Floatech®

Sustainable and high-performance silicon battery anodes

www.floatech.eu

Silicon nanotextile anodes for the next generation LIBs: from discovery to industrialisation

MeBattery Technology Transfer Workshop
Universidad de Burgos, 24-10-23

Juan José Vilatela
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European mobility landscape

> 300 GWh/YEAR

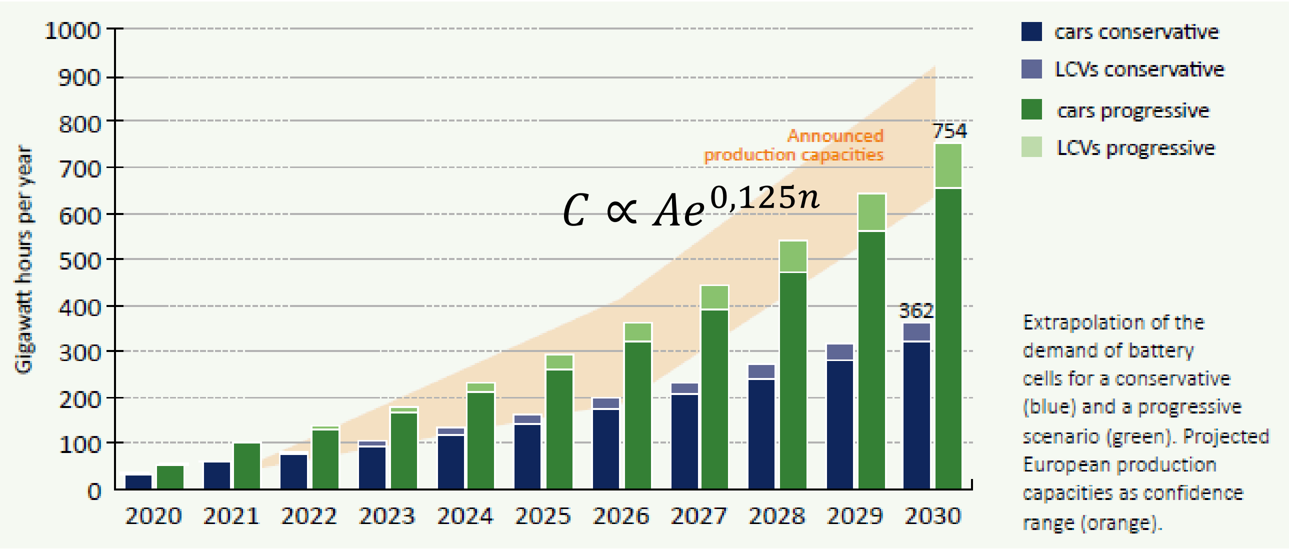
Required installed capacity estimated for Europe in 2030

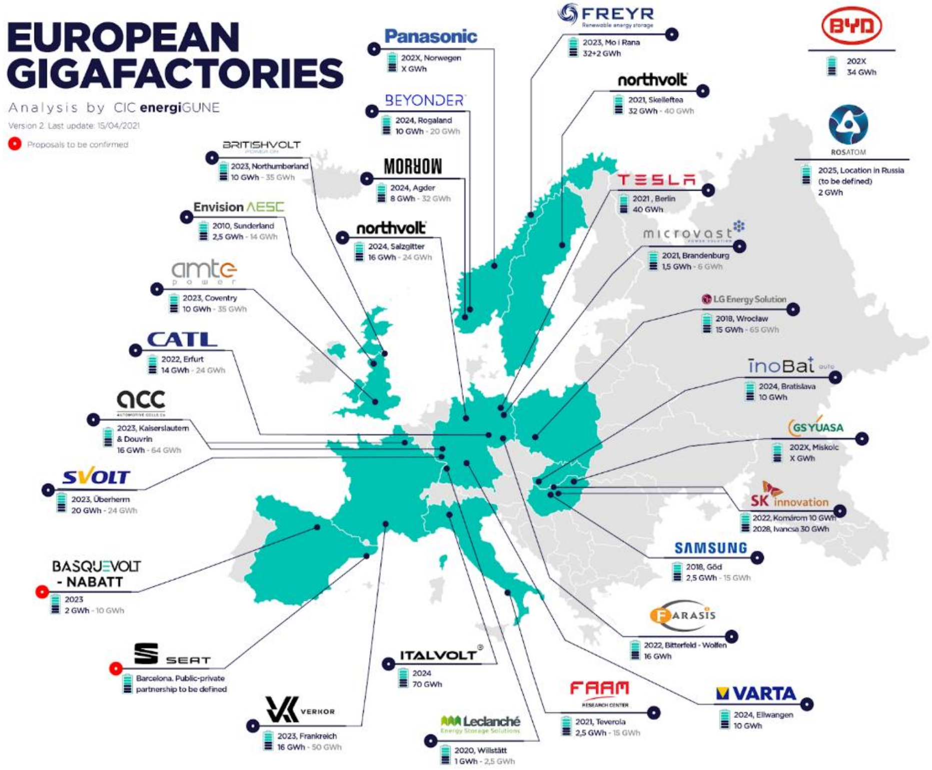
$116 billion annually

Battery market for electric vehicles in 2030

30% of global GHG reductions

Attributed to batteries





Sources:
VDI/VDE Innovation + Technik GmbH, 2022
http://www3.weforum.org/docs/WEF_A_Vision_for_a_Sustainable_Battery_Value_Chain_in_2030_Report.pdf
5 European Commission, EU energy in figures – statistical pocket book (2019).)
Batteries Europe 2020, European Technology and Innovation Platform

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The next generation LIBs

TABLE 1: BATTERY GENERATIONS CATEGORISATION

Battery Generation	Electrodes active materials	Cell Chemistry / Type	Forecast market deployment
Gen 1	• Cathode: LFP, NCA • Anode: 100% carbon	Li-ion Cell	current
Gen 2a	• Cathode: NMC111 • Anode: 100% carbon	Li-ion Cell	current
Gen 2b	• Cathode: NMC523 to NMC 622 • Anode: 100% carbon	Li-ion Cell	current
Gen 3a	• Cathode: NMC622 to NMC 811 • Anode: carbon (graphite) + silicon content (5-10%)	Optimised Li-ion	2020
Gen 3b	• Cathode: HE-NMC, HVS (high-voltage spinel) • Anode: silicon/carbon	Optimised Li-ion	2025
Gen 4a	• Cathode NMC • Anode Si/C • Solid electrolyte	Solid state Li-ion	2025
Gen 4b	• Cathode NMC • Anode: lithium metal • Solid electrolyte	Solid state Li metal	>2025
Gen 4c	• Cathode: HE-NMC, HVS (high-voltage spinel) • Anode: lithium metal • Solid electrolyte	Advanced solid state	2030
Gen 5	• Li|O_2 – lithium air / metal air • Conversion materials (primarily Li|S) • new ion-based systems (Na, Mg or Al)	New cell gen: metal-air/ conversion chemistries / new ion-based insertion chemistries	>2030

European Commission

BATTERIES EUROPE
EUROPEAN TECHNOLOGY AND INNOVATION PLATFORM

BATTERIES TO 2025 LI-ION DOMINATES THE MARKET

CONTINUED DIVERSIFICATION OF LI-ION TECHNOLOGIES

Li-ion batteries' scaling pathway is unlike that for silicon photovoltaic cells; investment continues to differentiate among chemistries with performance attributes that are best suited to specific use cases.

As investment in Li-ion grows, companies are pursuing different battery chemistry compositions with widely varying performance attributes (Exhibit 7). The number of battery types will likely continue to diverge in terms of the types of anodes, cathodes, separators, and electrolytes used. These various approaches are pursuing improvements across several areas:

Rocky Mountain Institute

Innovations in the battery industry affect all cell components.

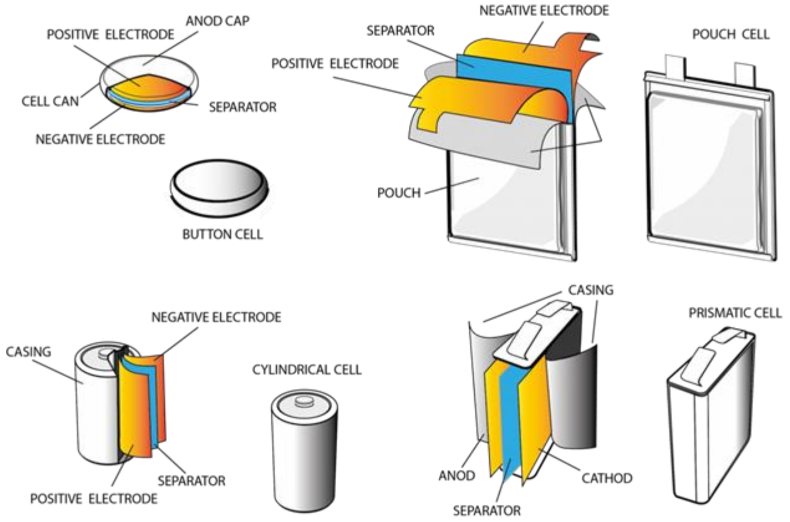
Common battery chemistries and form factor available

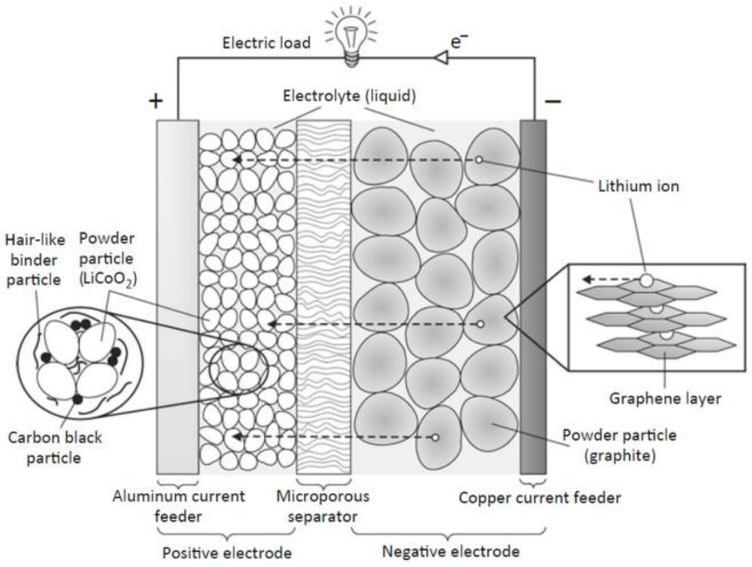
	2010s		2020s		2030s	
1 Cathode	LCO[1]	LMO[2] LFP[3] NMC[4]/NCA[5]	LFP[3] NMC[4]/NCA[5]	LFP[3] NMC[4]/NCA[5] LMFP[6]/LMNO[7]	NMC[4]/NCA[5] LMFP[6]/LMNO[7] Sulphur	LMFP[6]/LMNO[7] Sulphur
2 Separator/ electrolyte	Polymer/liquid	Polymer/liquid	Polymer/liquid	Polymer/liquid	Polymer/liquid Advanced liquid Semi-solid	Advanced liquid Semi-solid Solid
3 Anode	Graphite	Graphite	Graphite	Graphite Graphite and silicon	Graphite and silicon Lithium metal Silicon anode	Lithium metal Silicon anode
4 Casing	Cylindrical	Cylindrical Pouch	Prismatic Cylindrical Pouch	Prismatic Cylindrical Pouch	Cylindrical Pouch Prismatic	Cylindrical Pouch

[1] Lithium cobalt.
[2] Lithium manganese oxide.
[3] Lithium, iron, phosphate.
[4] Lithium, manganese cobalt.
[5] Lithium, nickel, cobalt, aluminum oxide.
[6] Lithium manganese iron phosphate.
[7] Lithium, manganese nickel oxide.
Source: McKinsey Battery Insights, 2022

Si:Coil. Reference product for next anode generation.

Lithium-ion battery (LIB) basics



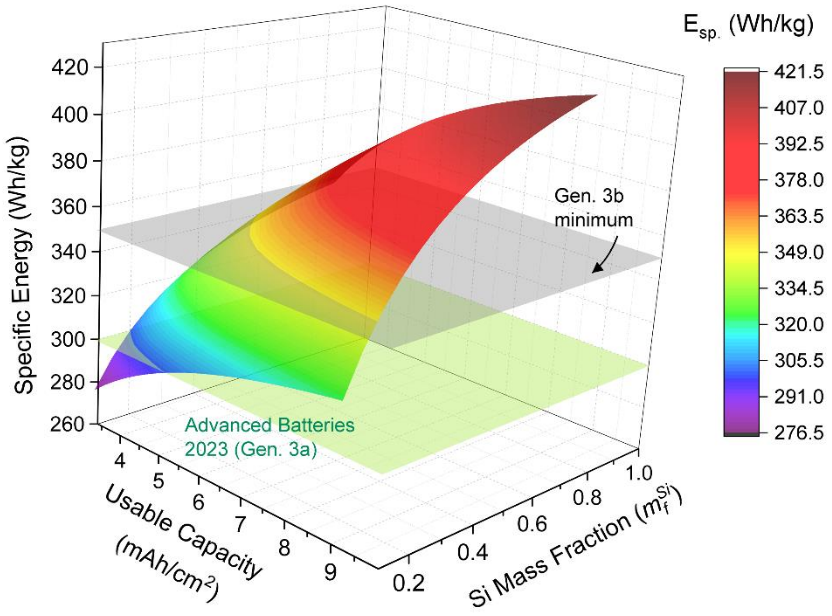


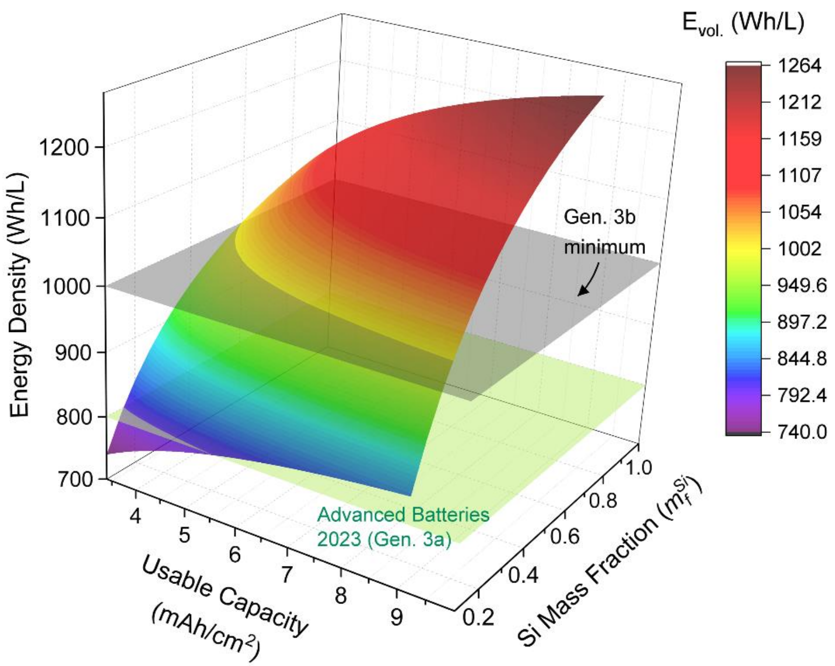
$$Energy\ density \approx \frac{capacity\ of\ limiting\ electrode\ X\ voltage}{mass\ (anode + cathode + other)}$$

	Current LIB cell	Next gen. LIB cell (2025)
Anode composition	5% Si/SiO, 80% graphite	> 95% Si
Anode thickness	100 microns	10 microns
Cathode thicnkess	100 microns	250 microns
Cell energy density	≈ 275 Wh/kg	> 400 Wh/kg

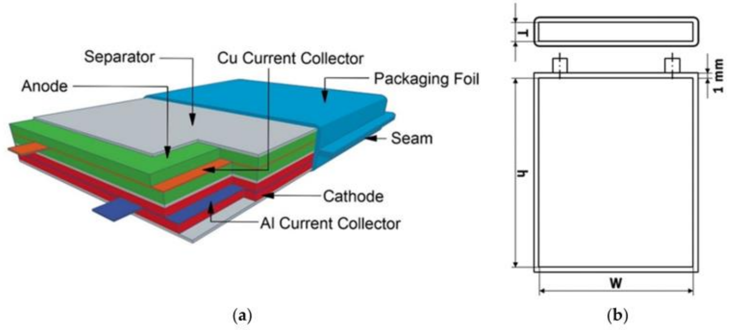
https://barnett-technical.com
Lithium-ion batteries: basics and applications. (Springer Berlin Heidelberg, 2017)

Design of high energy density LIB cell





Calculation for 50Ah cell with the CellEst model



Pendashteh et al, Nanotextile100% Si Anodes for the Next Generation Energy-Dense Li-ion Batteries, under review

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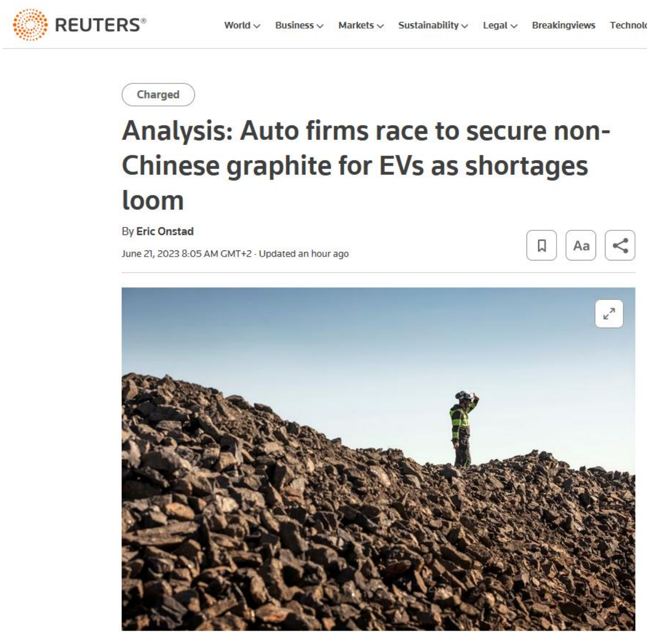
Raw materials availability



REUTERS® World Business Markets Sustainability Legal Breakingviews

Charged

Analysis: Auto firms race to secure non-Chinese graphite for EVs as shortages loom

By Eric Onstad

June 21, 2023 8:05 AM GMT+2 · Updated an hour ago

REUTERS® World Business Markets Sustainability Legal Breakingviews Technology

China

China, world's top graphite producer, to curb exports of key battery material

By Siyi Liu and Dominique Patton

October 20, 2023 1:09 PM GMT+2 · Updated 4 hours ago

"By 2032, China will still control 79% of production of a type of processed graphite - uncoated spheroidised purified graphite - compared to 100% in 2022, according to BMI."

Another anode ingredient is silicon, which also enables an EV to drive longer distances before recharging.

Currently, the maximum amount of silicon added to batteries is about 10% because the material expands during use and can degrade the battery.

Companies are **working on technology** that would allow larger amounts of silicon. If successful, that could be a threat to graphite in the long term.

Source: Reuters

N.B. The EU produces around 2% of its annual use of graphite

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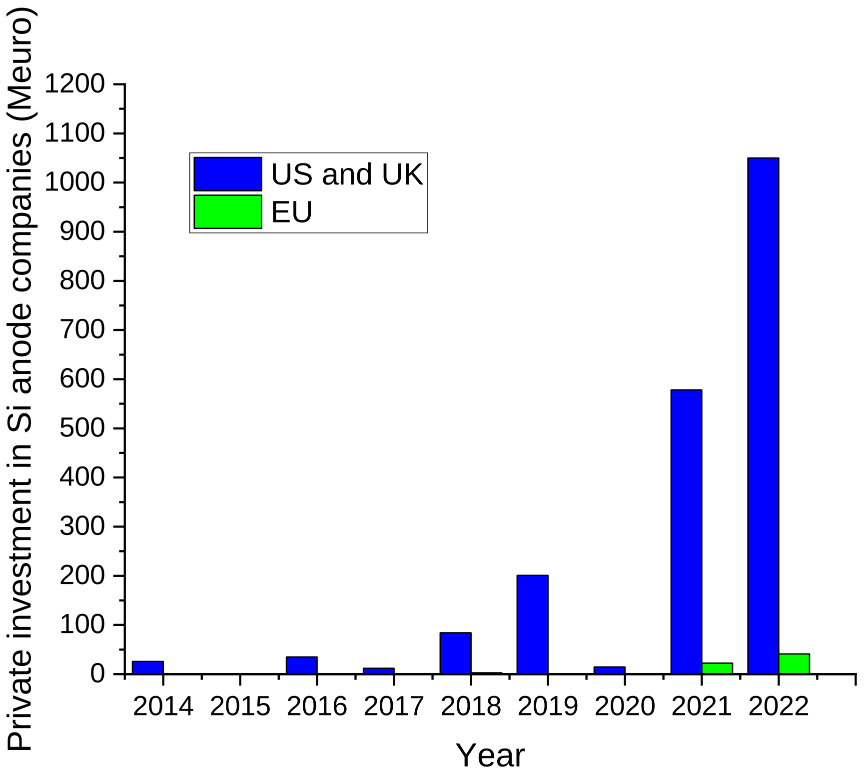
Silicon Anodes for high energy density LIBs

Innovators | Silicon Anode

Company	Technology	Tot. Funding, Stage	Partnerships / Investments
SILA NANOTECHNOLOGIES	Si nanocomposite	$930M, Series F	DAIMLER, WHOOP, CATL, TDK, SAMSUNG
enovix	3D Si architecture	$254M, SPAC	intel, Qualcomm
ENEVATE	Si porous film	$192M, Series E	RENAULT NISSAN MITSUBISHI, LG Chem, SAMSUNG
StoreDot	Si nanoparticles	$172M, Private	bp, EVE, DAIMLER, VINFAST, SAMSUNG, TDK
nexeon	Si porous columns	£130M, Private	WACKER, SK chemicals
OneD BATTERY SCIENCES	Si nanowires on graphite	$125M, Private	Financial VCs
amprius	Si nanowires	$191M, Series C	AIRBUS, U.S. ARMY
ADVANO	Si nanoparticles	$38.8M, Series A	MITSUI KINZOKU
GROUP14	Si/C nanocomposite	$41.5M, Series B	SK materials, TDK, BASF, FARASIS, StoreDot
LeydenJar ENERGISING TECHNOLOGIES	Si nanopillars	€33.2M, Series A	Financial VCs
Ionblox	nanoSi	€32M, Series B	LILIUM




materiales
materiales
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A differentiated **Si anode technology**
for a competitive and sustainable
European battery value chain

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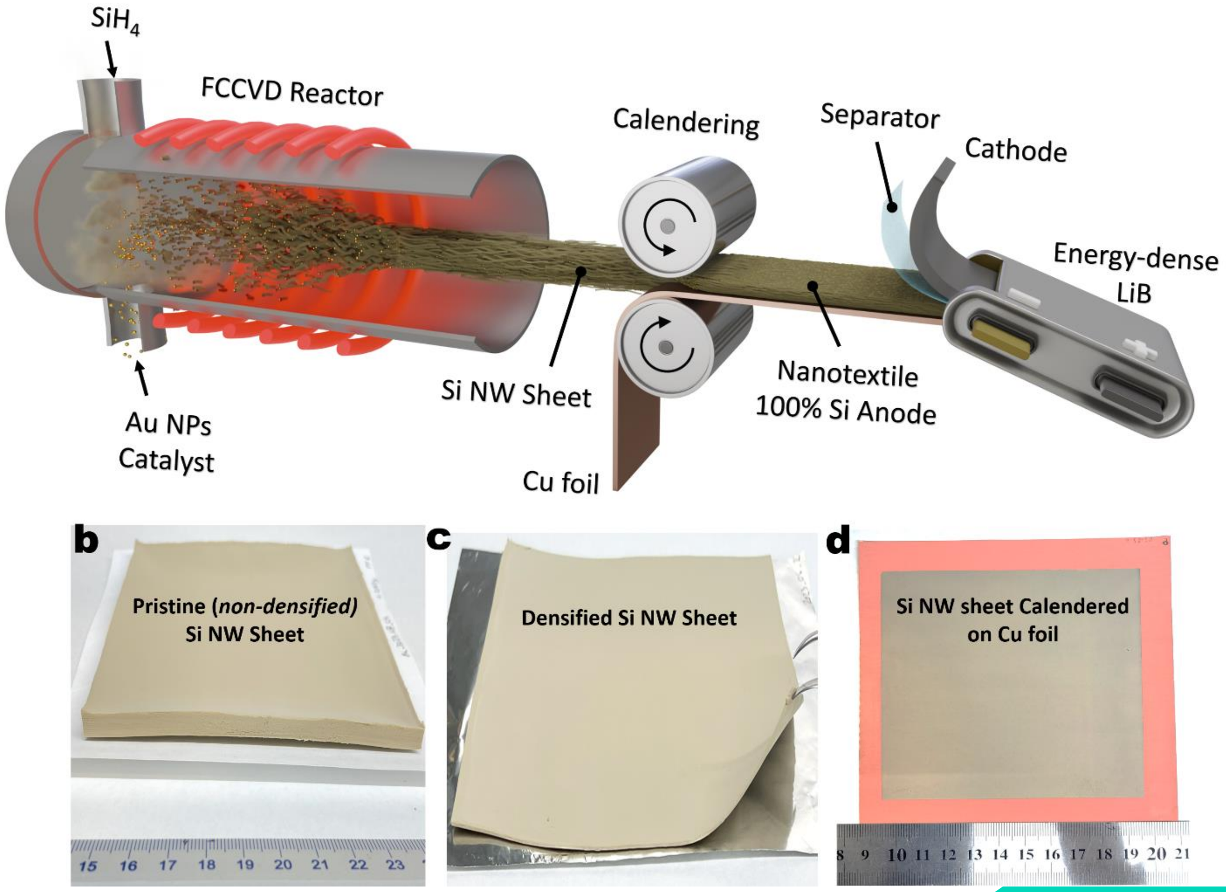
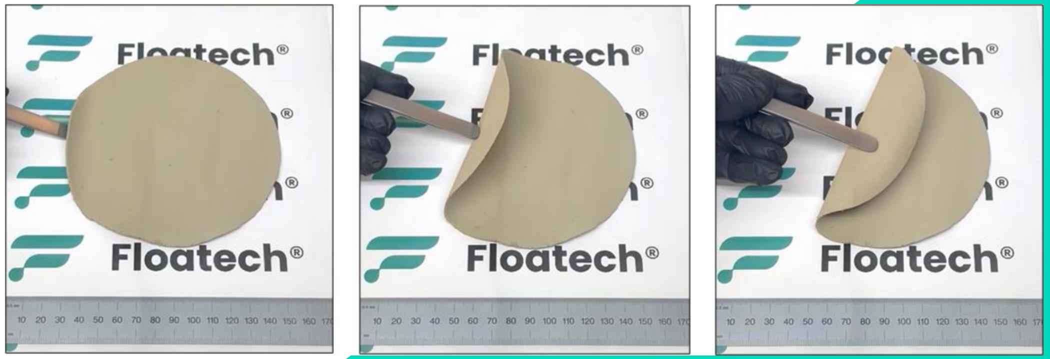
Proprietary manufacturing process





- Direct transformation of precursors (SiH_4) into electrodes **with 100 wt.% Si**
- Large, flexible electrodes for seamless integration with industrial cathodes and liquid/solid electrolytes
- High areal density (> 9mAh/cm2)
- Over 10-times more cost effective than competing Si anodes processes.

Pendashteh et al, Nanotextile100% Si Anodes for the Next Generation Energy-Dense Li-ion Batteries, under review

A more sustainable manufacturing process

Flexible finished anodes for seamless integration in LIB cells

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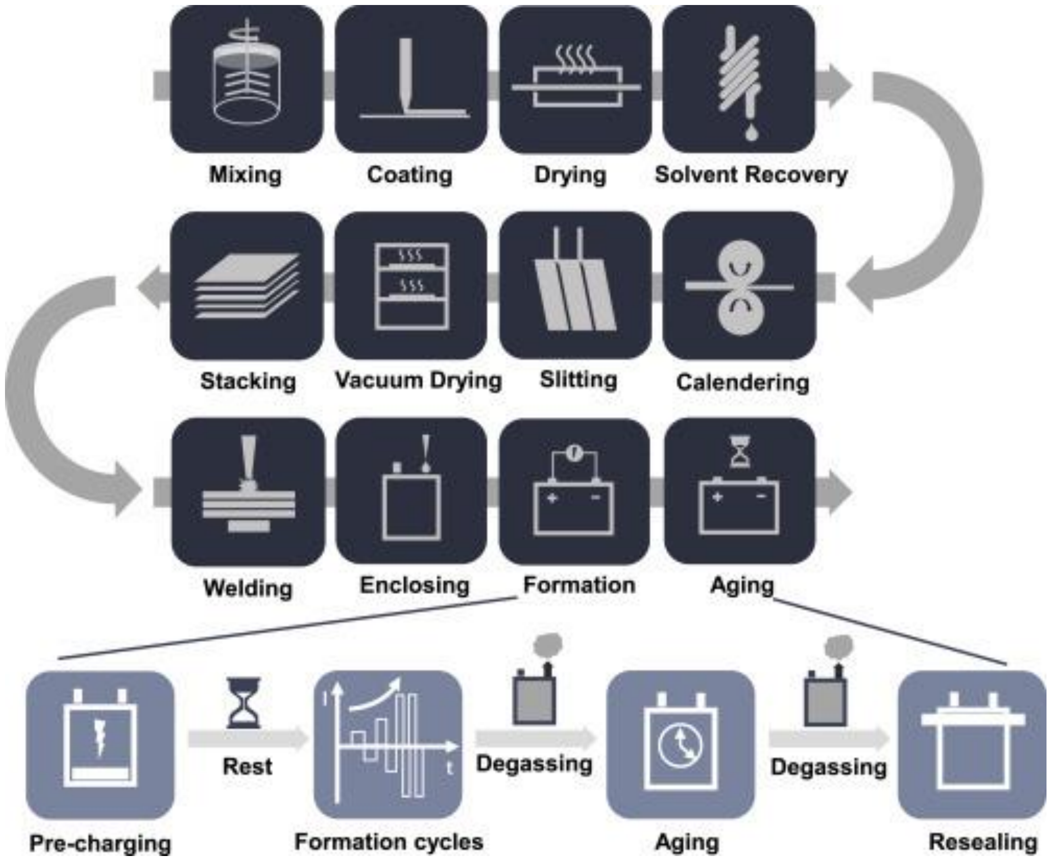
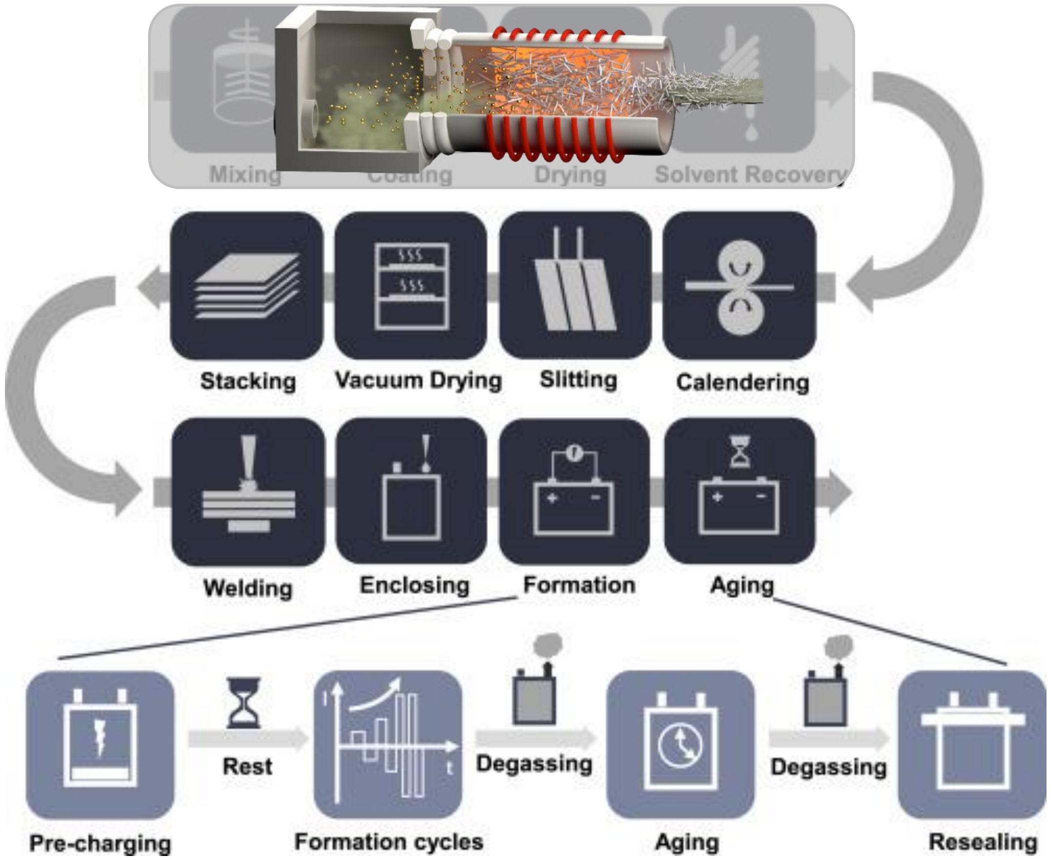
A more sustainable manufacturing process



Source: iScience, Volume 24, 2021, 102332

Processing raw materials into finished electrodes is about **50% of cell cost**.

A more sustainable manufacturing process



Source: iScience, Volume 24, 2021, 102332

Processing raw materials into finished electrodes is about **50% of cell cost**.

Eliminating mixing and coating from anode manufacture can translate into a **25% energy reduction** in cell manufacture, **equivalent to reducing around 2 tonnes of CO_2 per EV during LIB production.**

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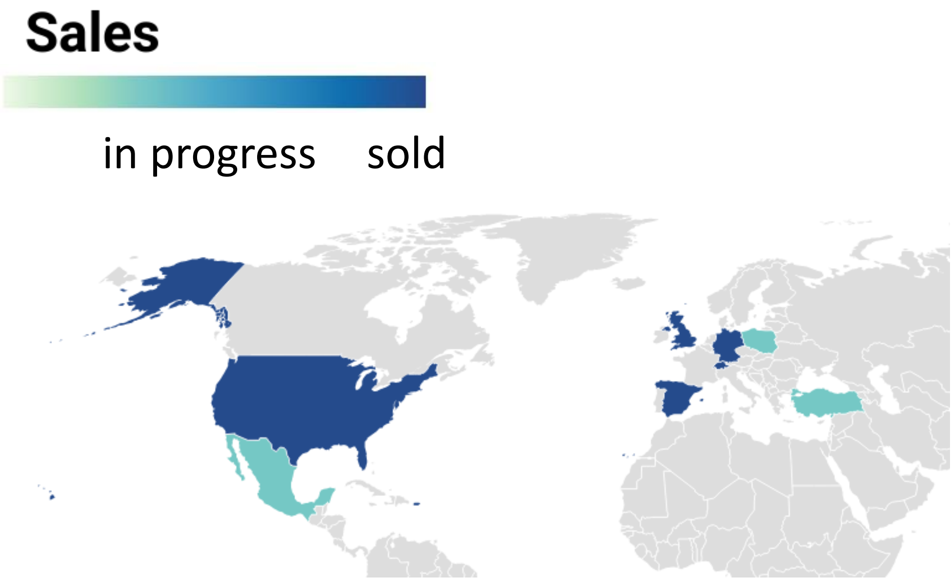
Accelerating the use of Si anodes

Registered product, Si:Coil, finished anode for integraiton inLIB cells.
Areal density uniformity meets industrial specifications.



Current clients: new LIB producers, electrode processing companies, R&D centres and Universities, including developers of cells with liquid and solid electrolyte

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Full cell manufacture tests

External validation of 60cm^2 cells at reference battery centre

cidetec


Anode (Floatech)


Cathode


Pouch cell (CIDETEC)

- Cell manufacture: excellent
- Adhesion to CC: excellent
- Electrode capacity: highest tested so far
- Capacity retention: medium

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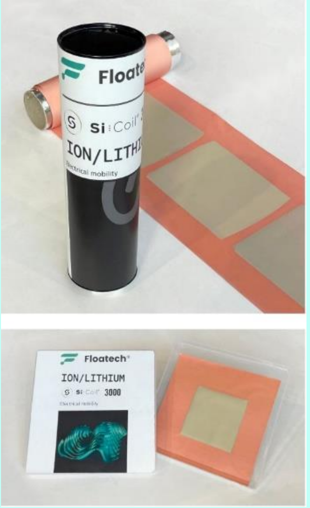
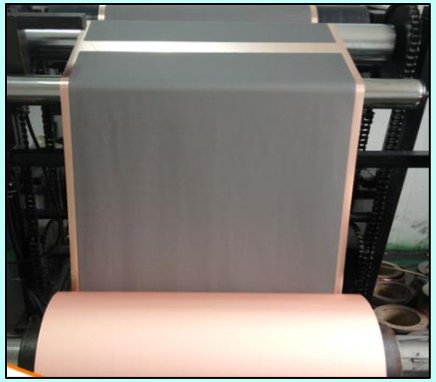
Project plan

Production capacity indicator	2023	2024 - 2025	2025 - 2030
Facility type	R&D production facility	Pilot plant	Industrial facility
Annual electrode production capacity (cell energy equiv.)	-	10 MWh/a	> 1 GWh/a
Annual Si production capacity (kg/a)	-	> 100	350 000
Validation	R&D electrode 	Electrode roll – industrial trials  *Generic electrode photograph	Electrode supply – drones, EVTOLs and microEV  Scheme of VW-SEAT gigafactory in Spain

institute imdea
madrid institute for advanced studies

820 Researchers

40 Nationalities

1500 R&D projects

3 Seal of Excellence Severo Ochoa & María de Maeztu

The IMDEA Materials Institute, one of the seven Madrid Institutes for Advanced Studies (IMDEA), is a public research centre (**non-profit research organisation**) founded in 2007 by Madrid's regional government.

The **Mission** of the Institute is to do research of excellence at the forefront of Materials Science and Engineering, contributing to tackle the challenges of society and fostering the sustainable development of the region of Madrid.

science

excellence
in materials **science**
and engineering
research

transfer

technology transfer to
industry to increase
competitiveness and
maintain technological
leadership

talent

attraction of talented
researchers from all over
the world to work in Madrid
in an international and
interdisciplinary
environment

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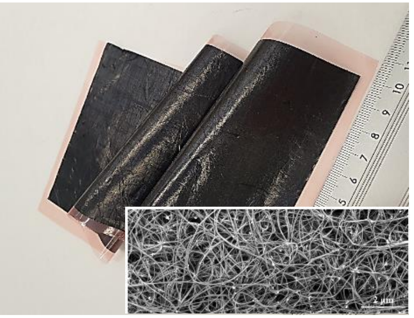
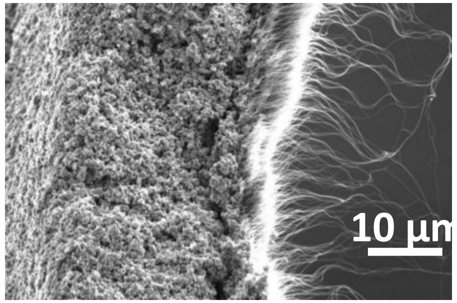
Brief timeline 2015-2021 (Research at IMDEA Materials)

TRL1 → TRL3

Seed idea: a scalable method to make nanostructured sheets interesting for energy applications





Thermoconformable LIB cell with CNT current collector and Polymer electrolyte

Boaretto et al, Adv. Mater. Technol., 2022

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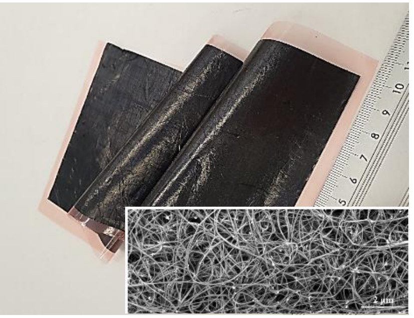

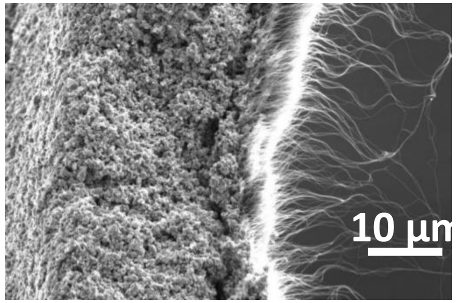

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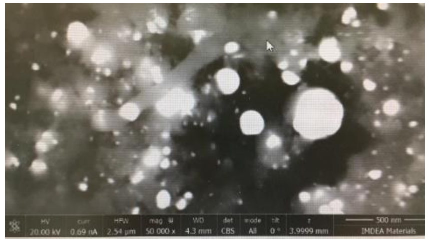
First efforts to develop a universal assembly route for 1D nanomaterials?



“Nanowires that I found in the filter from our FCVD experiment yesterday -> it is safe t say that these have been synthesised within the gas phase :))”, Richard Schäufele, 17/7/19

Schäufele et al, Mater. Horiz., 7, 2020

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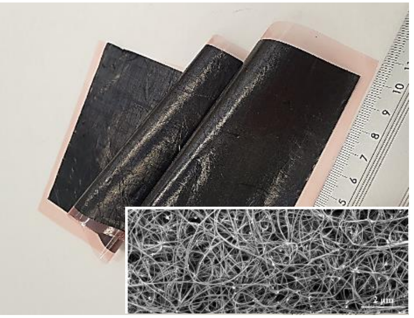

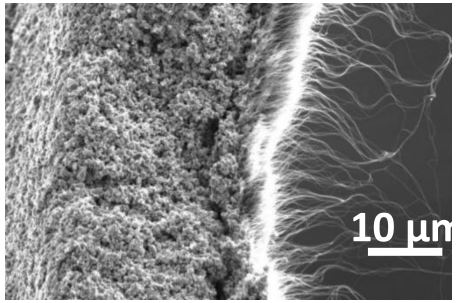

Thermoconformable LIB cell with CNT current collector and Polymer electrolyte

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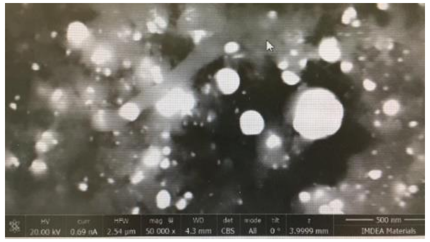
European Research Council



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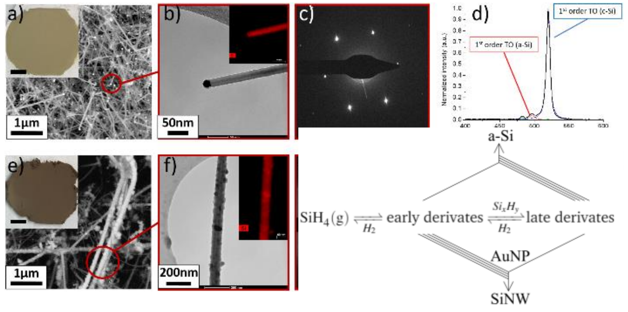
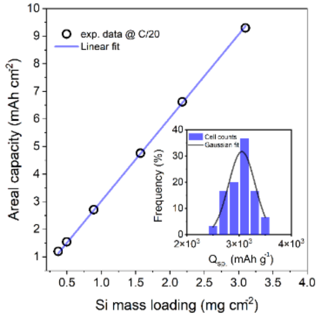
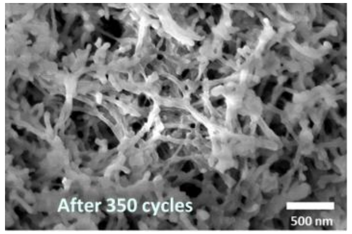
Schäufele et al, Mater. Horiz., 7, 2020

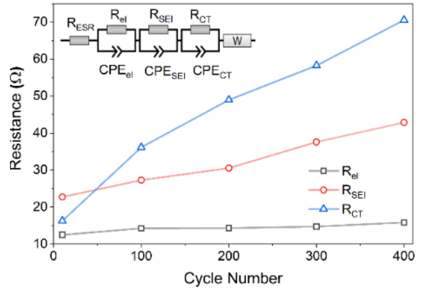
From discovery to a understanding reactions, materials and electrodes







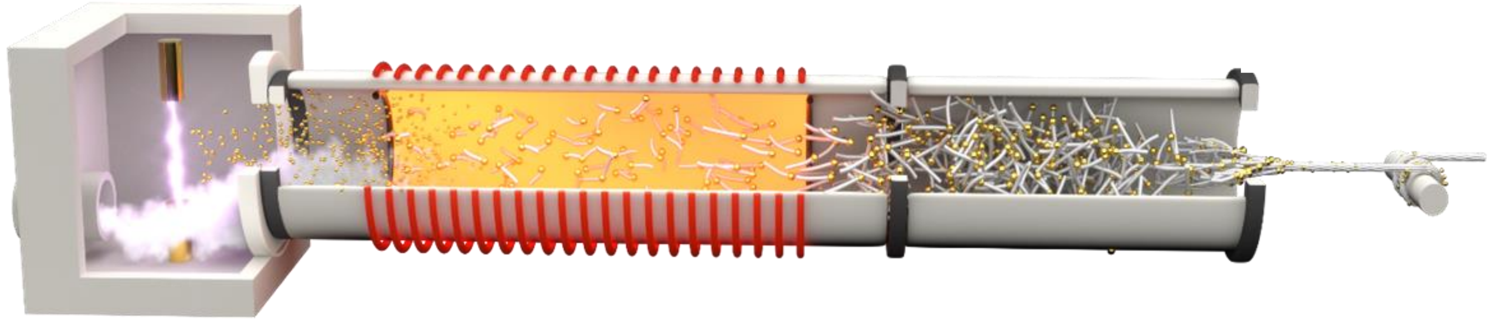
Schäufele et al, Nanoscale., 14, 2022

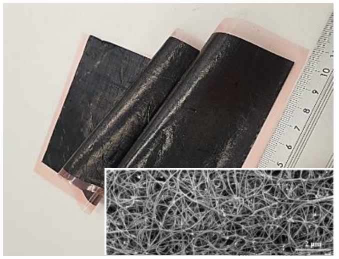


Rana et al, Adv. Ener. Mater., 2022

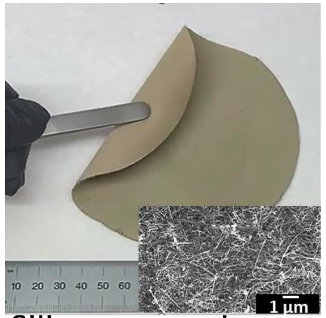
Brief timeline 2022-2027 (Research at IMDEA Materials)

TRL1 → TRL3

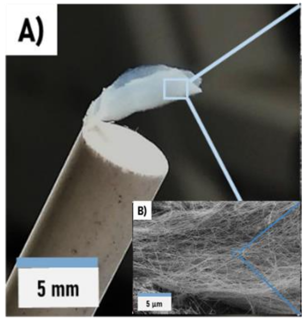




Carbon nanotubes



Silicon nanowires



Silicon carbide nanowires

About 100 more are possible!

Universal processing route for high-performance nanostructured yarns (UNIYARNS)

- Expand Chemistry
- Study aerogel formation
- Produce km-scale yarns
- Improve understanding of network structure and bulk mechanical and electrochemical properties

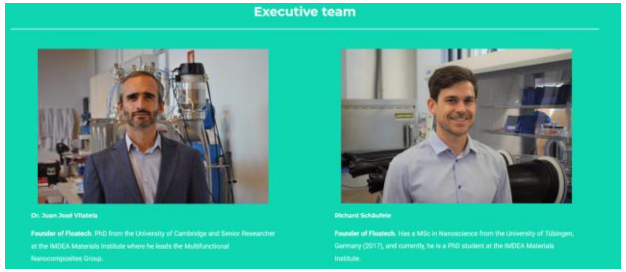
European Research Council

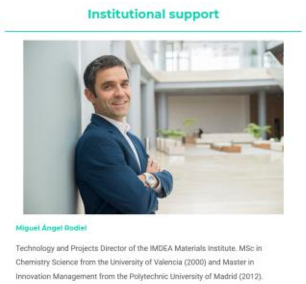
Floatech® Brief timeline 2021-2023 (Incubation at IMDEA Materials)

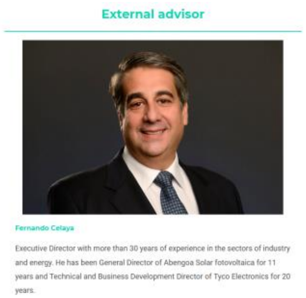
TRL3 → TRL5

The valley of death - using scarce resources to simulanteously achieve three objectives:

1. Creating a minnimum viable product
2. Consolidating an emerging market
3. Creating a company

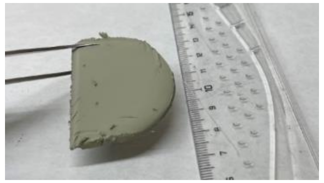


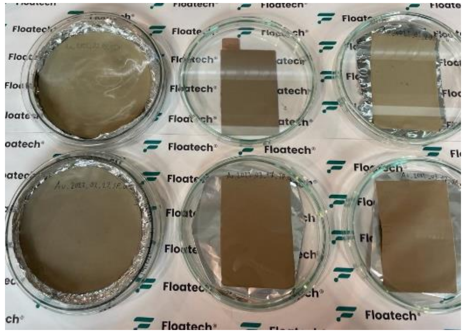




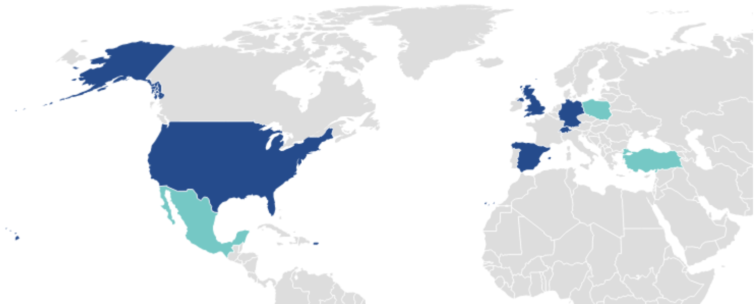
European Research Council

Proof of concept





Sales



CDTI INNOVACIÓN

Neotec (4th out of 200)

Comunidad de Madrid

Madrid (1st out of 120)

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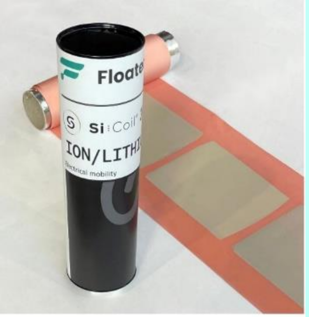
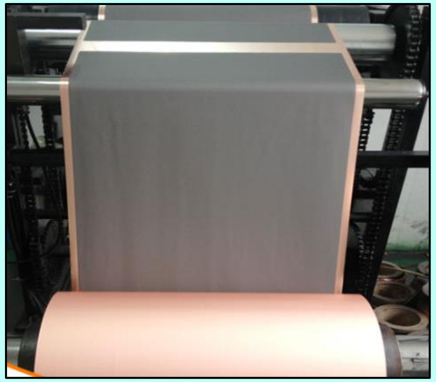
Project plan

Production capacity indicator	2023	2024 - 2025	2025 - 2030
Facility type	R&D production facility	Pilot plant	Industrial facility
Annual electrode production capacity (cell energy equiv.)	-	10 MWh/a	> 1 GWh/a
Annual Si production capacity (kg/a)	-	> 100	350 000
Validation	R&D electrode  	Electrode roll – industrial trials  *Generic electrode photograph	Electrode supply – drones, EVTOLs and microEV  Scheme of VW-SEAT gigafactory in Spain

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Facilities

Development team at a reputed research centre

- Reactor for process development
- Equipment for reaction and electrode characterisation
- Cell assembly and testing

First production site

- Pilot plant reactor
- Production of continuous anode roll (30cm X 100m in 2024)
- Inline anode QC and offline electrochemical QC testing

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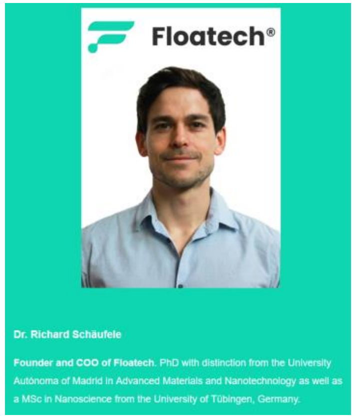
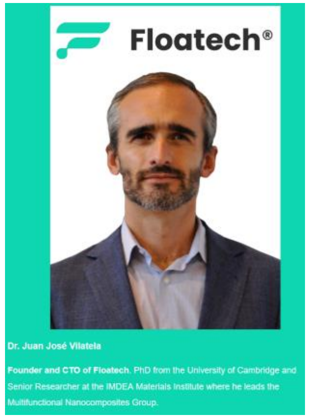
Floatech Team





3 Venture Capital Investors

CDTI INNOVACIÓN

U 23

Hopefully: European Innovation Council

Institutional support

Miguel Ángel Rodiel

Technology and Projects Director of the IMDEA Materials Institute. MSc in Chemistry Science from the University of Valencia (2000) and Master in Innovation Management from the Polytechnic University of Madrid (2012).

Dr Elisa Fresta
Advanced optical detection and optoelectronic markets
T.U. Münihc

We are hiring:

Automation and control

Pilot plant operation

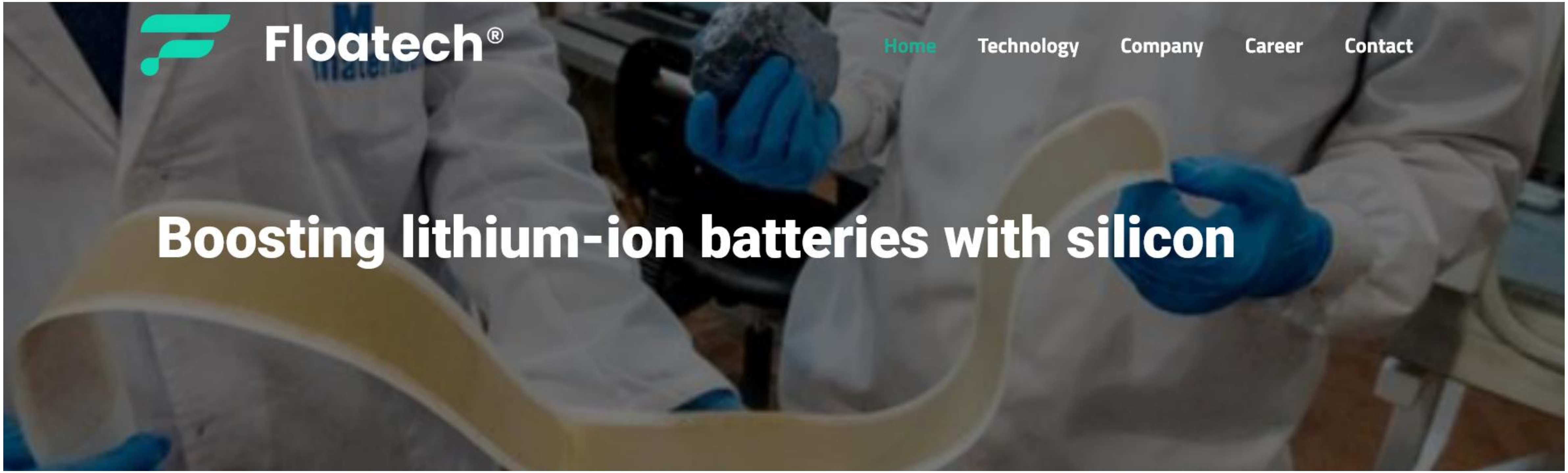
Senior electrochemist

Senior Chemical engineer

External advisor

Manuel Doblaré

Internationally reputed researcher, previously head of R&D at Abengoa, founder of 3 technological spin-offs (TALCO SL, Ebers medical technology, Beonchip SL), and a renowned academic (Spanish Royal Academies of Science and Engineering).



CONTACT

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Tecnogetafe

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Thank you