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London Environmental Investment Forum

The LEIF Brief:

New Fusions in Advanced Materials Innovation and Corporate Venture Capital

In association with

Global Corporate Venturing

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Saudi Aramco Energy Ventures

APWORKS by Airbus Group

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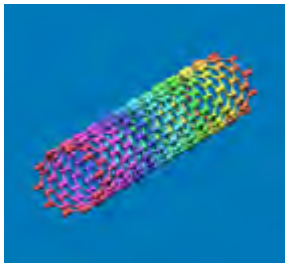
Batteries and energy storage Q3 2015

Battery innovation is fundamental to technological advances in several industries. Corporate venture capital activity in this area is on the rise with venture units from the electronics, automotive, robotics and engineering industries seeking out, and investing in, breakthrough battery technology businesses.



Water Q4 2015

Water management is increasingly critical to all industries. Food and beverages, oil and gas, mining and pharmaceuticals are among the industries that are under regulatory and cost pressures to innovate in their water management. Corporate venture capital units from these industries are therefore increasingly active.

2016

LEIF is in the early stages of developing programmes in robotics and 3D printing.

The views and information in this report were compiled by the London Environmental Investment Forum (LEIF)

February-April 2015

About LEIF

LEIF = Dynamic and collaborative customer and investment discovery

LEIF is a technology-focused advisory business that does three things:

1. We helps investors find investments and
2. We help companies find investors, customers and partners
3. We secure media coverage in influential magazines and newspapers

We do this through integrated marketing and communications programmes which are built around our research and our events.

Our methodology is simple and highly effective: research, connect, convene

- Research, write and communicate authoritative content - 'white papers' (LEIF Briefs), blogs, articles, 'teasers' and presentations - which positions our clients as leaders in fast growing industries and explains their needs to their most important audiences
- Connect our clients with the people they need to meet and influence
- Convene these people at events and meetings with our clients so that their expertise is demonstrated, their needs explained, and they get the opportunity to do business

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About Global Corporate Venturing

Global Corporate Venturing is both a monthly magazine and website written for the in-house venture capital units of businesses. The monthly magazine, due out the first Monday of each month, covers each economic sector in turn throughout the year to provide the most comprehensive data and analysis of companies' activities in buying minority stakes in third-party businesses as well as the best comment from the most highly-regarded thinkers. The analysis centres on an exclusive ranking of the top corporate venturing units in each sector.

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Contents

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Chairman, LEIF

Tom Whitehouse is founder and chairman of the London Environmental Investment Forum (LEIF). He also writes the 'The Clean Deal', a monthly column in Global Corporate Venturing. Before working in the environmental technology sector, Tom was a foreign correspondent. From 1997-1999 he was Moscow correspondent for The Guardian and from 1991-1997 he was a reporter for the BBC World Service, based in Prague and Moscow.

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Foreword

The world's largest businesses require advanced materials innovation if they are to stay at the top. Improving their industrial processes, making their existing products better and devising new products all need advanced materials.

Research conducted by LEIF and Global Corporate Venturing shows that the increasing number of companies with open innovation and corporate venture capital (CVC) units (and nearly half of the Fortune 100 now do have these units) are increasingly active in advanced materials commercialisation and investing.

To take best advantage of advanced materials innovation, it's not sufficient to wait for new technology businesses to mature before you use their products and services or acquire them. You need to incubate them and/or invest in them at an earlier stage to give yourself better acquisition, licensing and partnership opportunities; to secure the prospects for sustained long term growth.

This is the central thesis of open innovation and corporate venture capital; innovate and venture in order to stay ahead or run the risk of being a victim of 'creative destruction', of being a Kodak, a company that was once a titan but that ultimately dies because of its failure to identify and deploy disruptive innovation.

What we've found particularly interesting and revealing is how advanced materials innovation in one industry can migrate to another and flourish there. For example a material developed for the aviation industry is adopted by the robotics sector. This is the case with Scalmalloy, a new material developed by Airbus's 3D printing subsidiary APWorks (the co-sponsor of this report), which is now being used by the world's most advanced robots.

> "For a new material to be used in aviation it not only has to be innovative, it has to pass the most rigorous development and research programme. So it's not surprising that a new material proven in such a highly demanding industry is sought by other completely different industries."
>
> *Joachim Zettler*

"For a new material to be used in aviation it not only has to be innovative, it has to pass the most rigorous development, manufacturing and research programme," says Joachim Zettler, APWorks MD. "So it's not surprising that a new material developed in one highly demanding industry is sought by other completely different industries. We're very happy to see this." For the full interview with Joachim, please go to page 30.

A corollary of an advanced materials migrating across industries is corporate venture capital with different industrial backgrounds co-investing in the same advanced technology businesses. Co-investors in the advanced materials portfolio of Saudi Aramco Energy Ventures (the co-sponsor of this report) include health and nutrition conglomerates, broader industrial players, as well as financial VCs focused on biotech, pharma and ICT.

"Some of the most exciting [advanced materials] innovations come from cross-fertilisation between sectors," says Richard Riggs of SAEV's Europe-based investment team. "Advances in computing, microfluidics, nanotechnology and genetics are already driving innovation in new materials, and we expect this to continue." For the full interview with Richard, please go to page 27.

> "Some of the most exciting [advanced materials] innovations come from cross-fertilisation between sectors. Advances in computing, microfluidics, nanotechnology and genetics are already driving innovation in new materials, and we expect this to continue."
>
> *Richard Riggs, SAEV*

The most significant finding of our research is that corporations are innovating and venturing at the borders of their traditional domains in search of breakthrough advanced materials innovation. This is a trend we expect to continue.

We thank Richard, Joachim and the Brief's other contributors and interviewees. Richard joined SAEV's Aberdeen-based team in his native Scotland last year after eight years at the German chemicals giant BASF, most recently in its corporate venturing unit.

Joachim became Managing Director of APWorks when it was set up as a subsidiary of Airbus in 2013, having previously worked as an Airbus project engineer specialising in production technology.

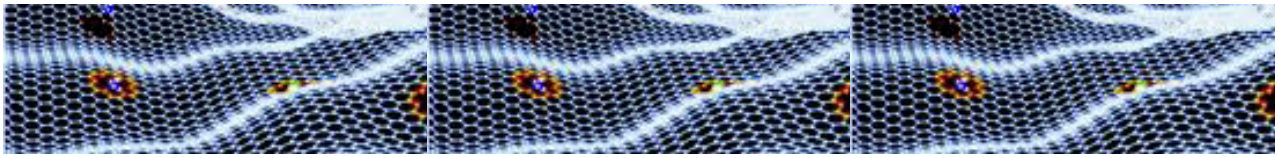
In addition to highlighting the sponsors' role in advanced materials commercialisation, this report also highlights other leading companies and investors. Our Transaction Report (from page 18) provides a snapshot of innovation and investment activity in this area. We hope you enjoy it and look forward to your feedback.

We'd also like to thank the law firm Norton Rose Fulbright, our generous host for the launch of this report.

Tom Whitehouse, Chairman, LEIF
Toby Lewis, Editor, Global Corporate Venturing

"Breakthroughs in advanced materials are becoming increasingly important for companies to excel in almost any market. Advanced materials are solving fundamental problems necessary to make products more efficient, sustainable, less expensive, and better performing, key attributes necessary for widespread adoption of any product."

Keith Gillard, General Partner, Pangaea Ventures



Executive Summary

1. **Advanced materials open innovation and corporate venture capital is on the increase**
    - The top ten corporate VC investors in advanced materials (see page 23) have committed more than $2bn to this sector over the last five years. This figure is dwarfed by the sums the same corporations are committing to internal and external research.
    - The top twelve advanced material technology businesses with corporate backers (see page 18) are commercialising technologies for a very wide variety of industries (steel, oil and gas, ICT, health and nutrition) and have between them raised more than $150m in the last 30 months from corporate VCs in the industries they serve.
    - Though CVC activity in advanced materials has traditionally been dominated by the oil and chemicals industries, other industries have begun to increase their venture activities: automotive (e.g. GM), steel (e.g. ArcelorMittal), ICT (e.g. Samsung and Google) and consumer (e.g. Coca Cola).
    - This deepening and widening of the pool of corporate venture capital available to advanced materials start-ups is set to continue as several industries require the benefits that advanced materials offer. For example, 'light-weighting' (making materials lighter without compromising on strength) is of equal importance to the aviation, automotive, robotics and manufacturing sectors; anti-corrosion technologies are of equal interest to the oil and gas industry as they are to steel and construction.
    - Co-investment among corporate VCs from different industries is therefore increasingly common, which brings strategic benefits to their investee companies.

2. **This growth is driven by several factors:**
    - Innovation across various technology sectors (such as nano-tech) and 'discovery' of new materials (such as graphene)
    - Regulation e.g. for better environmental and technical performance (e.g. increased fuel efficiency requiring lighter materials)
    - Growth of the 'hardware' sector (particularly robotics, drones and advanced manufacturing) increasing the need for smarter and better-performing materials that combine strength with durability

LEIF formula for successful commercialisation and investment:

(Innovation + regulatory change) x corporate appetite
=
a potentially very good deal

APWORKS by Airbus Group AIRBUS GROUP

Transformative materials, advanced manufacturing

APWorks is the advanced materials and additive manufacturing (3D printing) subsidiary of Airbus Group, the European aerospace and defence company. Established in 2013 and located near Munich, APWorks works closely with the Airbus Group research and technology arm Airbus Group Innovations, as well as Airbus Commercial, Airbus Helicopters and Airbus Defence & Space. In addition to developing and optimising new materials and parts for Airbus, APWorks is also serving companies in the robotics, automotive and medical technology industries.

APWorks offers new advanced materials, being developed by Airbus Group, such as its proprietary alloy **Scalmalloy®**, and advanced manufacturing services such as 3D printing and engineering consultation.

"We believe that Scalmalloy® will be a transformative material for all industries that have fast moving parts that bear heavy loads. Outside of Airbus, we foresee its most rapid adoption in the robotics and automotive industries where interest is already strong."

"Through the 3D printing of the Scalmalloy® powder, we can ensure that the scandium, which is one of its most important components, remains in an over-saturated condition. This gives the final part incredible strength and outstanding ductility."

Joachim Zettler, APWorks MD

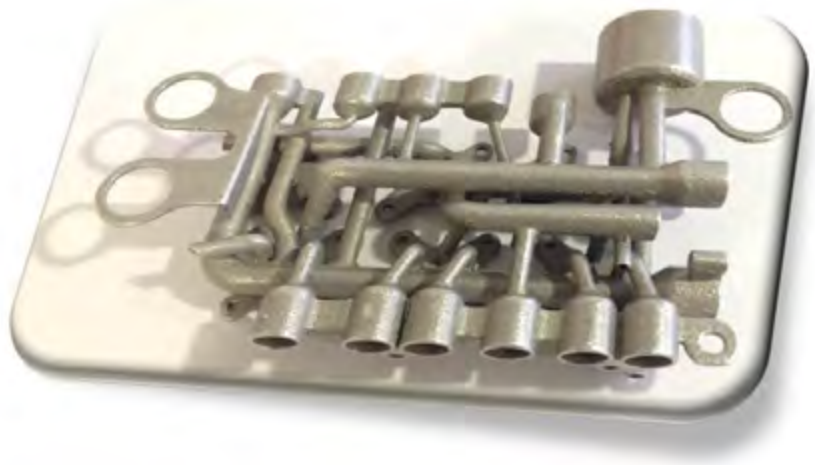
Scalmalloy® is a protected trade mark and unauthorised or unlawful copying of the material concept is prohibited.

Scalmalloy® (AlMgSc) – a transformative advanced material

Scalmalloy® material is designed to be processed using Laser Powder Bed Additive Layer Manufacturing (ALM) processes. Due to the high cooling rates and rapid solidification, a unique microstructure is achieved which rivals the performance of the highest grade aluminium foundry products. Coupling these material properties with the design freedom provided by ALM processes can enable high performance parts with a level of functionality previously impossible to achieve.

Typical Values	Scalmalloy®
0.2% Offset Strength (MPa)	450
Tensile Strength (Mpa)	490
Elongation (%)	8
Vickers Hardness HV0,3	177
Fatigue Limit 3E7 cycles (MPa) Kt=1, R=0.1	300
Density (g/cm³)	2.70
Fracture toughness K1c (MPa √m)	25

Properties achieved using proprietary process parameters.



Complex lightweight hydraulic manifold produced in Scalmalloy®.

Airbus Group Innovation Nursery

APWorks began its life at the Airbus Group Innovation Nursery whose other projects include **Speetect** and **High Altitude Pseudo Satellite (HAPS) Zephyr**.

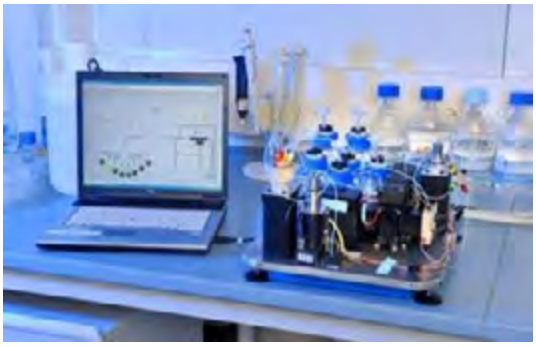
Speetect is a spin-off company for bacteria detection in liquids, water and air. It was born of Airbus's need for a new mobile technology to rapidly and automatically identify bacteria in water used for sanitary purposes on planes. Speetect will achieve its full potential outside of aviation in industrial waste water markets. Airbus is therefore seeking co-investors for its spin-out's commercialisation.

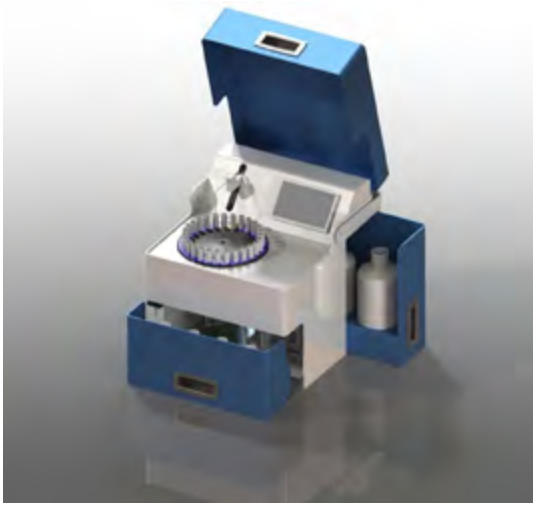
SPEETECT

The first Speetect device detects non-specific bacteria within less than 20 minutes while the second generation product will enable the rapid detection of specific and highly dangerous bacteria such as E.coli, legionella, enterococci, coliform bacteria in one hour, thanks to a unique combination of flow cytometry, automated sample preparation and antigens. The technology platform is covered by 11 patents.

Headquarters: Munich, Germany

Airbus is seeking co-investors for its spin-out's commercialisation.





Speetect rapid bacteria detection.

HAPS Zephyr

HAPS Zephyr is based on solar-powered glider aircraft technology and provides services in earth observation, telecommunication, positioning and meteorology with extremely long unmanned flights in the stratosphere over the specific area of interest.

HAPS Zephyr is based on Airbus solar-powered glider aircraft technology.

Saudi Aramco Energy Ventures

Pursuing material advances

Saudi Aramco Energy Ventures LLC (SAEV) is the corporate venturing subsidiary of the Saudi Arabian Oil Company (Saudi Aramco), the world's leading fully integrated energy and petrochemical enterprise. Headquartered in Dhahran with offices in North America and Europe, SAEV's mission is to invest globally in start-ups and high growth companies with technologies of strategic importance to its parent, Saudi Aramco.

SAEV invests in upstream and downstream oil and gas, petrochemicals, renewables, energy efficiency and water sectors. The group was established in 2012 with a $500m investment capital allocation. Typical investments are $5-10m.

Already the world's largest oil producer, Aramco has ambitious aims to grow its petrochemicals business. SAEV will help fulfil this ambition by investing in break-through advanced materials technology businesses that can provide competitive advantage to Aramco's chemicals businesses midstream and downstream.

The advanced materials investments in its portfolio today include **Novomer** and **Rive Technology**.

SAEV advanced materials portfolio

NOVOMER
Catalyzing Green Chemistry

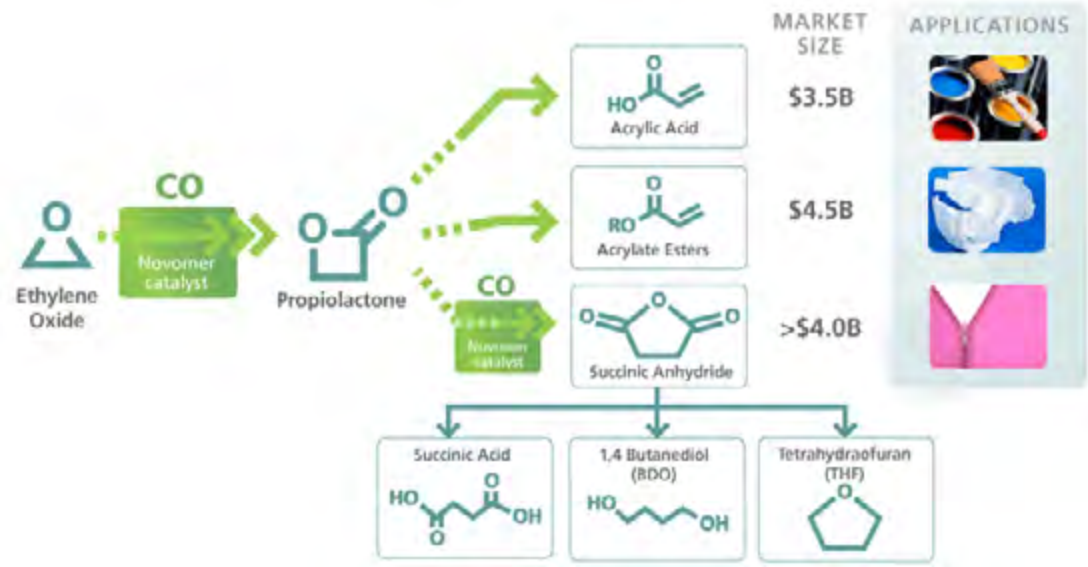
The commercial introduction of Novomer's Converge® polypropylene carbonate (PPC) polyols chemistry for use in polyurethane formulations has given innovators a new building block from which to design and create new products.

Headquarters: Massachusetts, USA

Advanced materials innovation: Novel catalysts that transforms carbon dioxide and carbon monoxide into high performance, low cost polymers

In their own words: "We're commercializing a family of high performance, cost effective, environmentally responsible polymers and chemicals based on proprietary catalyst technology."

SAEV's co-investors in Novomer: Physic Ventures, Flagship Ventures, DSM Venturing, OVP Venture Partners.



"Novomer uses novel catalysts that enable the cost-effective co-polymerisation of CO2 with other basic chemical feedstocks like ethylene oxide or propylene oxide."

Richard Riggs, SAEV

Saudi Aramco Energy Ventures

SAEV advanced materials portfolio

Rive Technology

"Rive re-engineered conventional catalysts used by refineries so they can "crack" bigger molecules of crude oil into more valuable transportation fuels instead of selling it off as low quality, coke, bunker fuel or asphalt. The company accomplished this by essentially blasting bigger holes into the crystalline structures that absorb oil."

The Wall Street Journal — December 13, 2010

Headquarters: Princeton, New Jersey, USA

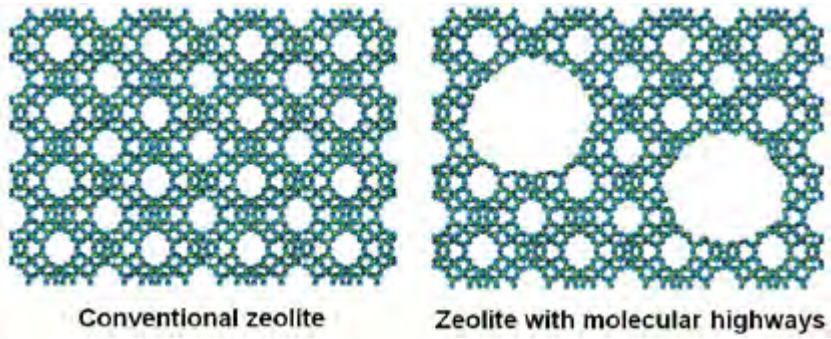
Advanced materials innovation:'Molecular highway' technology that increases catalyst performance through improved diffusion

In their own words:"Invented at MIT, Rive's proprietary technology improves traditional zeolite catalysts and adsorbents through the introduction of broad channels, or molecular highways, which overcome the diffusion limits of these materials, leading to better yields, process efficiency and process economics."

SAEV's co-investors in Novomer: Charles River Ventures, Blackstone Group, Mitsui & Co. Global Investment Advanced Technology Ventures.

"Rive Technology improves the performance of zeolite catalysts by enhancing diffusion to improve liquids yields and reduce residuals. They have repeatedly shown value in full-scale refinery trials and can assist in compliance with upcoming ultra low sulphur gasoline requirements."

Richard Riggs, SAEV

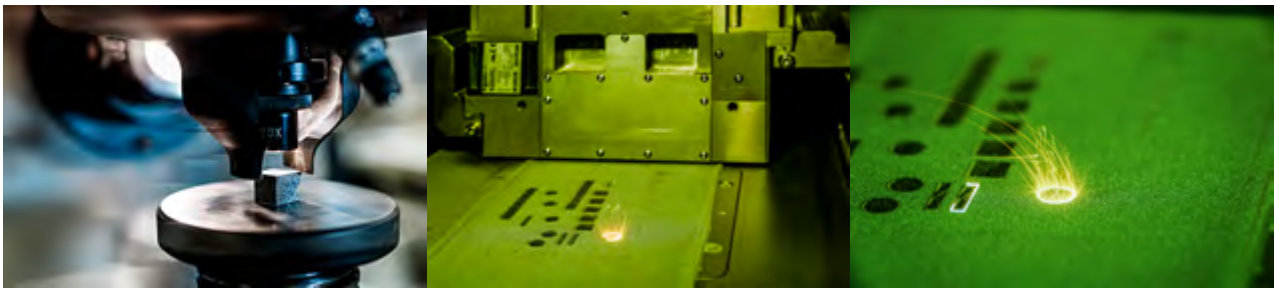


Advanced chemistry at work in Aramco R&D centre.

Top 12 advanced material start-ups with corporate backers

	Company	HQ	Technology	Corporate backers	Latest fund-raising
1	APWorks	Germany	scalmalloy' for strength and ductility + 3D printing	Airbus	n/a - APWorks is an Airbus subsidiary
2	Avantium	Holland	novel catalysts, bio-plastics	Danone, Coca Cola, Alpla	$50m, June 2014
3	Expanite	Denmark	surface hardening of stainless steel	Finindus (ArcelorMittal)	amount undisclosed, June 2014
4	Heliatek	Germany	organic based photovoltaic materials	BASF, Bosch	$22.8m, series C , Sept 2014
5	Imprint	US	thin, flexible, rechargeable batteries	Flextronics	$6m, series A, June 2014
6	Modumetal	US	nano-laminated alloys	Chevron, Conocophillips	$4.73m, Series B, Nov 2012
7	Novomer	US	novel catalysts for converting CO2 and CO to chemicals	Saudi Aramco, DSM	$15m, Dec 2013
8	Polyera	Taiwan/ US	flexible transistor technology	Solvay, Tsing*	$7.4m debt financing, Aug 2014
9	Rive Technology	US	'molecular highway' technology for chemicals etc.	Saudi Aramco, Mitsui & Co.	$20m, series D, Aug 2013
10	Slips Technologies	US	coatings that repels liquids and solids	BASF	$3M, series A, Oct 2014
11	SmartKem	UK	organic semiconductor materials for flexible displays	BASF	$4m, series A, Aug 2014
12	XG Sciences	US	graphene nanoplatelets for printed electronics	Samsung	amount undisclosed, Jan 2014

The twelve companies above are presented in alphabetical order and have been compiled from a list of start-ups that have been backed in the last three years by large corporations with a strategic interest in advanced materials. The companies directly address the innovation needs of the large corporations and corporate VCs interviewed and consulted for this report.



APWorks micro hardness measurement and selective laser sintering

The need for greater resilience in materials extends to several industries

"Materials that can eliminate or reduce corrosion are at the top of our wish list along with new membrane materials that can be used for gas separation and water desalination," says Richard Riggs, part of the investment team at Saudi Aramco Energy Ventures, SAEV. "Other areas of interest include; fuel additives, water treatment systems, drilling and well treatment materials, enhanced oil recovery systems, tracer materials, desulfurization systems, high-efficiency photovoltaic systems, thermal insulation and heat transfer materials," he adds.

Ultimately, because of its size and scope, Aramco's advanced materials interests are very broad. "SAEV is interested in materials innovation that can improve all the processes of an integrated oil and gas company. Solar and water are also strategic issues for Aramco and the Kingdom of Saudi Arabia," says Riggs.

According to Graham Howes of BP Ventures and the Manchester-based International Centre for Advanced Materials (which BP funds), BP's advanced materials needs include: "Extending the operating envelope of steel through changing the physical properties and/or applying coatings to make the native material more resilient to conditions experienced in the operating environment" and "identifying alternative cost effective materials as potential replacements to steel".

Howes says that BP's wish list of advanced materials technologies includes: "advanced steels, protective coatings that are compatible with non-pristine surfaces, surface modification to reduce fouling. All solutions will ideally have the ability to report on health and/or NDT/NDI (non-destructive testing / non-destructive inspection) techniques to confirm the integrity of materials." In the long term BP wants "materials that can report on their health or condition and self-heal." (For the full interview with Graham Howes, please go to http://blog.london-eif.com)

The need for greater resilience in materials extends to several industries. Robotics, med-tech, aviation, automotive and all other parts of the broader 'hardware' sector need to combine greater strength with reduced weight and higher durability – a circle which can ultimately only be squared with advanced materials.

> "SAEV is interested in materials innovation that can improve all the processes of an integrated oil and gas company. Solar and water are also strategic issues for Aramco and the Kingdom of Saudi Arabia."
>
> *Richard Riggs, SAEV*

Hardware, meet advanced materials

"Through advanced manufacturing, we can achieve significant incremental improvements in the properties of common materials like aluminium," says Joachim Zettler, Managing Director of APWorks, the advanced materials and 3D printing subsidiary of Airbus. "But to make radical progress in lightness, strength and ductility we need advanced materials, which will achieve their full potential when combined with advanced manufacturing."

This is APWorks' intention with Scalmalloy, Airbus Group's second-generation aluminium-magnesium-scandium (AlMgSc) alloy, a new proprietary material.

"Scalmalloy will be a transformative material for all industries that have fast moving parts that bear heavy loads," says Zettler. "Outside of Airbus, we foresee its most rapid adoption in the robotics and automotive industries where interest is already strong".

The robotics and automotive industries are part of the growing but often overlooked 'hardware' sector, which is the focus of attention from a broad range of very powerful corporations including the ICT giants Google, Apple and Samsung, as well as their manufacturing partners such as Flextronics, whose incubator Lab IX has been an active hardware investor. By definition, hardware requires durable materials that are also light and strong.

> "To make radical progress in lightness, strength and ductility we need advanced materials, which will achieve their full potential when combined with advanced manufacturing."
>
> *Joachim Zettler, APWorks*

APWorks testing for tensile strength.

High efficiency cake-baking

“Robots are seen as very cool right now,” says APWorks’ Zettler. “But most robots are still using conventional materials that are manufactured conventionally. Robotics will only really begin to fulfil their potential when advanced materials are combined with advanced manufacturing.”

The relationship between advanced materials and advanced manufacturing is dynamic. For example, 3D printing has the ability to distribute the new Airbus alloy Scalmalloy equally throughout a newly printed part, greatly increasing its functionality.

“Through the 3D printing of the Scalmalloy powder, we can ensure that the scandium, which is one of its most important components, remains in an over-saturated condition. This gives the part we’ve manufactured incredible strength and ductility. This can’t be done with conventional manufacturing,” says Zettler. “It’s like baking a cake. You want the sugar evenly distributed throughout. It’s no good if it’s concentrated in one place. 3D printing spreads the crucial ingredients evenly.”

So advanced materials can be fully optimised by advanced manufacturing. But established and conventional manufacturing and industrial processes can also be transformed by advanced materials.

"A good example is in processes for the production of acrylic acid and acrylates, basic petrochemicals which have been around for decades and are one of the cornerstones of the chemical industry, says Riggs. “Aside from their CO2 to polymers platform, new catalysts developed by Novomer are providing alternative production methods for acrylates using CO as a feedstock."

> “Robotics will only really begin to fulfil their potential when advanced materials are combined with advanced manufacturing.”
>
> *Joachim Zettler, APWorks*

Riggs adds: "Similarly, fluid catalytic cracking (FCC) is a fundamental process in petroleum refining. Rive Technology has developed catalysts for this process that give a higher value mixture of products from the cracking process. As such, Rive's catalysts are drop-in replacements for standard catalysts used in cracking processes."

Catalyst innovation is a strong theme across SAEV's advanced materials portfolio. "Catalyst technology requires innovation in materials science. Catalysts can be seen as advanced materials themselves. We have good examples of this within our portfolio," says Riggs.

Co-investors in SAEV's advanced catalyst portfolio include health and nutrition conglomerates, and broader industrial players. They are testament to the growing awareness of the need for advanced materials innovation from nearly all industries. This is no longer the province of chemicals and oil and gas. Advanced materials are going mainstream.

SAEV, ABB, Applied Materials, BASF, Bekaert, BP, DSM, and EDF are among the diverse backers of Beijing-based clean-tech venture company Tsing Capital, which targets advanced materials investments in sustainable agriculture and transportation, environment protection, alternative and efficient energy, and new materials in China. It pays to be eclectic and collaborative when sourcing technology investment opportunities.

"We keep an open mind and try not to be too prescriptive because there are technologies out there that could be of benefit to us, but that don't yet know it," says Nuno Carvalho, head of venturing at Bekaert, the Belgium-based steel wire transformation and coatings business.

"Some start-ups do not know that their technology has applications for us. We want to talk to them too. It's good to have a shopping list, but you also have to be ready for 'unusual suspects'," he adds.

APWorks completed build job with surrounding metal powder.

Top 10 advanced material (AM) corporate VCs

	Corporate venture capitalist	HQ	Direct investments in AM start-ups include:	Investments in venture funds with an AM focus include:
1	AGC	Japan		Emerald, NGEN, Pangaea
2	BASF	Germany	Slipps, SmartKem, FRX Polymers	Arch , Chrysalix , Fintech GIMV fund, NGEN, Pangaea, Tsing
3	Bekaert	Belgium	Sage Electronics (aquired by Saint Gobain)	Munich Venture Partners, NGEN, Pangaea, Tsing
4	BP	UK	BP funds the Manchester-based Centre for Advanced Materials	Ngen, Pangaea (through Castrol innoVentures), Tsing
5	Evonik	Germany	FRX Polymers, Nanocomp	Emerald, Hightech Gruenderfonds, Pangaea
6	SABIC	Saudi Arabia	Fiberio	Chrysalix, Pangaea
7	Saint Gobain	France	Sage Electronics (subsequently aquired)	Emerald, Environmental Technologies Fund, Navitas Capital, Phoenix
8	Samsung Ventures	South Korea	XG Sciences, Kateeva	Pangaea
9	Saudi Aramco Energy Ventures	Saudi Arabia	Rive, Novomer	Braemar,Tsing, Zouk
10	Solvay	Belgium	Polyera	Aster, Capricorn, Conduit, Korea Advanced Materials Fund, Pangaea, Phoenix, Soffinova

The ten corporations above have all committed capital to at least one VC with an advanced materials focus. Eight out of ten have also invested directly in at least one advanced materials technology business.

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Strategic cross fertilisation in advanced materials

The cross-fertilisation we're witnessing in advanced materials open innovation and corporate venture capital began with a relatively small number of corporations. Solvay, Evonik, BASF, Saint Gobain and Bekaert are among the early pioneers. They have served as a role model and catalyst for others, who are following their path as limited partners in venture funds and/or as direct investors in advanced materials companies. Such is the vastness and diversity of these corporations' markets that whichever way they look they see advanced materials innovation expanding new industries and threatening to destroy old ones. Their venturing activity reflects their intention to be the beneficiaries of creative destruction unleashed by advanced materials, rather than its victims.

"Advanced materials are solving fundamental problems necessary to make products more efficient, sustainable, less expensive, and better performing, key attributes necessary for widespread adoption of any product," says Keith Gillard, General Partner at Vancouver-based Pangaea Ventures, the advanced materials venture investor whose backers include Solvay, Evonik, BASF, Bekaert and several other corporations. "Breakthroughs in advanced materials are becoming increasingly important for companies to excel in almost any market," he adds. (For the full interview with Gillard go to http://blog.london-eif.com)

Corporate VC happiness is 'dealflow' from multiple regions and sources

Such corporations need awareness of, and access to, advanced material innovation across the world. Happiness is 'dealflow' from multiple regions and sources. They are increasingly active, collaborative and international. Their venture directors must see a lot of each other at limited partner meetings, board meetings and parties.

Belgium-based chemicals giant Solvay may hold the record for being the most active corporate venture capital investor in advanced materials, with investments in six venture funds in addition to Pangaea: Aster Capital, Phoenix Venture Partners, Conduit Ventures, Capricorn Venture Partners, Sofinnova Ventures and the Korea Advanced Materials Fund. Solvay also invests directly from its in house venture unit.

Germany-based chemicals giants Evonik is not far behind. In addition to backing Pangaea, Evonik is an investor in High-tech Gruenderfonds, the German early stage investment company, and in Zurich and Toronto-based Emerald Technology Ventures. Both High-tech Gruenderfonds and Emerald include advanced materials in their investment focus. Emerald's other corporate backers include Saint Gobain.

New bedfellows with shared strategic interests

Nova External Venturing, France-based Saint Gobain's venture unit, backs the US venture companies Phoenix Venture Partners and Navitas Capital, and the UK-based Environmental Technologies Fund.

Back in Germany, the chemicals company BASF backs Pangaea and the US-based venture funds Arch Venture Partners and NGEN, Canada-based Crysalix Energy Limited Partnership, Japan-based Fintech GIMV fund, and Taipei-based Tsing Capital, all of which have an advanced materials focus.

Tsing Capital is backed by Belgian steel wire and coatings company Bekaert, whose other investments in venture funds are Pangaea, US-based NGEN Partners and Germany-based Munich Venture Partners, which also have an advanced materials focus. Other backers of Tsing Capital include the oil and gas company BP, the health and nutrition company DSM, the power company ABB, and the materials company Applied Materials.

Tsing Capital brings us back to Solvay. One of Tsing Capital's most recent investments was in Polyera, a US-based business supplying advanced semiconductor materials for the printed and flexible electronics industry. Tsing Capital's co-investors in Polyera include Solvay, which invested directly from its in-house venture unit.

As more corporations follow these pioneers' lead, the specialist advanced materials investors like Tsing and Pangaea are getting funds from quite diverse industries.

Which other corporate venture capitalists are coming to the table?

ICT venturers like Google and Samsung have sought synergies and therefore investments along the value chain to health care and smart cars and homes. They are now entering the fray in advanced materials because that's where they will find the innovation they need to stay ahead in for example, LED lighting, touch screen technology and batteries.

Dow Venture Capital, the venture unit of the eponymous US chemicals giant, provided an early example of this. It anticipated the need for innovative materials in LED lighting through its investment in, and subsequent 2012 acquisition of, Lightscape Materials, a US developer of novel phosphor solutions. Dow set out the strategic rationale on its website thus: "Dow's investment in this technology aligns to the strategic growth interests of the Dow Electronic Materials business which has been an important player in the solid-state lighting market for over 35 years."

In January 2014, Samsung Ventures invested an undisclosed sum in XG Sciences, a US company manufacturing graphene nanoplatelets, which it describes as “a new class of carbon nanoparticles with multifunctional properties.” XG Sciences’ end markets include printed electronics, where graphene can play an important role in the formulation of coatings or inks for electrical and thermal conductivity.

This is the taste of things to come because flexible displays for future smart phones, computers, roll-up televisions, reusable electronic newspapers, electronic wallpaper etc. require advanced materials. The crucial element in flexibly displays is transparent conductive electrodes which currently require indium tin oxide (ITO), a very expensive metal. “If you’ve ever questioned why your smartphone has a sticker price of over $500 – you can blame ITO in part as it can account for up to 40% of touch screen production costs,” says Pangaea Ventures’ Sarah Applebaum.

Applebaum cites “6 main contenders” to replace ITO: “silver nanowires, carbon nanotubes (CNTs), metal mesh, graphene, conductive polymers, and other transparent conductive oxides (TCOs), which are largely doped zinc oxides.”

Petro Rabigh - an integral part of Saudi Aramco’s refining-petrochemical integration strategy.

Corporate Venture Capitalist Q&A

Richard Riggs
SAEV

Richard Riggs joined SAEV's Aberdeen-based team in his native Scotland last year after eight years at the German chemicals giant BASF, most recently in its corporate venturing unit. One of his responsibilities at SAEV is to help increase the number of advanced material technology businesses in the portfolio.

Q SAEV's current advanced materials investments are all based on innovative catalysts. What is the relevance of advanced materials to catalysts?

Catalysts are materials that accelerate chemical reactions. They are universal in the chemicals industry. Through new catalysts, chemical processes can be improved or indeed new chemical processes and products can be developed. Such catalyst technology requires innovation in materials science – catalysts can be seen as advanced materials themselves. We have good examples of this within our portfolio. Novomer, which is based in Massachusetts, uses novel catalysts developed at Cornell University that enable the cost-effective co-polymerisation of CO2 with other basic chemical feedstocks like ethylene oxide or propylene oxide. New Jersey-based Rive Technology improves the performance of catalysts at the molecular level to enhance their performance.

Q SAEV's investments have to have strategic relevance to Aramco and Saudi Arabia. What impact will advanced catalysts and catalytic processes have on the ground for Aramco?

Saudi Arabia has the largest reserves of the most important chemical feedstock, oil. What's more, oil is cheaper to produce in Saudi Arabia than anywhere else in the world. So we already have a strategic advantage, which we want to build on. We are interested in catalytic process that can transform oil into chemicals as quickly and efficiently as possible, as well as those which allow the development of novel value-added materials systems. We're also interested in advanced materials innovation that allows us to use gas as a chemical feedstock, and there is an abundance of unconventional feedstocks such as carbon monoxide and carbon dioxide, which can be captured and used to create valuable products.

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Q What are SAEV's interests in advanced materials outside of the realm of catalysts?

SAEV is interested in materials innovation that can improve all the processes of an integrated oil and gas company. Solar and water are also strategic issues for Aramco and the Kingdom of Saudi Arabia.

Materials that can eliminate or reduce corrosion are at the top of our wish list, along with new membrane materials that can be used for gas separation and water desalination. Other areas of interest include fuel additives, water treatment systems, drilling and well treatment materials, enhanced oil recovery systems, tracer materials, desulfurization systems, high-efficiency photovoltaic systems, thermal insulation and heat transfer materials etc.

Q How does Aramco work with SAEV portfolio companies?

SAEV will only invest in companies where we see a strong possibility that the technology will be adopted in Saudi Arabia. SAEV has an in-house business development team whose job is to connect our portfolio companies to the right technical specialists in business groups in Saudi Aramco, whether for piloting, commercial deployment, or for joint development projects. We also aim to support portfolio companies doing business in the Kingdom by helping them navigate contracting processes, providing support with setting up local operations, introductions to other potential customers in the Kingdom, and so on. On the other hand, our investment team is comprised of a highly-experienced group of professionals with backgrounds in VC, corporate VC, corporate development, investment banking, entrepreneurial management, and strategy consulting. We are actively engaged with our portfolio companies at management level, often taking seats on the board and helping wherever we can to support the companies' growth. Our aim is to be known in the market as a value-adding strategic investor.

"SAEV will only invest in companies where we see a strong possibility that the technology will be adopted in Saudi Arabia."

"SAEV has an in-house business development team whose job is to connect our portfolio companies to the right technical specialists in business groups in Saudi Aramco."

Q Who are the other active investors in this sector?

The venture units of the other oil and gas majors are also active, though they may have different priorities to us. But there are several other co-investors in SAEV's advanced materials portfolio that aren't focused exclusively or even mainly on oil and gas. Corporate venturing groups in the chemicals, automotive, power and industrial sectors are active in this area. It's good for companies when they have investors from different industries behind them. There are also several highly experienced financial venture capitalists with an advanced materials focus. We've co-invested with some and are keen to do more in the future.

Q Which parts of the world do you expect to source your investments?

The Aberdeen office where I'm based looks at Europe, though SAEV invests globally. Besides Saudi Arabia, we have offices in North America, Japan and Korea. My experience in European venture capital gives me confidence that we won't lack dealflow in Europe.

Q What areas of technology innovation excite you most? Where do you foresee technological breakthroughs?

Technology innovation can come from all sectors, however it's pretty difficult to predict what is coming up next. It is important to be open to look into all sorts of technologies, and from different sources. Some of the most exciting innovations come from cross-fertilisation between sectors.

Innovator Q&A

Joachim Zettler
APWorks

When APWorks was established in 2013, Joachim Zettler became its founding MD, after previously working as an Airbus project engineer specialising in production technology.

Q What does APWorks offer its clients?

We offer new advanced materials, such as our proprietary alloy Scalmalloy®, and advanced manufacturing services such as 3D printing. There are lots of 3D printers in the world and soon there will be many more. APWorks is unique in being able to combine fast 3D printing – the fastest in the world we believe – with design optimisation based on Airbus expertise in advanced materials, complex technologies and manufacturing process solutions.

Q What is Scalmalloy®? What are its properties?

Scalmalloy® is Airbus Group's second-generation aluminium-magnesium-scandium alloy (AlMgSc). It was developed for high and very high-strength extrusions, offering exceptionally high fatigue properties. Scalmalloy® offers the specific strength of titanium, combined with the extreme lightweight potential of aluminium and an outstanding level of ductility. But I want to stress that we are also keen to work with others' proprietary materials. We can help optimise their manufacturing.

> "APWorks is unique in being able to combine fast 3D printing – the fastest in the world we believe – with design optimisation."

Q What are the most important markets for Scalmalloy®?

We believe that Scalmalloy® will be a transformative material for all industries that have fast moving parts that bear heavy loads. Outside of Airbus, we foresee its most rapid adoption in the robotics and automotive industries where interest is already strong. For a new material to be used in aviation it not only has to be innovative, it has to pass the most rigorous development and research programme. So it's not surprising that a new material proven in such a highly demanding industry is sought by other completely different industries. We're very happy to see this.

Q What are your target industries and commercial priorities?

We are prioritising the design and small series production of fast moving heavily-loaded parts found in the robotics, automotive, aviation and other hardware industries. These industries share the fundamental goal of combining strength and light weight that Scalmalloy® provides, and that we can help deliver through advanced manufacturing.

Q What is the potential of 3D printing?

In the next two to three years, rapid prototyping and small series production of parts used in robots, planes, cars and medical devices is going to be what 3D printing does best. Despite the hype, I believe that in the short to medium term 3D printing will not replace mainstream manufacturing. So APWorks is focusing on our priority markets (as mentioned already) where we know that 3D printing can quickly help perfect prototype products. In some cases we will go on to manufacture these products for market. In other cases, the products may be manufactured with conventional techniques and processes after we have optimised the design.

> "We are prioritising the design and small series production of fast moving heavily-loaded parts found in the robotics, automotive, aviation and other hardware industries."

Q What is the relationship between advanced materials and advanced manufacturing? Does one automatically go hand-in-hand with the other?

Through advanced manufacturing, we can achieve significant incremental improvements in the properties of common materials like aluminium. But to make radical progress in lightness, strength and ductility we need advanced materials, which will achieve their full potential when combined with advanced manufacturing. This is what we can do with Scalmalloy®. For example, robots are seen as very cool right now and some certainly are. But most robots are still using conventional materials that are manufactured conventionally. Robotics will only really begin to fulfil their potential when advanced materials are combined with advanced manufacturing. Through the 3D printing of the Scalmalloy® powder, we can ensure that the scandium, which is one of its most important components, remains in an over-saturated condition. This gives the final part incredible strength and outstanding ductility. This can't be done with conventional manufacturing. It's like baking a cake. You want the sugar evenly distributed throughout. It's no good if it's concentrated in one place. 3D printing spreads the crucial ingredients evenly throughout.

Q Why has APWorks been set up as a separate company?

APWorks remains core to Airbus. We sit within the research centre. But it was necessary to establish it as a start-up within the overall group, as the research centre itself is not structured for external business and commercialisation. But Airbus is the right company to help APWorks reach its full potential so it will remain within the Group.

Powder quality testing (flow ability and apparent density).

Notes

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