 ; http://doi.org/10.1103/PhysRevB.107.054408 ; http://doi.org/10.1103/PhysRevLett.130.126303

(TIM)

NUMBER | TITLE
854 | Mxenes nanosheets
UNDERLYING TECHNOLOGY OR INNOVATION
n/a
SUGGESTED MATURITY
Emerging (TRL 4-6)
SUMMARY DESCRIPTION
Mxenes nanosheets are two-dimensional materials made from transition metal carbides, nitrides, or carbonitrides. As an advanced material, they possess unique properties such as good conductivity, hydrophilicity, and a large specific surface area, making them attractive for various applications. They are typically synthesized by selective etching of the A layers in MAX phases (where M is an early transition metal, A is an element from groups 13-16, and X is either C or N). The novelty of Mxenes nanosheets lies in their unique combination of properties that offer immense potential in numerous applications. The high electrical conductivity makes them suitable for energy storage applications, such as batteries and supercapacitors. Their hydrophilic nature enables compatibility with water-based processes and applications. The large surface area enhances their performance in catalysis and sensing. Recent developments in the synthesis and manipulation of Mxenes have expanded their potential, opening new avenues in the field of advanced materials.
SOURCE
TIM signals. Sources used in the signal's detection and description include, but are not limited to: http://doi.org/10.1002/adfm.201701264 ; http://doi.org/10.1016/j.cej.2022.138735 ; http://doi.org/10.1002/adfm.202210322 ; http://doi.org/10.1002/adfm.202209777 ; http://doi.org/10.1007/s12274-022-5368-1

(TIM)

NUMBER | TITLE
855 | Eutectic high-entropy alloy
UNDERLYING TECHNOLOGY OR INNOVATION
n/a
SUGGESTED MATURITY
Emerging (TRL 4-6)
SUMMARY DESCRIPTION
Eutectic high-entropy alloys (EHEAs) are a class of advanced materials characterized by a unique combination of multi-component compositions and eutectic structures. They are synthesized through a process called "eutectic reaction, " which involves the simultaneous solidification of multiple elements from a liquid mixture at a specific temperature. This yields an alloy with an intricate microstructure and often superior properties, including high strength, excellent ductility, and outstanding resistance to wear, corrosion, and high-temperature oxidation. The novelty of EHEAs lies in their multi-principal element composition, which diverges from traditional alloys that generally have one or two principal elements. This compositional complexity leads to a high degree of disorder at the atomic level, contributing to their exceptional mechanical and chemical properties. The eutectic structure also enhances the properties by creating a fine-scale interpenetrating network of phases, which can be tailored by adjusting the alloy components. Recent developments in EHEAs have demonstrated their potential for a wide range of applications, including in aerospace, automotive, and energy sectors where high-performance materials are required. However, further research is needed to fully understand the behavior of these alloys and optimize their design for specific applications.
SOURCE
TIM signals. Sources used in the signal's detection and description include, but are not limited to: http://doi.org/10.1038/srep06200 ; http://doi.org/10.1016/j.actamat.2016.11.016 ; http://doi.org/10.1126/science.abf6986 ; http://doi.org/10.1016/j.jmst.2022.05.060 ; http://doi.org/10.1016/j.jmst.2022.07.023

(TIM)

NUMBER | TITLE
856 | Tellurene
UNDERLYING TECHNOLOGY OR INNOVATION
n/a
SUGGESTED MATURITY
Emerging (TRL 4-6)
SUMMARY DESCRIPTION
Tellurene is a two-dimensional (2D) material that exhibits unique properties in the field of advanced materials. This material, with its atomically thin structure, has shown promising applications in electronics due to its high carrier mobility and excellent conductivity. Furthermore, the material's flexibility and robustness make it ideal for use in wearable technology, sensors and optoelectronics. Tellurene's properties can be tuned by manipulating its structure, making it adaptable for various technological applications. The novelty of tellurene lies in its exceptional properties that set it apart from other 2D materials. It has a higher degree of flexibility and mechanical strength compared to other materials in its class. Its superior electronic properties also surpass those of traditional semiconductors, making it a promising material for next-generation electronic devices. The ability to fine-tune tellurene's properties through structural manipulation further enhances its potential for diverse applications. Despite being relatively new, recent developments suggest that tellurene might revolutionize the advanced materials sector.
SOURCE
TIM signals. Sources used in the signal's detection and description include, but are not limited to: http://doi.org/10.1515/nanoph-2019-0545 ; http://doi.org/10.1021/acs.chemrev.1c00165 ; http://doi.org/10.1002/adma.202109521 ; http://doi.org/10.1002/adma.202211562 ; http://doi.org/10.1016/j.ensm.2023.102780

(TIM)

NUMBER | TITLE
857 | Heterojunction catalysts
UNDERLYING TECHNOLOGY OR INNOVATION
n/a
SUGGESTED MATURITY
Emerging (TRL 4-6)
SUMMARY DESCRIPTION
Heterojunction catalysts are advanced materials developed for catalytic applications. They are designed to take advantage of the unique properties and advantages of different catalyst materials by combining them at the atomic level. The goal is to create new catalytic materials with enhanced activity, selectivity, and stability. This technology typically employs semiconductors and is used in a wide variety of applications, including energy conversion, environmental remediation, and chemical synthesis. The novelty of heterojunction catalysts lies in the unique combination of catalyst materials that result in improved catalytic properties. This innovative approach allows for greater control over the catalytic process and enhanced performance. Recent developments in this field have focused on optimizing the synthesis methods and understanding the underlying mechanisms to further improve the efficiency of these catalysts. These advancements have the potential to revolutionize many industrial processes, making them more efficient and environmentally friendly.
SOURCE
TIM signals. Sources used in the signal's detection and description include, but are not limited to: http://doi.org/10.1016/j.apcatb.2022.121979 ; http://doi.org/10.1016/j.jallcom.2022.167784 ; http://doi.org/10.1002/advs.202205020 ; http://doi.org/10.1016/j.apcatb.2023.122551 ; http://doi.org/10.1016/j.apcatb.2023.123284

(TIM)

NUMBER | TITLE
860 | Borophene
UNDERLYING TECHNOLOGY OR INNOVATION
n/a
SUGGESTED MATURITY
Emerging (TRL 4-6)
SUMMARY DESCRIPTION
Borophene is a two-dimensional, single-atom-thick sheet of boron, similar in structure to graphene. Its unique properties, including high thermal and electronic conductivity, flexibility, strength, and light weight make it a valuable advanced material. Borophene's metallic nature allows it to display superconductivity and plasmonic behaviors, making it ideal for potential applications in nanoelectronics, sensing, and energy storage. The novelty of borophene lies in its unique structural flexibility, allowing for various phases with different electronic properties, unlike the rigid structure of graphene. It exhibits a combination of properties not found in other two-dimensional materials, such as directional anisotropy, tunable bandgaps, and high carrier mobility. Additionally, recent developments highlight the potential of borophene in the realization of flexible, wearable electronics and energy storage devices, marking it as a promising material for future technological applications.
SOURCE
TIM signals. Sources used in the signal's detection and description include, but are not limited to: http://doi.org/10.1126/science.aad1080 ; http://doi.org/10.1038/nchem.2491 ; http://doi.org/10.1038/s41563-021-01084-2 ; http://doi.org/10.1002/advs.202205809 ; http://doi.org/10.1063/5.0136110

(TIM)

NUMBER | TITLE
861 | Vanadium disulfide
UNDERLYING TECHNOLOGY OR INNOVATION
n/a
SUGGESTED MATURITY
Novel (TRL 1-3)
SUMMARY DESCRIPTION
Vanadium disulfide is an advanced material that exhibits unique properties useful for a variety of applications. A layered transition metal dichalcogenide, its inherent structure enables unique electronic and optical characteristics. Particularly, it shows promise for use in nanoscale electronics, optoelectronics, and energy storage technologies. This material can demonstrate high conductivity and charge density, along with tunable bandgap, making it suitable for a wide range of electronic applications. The novelty of vanadium disulfide lies in its distinctive material characteristics and versatility. Recent developments have uncovered its potential in enhancing the efficiency of energy storage devices and improving the performance of electronic and optoelectronic devices. Its adjustable bandgap and high charge density are particularly novel aspects, offering new opportunities for technological advancements. However, as a relatively new material in the field of advanced materials, more research is needed to fully understand its properties and potential applications.
SOURCE
TIM signals. Sources used in the signal's detection and description include, but are not limited to: http://doi.org/10.1021/ja207176c ; http://doi.org/10.1002/adma.201104681 ; http://doi.org/10.1002/adma.201702061 ; http://doi.org/10.1016/j.jechem.2019.08.003 ; http://doi.org/10.1016/j.jmst.2021.08.005

(TIM)

NUMBER | TITLE
862 | Antimonene
UNDERLYING TECHNOLOGY OR INNOVATION
n/a
SUGGESTED MATURITY
Emerging (TRL 4-6)
SUMMARY DESCRIPTION
Antimonene is a new technology in the field of advanced materials, characterized by a single layer of antimony atoms. As a two-dimensional (2D) material, it exhibits unique properties such as high carrier mobility, large bandgap, and excellent mechanical flexibility. The manipulation of these properties can be achieved through external stimuli, making Antimonene highly promising for applications in electronics, optoelectronics, and catalysis, among others. The novelty of Antimonene lies in its unique structural, electronic, and optical properties, which are distinct from its bulk counterpart and other 2D materials. uRecent developments in Antimonene technology have demonstrated its potential for high-performance applications in areas such as energy storage and conversion, flexible electronics, and sensing. However, challenges remain in achieving scalable and reproducible synthesis of high-quality Antimonene, which is crucial for its practical applications. Despite these challenges, Antimonene represents a new frontier in the realm of advanced materials, opening up exciting possibilities for future technological innovations.
SOURCE
TIM signals. Sources used in the signal's detection and description include, but are not limited to: http://doi.org/10.1002/anie.201411246 ; http://doi.org/10.1002/anie.201507568 ; http://doi.org/10.1038/ncomms13352 ; http://doi.org/10.1038/s41467-018-07947-8 ; http://doi.org/10.1103/PhysRevLett.125.247002

(TIM)

NUMBER | TITLE
863 | 2D hexagonal boron nitrides
UNDERLYING TECHNOLOGY OR INNOVATION
n/a
SUGGESTED MATURITY
Emerging (TRL 4-6)
SUMMARY DESCRIPTION
2D Hexagonal Boron Nitrides (h-BN) is a cutting-edge technology in the field of advanced materials. This technology utilizes two-dimensional layers of hexagonal boron nitride, a compound made up of boron and nitrogen, to create materials with unique properties. Notably, these materials have excellent thermal and chemical stability, remarkable mechanical strength, high electrical insulation, and the ability to support large electric fields. The novelty of 2D h-BN technology lies in its potential for wide-ranging applications. Recent advancements have unlocked the potential of this material in various sectors such as electronics, where it can be used in the design of high-performance devices due to its superior electrical insulation properties. Also, its unique thermal and chemical stability makes it suitable for extreme environments, which opens up new potential applications in fields such as aerospace and nuclear power. Despite these advancements, the technology remains in its early stages, with ongoing research aimed at further understanding and optimizing the properties and potential applications of 2D h-BN.
SOURCE
TIM signals. Sources used in the signal's detection and description include, but are not limited to: http://doi.org/10.1021/nl504397h ; http://doi.org/10.1021/acsnano.5b00655 ; http://doi.org/10.1038/nnano.2015.242 ; http://doi.org/10.1038/s41563-020-0619-6 ; http://doi.org/10.1016/j.molliq.2020.113185

(TIM)

NUMBER | TITLE
866 | Self-healing ionogel
UNDERLYING TECHNOLOGY OR INNOVATION
n/a
SUGGESTED MATURITY
Emerging (TRL 4-6)
SUMMARY DESCRIPTION
Self-healing ionogels are a class of advanced materials that possess the unique ability to repair themselves when damaged. These ionogels are composed of an ionic liquid, a type of salt in a liquid state, embedded within a polymer network. The special characteristics of the ionic liquid, such as high conductivity, stability and low volatility, combined with the mechanical strength of the polymer, result in a material with a wide range of potential applications. The primary novelty of self-healing ionogels lies in their self-repairing ability, which significantly enhances the durability and longevity of the material. This feature is achieved through dynamic chemical bonds that can break and reform, allowing the material to heal itself when damaged. This self-healing process can occur multiple times without affecting the original properties of the ionogel. The technology is still in its early stages of development, but recent advancements show great promise for applications in areas such as electronics, energy storage systems, and sensors. This innovative technology has the potential to significantly impact these fields by providing more reliable and longer-lasting materials.
SOURCE
TIM signals. Sources used in the signal's detection and description include, but are not limited to: http://doi.org/10.1002/adma.202008479 ; http://doi.org/10.1002/adma.202105306 ; http://doi.org/10.1007/s42765-021-00086-8 ; http://doi.org/10.1002/adma.202203049 ; http://doi.org/10.1016/j.ensm.2023.03.003

(TIM)

NUMBER | TITLE
867 | Vitrimers
UNDERLYING TECHNOLOGY OR INNOVATION
n/a
SUGGESTED MATURITY
Emerging (TRL 4-6)
SUMMARY DESCRIPTION
Vitrimers are a class of advanced materials, specifically a new type of polymer network. These materials exhibit unique properties, combining the processability of thermoplastics with the high mechanical resistance and dimensional stability of thermosets. Unlike traditional polymers, vitrimers undergo bond exchange reactions at high temperatures, which allows them to flow and reshape without breaking down. The novelty of vitrimers lies in their dynamic and adaptive nature. Traditional polymers are static and cannot adapt to changes in their environment. In contrast, vitrimers' bond exchange reactions allow them to rearrange their structure and adapt to external stimuli. This property opens up potential applications in various fields, including self-healing materials, recyclable thermosets, and moldable composites. Recent developments have focused on expanding the types of bond exchange reactions used in vitrimers, improving their processability, and enhancing their mechanical properties. The continual evolution and refinement of vitrimer technology signify its potential for significant impact in materials science and engineering.
SOURCE
TIM signals. Sources used in the signal's detection and description include, but are not limited to: http://doi.org/10.1021/acs.macromol.1c02247 ; http://doi.org/10.1021/acsapm.2c00230 ; http://doi.org/10.1016/j.cej.2022.138610 ; http://doi.org/10.1007/978-981-19-6038-3_4 ; http://doi.org/10.1007/s10118-023-3045-9

(TIM)

NUMBER | TITLE
868 | Nanoenzyme
UNDERLYING TECHNOLOGY OR INNOVATION
n/a
SUGGESTED MATURITY
Emerging (TRL 4-6)
SUMMARY DESCRIPTION
Nanoenzyme technology refers to the development and application of nanomaterials that exhibit enzyme-like activities. These nanozymes can mimic natural enzymes by catalyzing reactions, but they offer enhanced stability, cost-effectiveness, and versatility. In the field of advanced materials, nanozymes have found wide-ranging applications, from environmental remediation and biosensing to targeted therapy and diagnostic imaging. The novelty of nanoenzyme technology lies in the unique properties of nanomaterials that allow them to mimic enzymatic activity. This ability to catalyze reactions under conditions where natural enzymes are unstable or ineffective expands the scope of potential applications. Recent developments have seen nanozymes being tailored for specific applications, such as targeted drug delivery in cancer therapy or as diagnostic imaging agents. As a new class of enzyme mimics, nanozymes provide a groundbreaking approach to the design of advanced materials with tunable functions.
SOURCE
TIM signals. Sources used in the signal's detection and description include, but are not limited to: http://doi.org/10.1021/acs.nanolett.0c01371 ; http://doi.org/10.1021/acsnano.1c08664 ; http://doi.org/10.1016/j.foodchem.2022.135017 ; http://doi.org/10.1002/adma.202208817 ; http://doi.org/10.1016/j.bios.2022.114996

(TIM)

NUMBER | TITLE
870 | Nano encapsulated phase change material
UNDERLYING TECHNOLOGY OR INNOVATION
n/a
SUGGESTED MATURITY
Emerging (TRL 4-6)
SUMMARY DESCRIPTION
Nano encapsulated phase change materials (NEPCMs) are advanced materials that leverage the properties of phase change materials (PCMs) and nanotechnology. NEPCMs can store and release large amounts of thermal energy during the phase change process, making them ideal for thermal energy storage applications. The nano-encapsulation enhances their thermal conductivity, stability, and controllability, while also minimizing leakage during phase transitions. The novelty of NEPCMs lies in the combination of nano-encapsulation techniques with PCMs, enhancing their properties and expanding their potential applications. Recent developments in this field have focused on improving the encapsulation process and the thermal properties of the NEPCMs. Despite being a relatively new technology, NEPCMs have shown promising potential in areas such as building heating/cooling, solar thermal power, and electronic device cooling. Overall, the innovation of NEPCMs represents an important advancement in the field of thermal energy storage and management.
SOURCE
TIM signals. Sources used in the signal's detection and description include, but are not limited to: http://doi.org/10.1016/j.ijheatmasstransfer.2019.04.037 ; http://doi.org/10.1016/j.est.2021.103606 ; http://doi.org/10.1016/j.tsep.2022.101552 ; http://doi.org/10.1016/j.est.2022.106213 ; http://doi.org/10.1016/j.est.2022.106492

(TIM)

NUMBER | TITLE
873 | Self-healing polyurethane
UNDERLYING TECHNOLOGY OR INNOVATION
n/a
SUGGESTED MATURITY
Emerging (TRL 4-6)
SUMMARY DESCRIPTION
Self-healing polyurethane is a type of advanced material that has the capacity to repair itself when damaged, without any external intervention. The technology works by incorporating microcapsules filled with healing agents into the material. When the material is damaged, these capsules break, releasing the healing agent which reacts with the material to seal the damage, thereby restoring the material's integrity and functionality. The novelty of self-healing polyurethane lies in its ability to prolong lifespan and maintain functionality of products made from it, potentially reducing costs and waste associated with repair or replacement. It is an active area of research with potential applications in diverse sectors, including construction, aerospace, and consumer goods. The technology has been progressively refined, with recent developments focusing on improving healing efficiency, versatility, and the range of materials with which the technology can be integrated. However, challenges remain in terms of scalability and in achieving efficient healing under diverse environmental conditions.
SOURCE
TIM signals. Sources used in the signal's detection and description include, but are not limited to: http://doi.org/10.1016/j.cej.2022.138673 ; http://doi.org/10.1016/j.porgcoat.2022.107256 ; http://doi.org/10.1016/j.cej.2022.140187 ; http://doi.org/10.1016/j.nanoen.2023.108243 ; http://doi.org/10.1016/j.carbpol.2023.120654

(TIM)

NUMBER | TITLE
874 | Bimetallic zeolitic imidazolate framework
UNDERLYING TECHNOLOGY OR INNOVATION
n/a
SUGGESTED MATURITY
Emerging (TRL 4-6)
SUMMARY DESCRIPTION
Bimetallic zeolitic imidazolate framework (ZIF) is a type of advanced material in the field of nanotechnology, composed of two metal ions and organic imidazolate linkers. This structure is characterized by its high porosity, large surface area, and stable chemical and thermal properties. The customizable nature of the metal ions and linkers allows for a broad range of potential applications, including in gas storage, catalysis, drug delivery, and environmental remediation. The novelty of bimetallic ZIFs lies in their remarkable adaptability and versatility. The inclusion of two metal ions, as opposed to one, significantly broadens the range of achievable properties and functionalities. Moreover, recent developments have shown that by manipulating the spatial arrangement and composition of these ions, researchers can further tailor the properties of the ZIFs to suit specific applications. This flexibility, coupled with their inherent stability and high performance, positions bimetallic ZIFs at the forefront of advanced material research.
SOURCE
TIM signals. Sources used in the signal's detection and description include, but are not limited to: http://doi.org/10.1039/c8ee00133b ; http://doi.org/10.1021/acs.est.2c00706 ; http://doi.org/10.1016/j.esci.2022.03.007 ; http://doi.org/10.1016/j.surfin.2022.102324 ; http://doi.org/10.1016/j.ijbiomac.2023.123410

(TIM)

NUMBER | TITLE
875 | Metal foam Phase Changing Material
UNDERLYING TECHNOLOGY OR INNOVATION
n/a
SUGGESTED MATURITY
Emerging (TRL 4-6)
SUMMARY DESCRIPTION
Metal foam Phase Changing Material (PCM) is an advanced material technology that combines metallic foam's thermal conductivity with the energy storage capabilities of PCMs. In this technology, a PCM is impregnated into a metal foam, creating a composite material that can absorb, store, and release large amounts of thermal energy. This is achieved through the phase change of the PCM, which can transition between solid and liquid states. The metal foam provides a high surface area for heat transfer, enhancing the PCM's thermal performance. The novelty of Metal foam PCM lies in its unique combination of thermal conductivity and energy storage. Traditional PCMs often struggle with slow thermal response rates due to low thermal conductivity, but the integration with metal foam overcomes this issue. Additionally, the composite material's ability to store and release large amounts of heat offers potential for various applications, including thermal energy storage, heat exchangers, and cooling systems. The recent developments in this field suggest a promising future for this technology, but more research is needed to optimize the performance and develop practical applications.
SOURCE
TIM signals. Sources used in the signal's detection and description include, but are not limited to: http://doi.org/10.1016/j.solener.2010.04.022 ; http://doi.org/10.1016/j.energy.2011.07.019 ; http://doi.org/10.1016/j.apenergy.2013.04.050 ; http://doi.org/10.1016/j.ijheatmasstransfer.2021.121001 ; http://doi.org/10.1016/j.enbenv.2021.08.002

(TIM)

NUMBER | TITLE
878 | Nanocellulose materials
UNDERLYING TECHNOLOGY OR INNOVATION
n/a
SUGGESTED MATURITY
Emerging (TRL 4-6)
SUMMARY DESCRIPTION
Nanocellulose materials, derived from plant fibers, are increasingly utilized in the field of advanced materials due to their unique properties. These materials are known for their lightweight nature, high mechanical strength, biodegradability, and the ability to form flexible films or gels. They can be altered at the nanoscale to exhibit different characteristics like transparency or improved thermal stability, making them versatile for various applications. The novelty of nanocellulose materials lies in their sustainable properties and potential for diverse applications. Recent developments have shown their use in areas such as electronics, biomedicine, and energy storage, providing environmentally friendly solutions. They are also being explored as potential replacements for non-renewable materials in various industries. However, while the technology is innovative, further research is needed to optimize its properties and expand its commercial viability.
SOURCE
TIM signals. Sources used in the signal's detection and description include, but are not limited to: http://doi.org/10.1016/j.jobab.2022.05.003 ; http://doi.org/10.1016/j.indcrop.2022.116204 ; http://doi.org/10.1021/acs.chemrev.2c00611 ; http://doi.org/10.1002/adfm.202214245 ; http://doi.org/10.13360/j.issn.2096-1359.202208003

(TIM)

NUMBER | TITLE
915 | Goldene, better than graphene?
UNDERLYING TECHNOLOGY OR INNOVATION
catalysis (e.g., waste treatment), photonic (plasmonic, photothermal, photovoltaic, etc.)
SUGGESTED MATURITY
Novel (TRL 1-3)
SUMMARY DESCRIPTION
Researchers at Linköping University in Sweden have successfully created single-atom-layer gold , named 'Goldene' through wet-chemical etching schemes. The developed method claimed to be facile, scalable and safe (HF acid free) can give a novel synthesis path to creating a large-size 2D Au sheets. Given the already known enhancement of electronic and plasmonic properties of gold induced by nano- and anisotropic structuration, the future development of large-sized 2D, 1-atomic layer gold sheets will not only be beneficial in a plethora of photonic and electrochemical technologies (photovoltaic, photothermal, catlaytic), and can greatly reduce the quantity of gold needed in each application.
SOURCE
Kashiwaya, S., Shi, Y., Lu, J. et al. https://doi.org/10.1038/s44160-024-00518-4

(External experts)

NUMBER | TITLE
918 | new 2D topological materials
UNDERLYING TECHNOLOGY OR INNOVATION
quantum materials
SUGGESTED MATURITY
Novel (TRL 1-3)
SUMMARY DESCRIPTION
Thes new materials can constitute a real shift in the paradigm considering that will be able to enhance strangly the zT value for Thermolectric material. We can imagine to develop thermoelectric generators with an effciency larger than 50% which is a real shift in terms of performances and could help thermoelectric to get through the present technological stagnation.
SOURCE
Xu, N., Xu, Y. & Zhu, J. https://www.nature.com/articles/s41535-017-0054-3

(External experts)

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