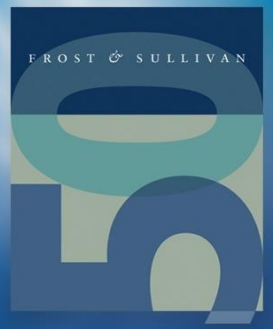
Advanced Manufacturing Technology (TechVision)

Metal Hard-facing Innovations

Key Technologies for hard-face metals (such as carbon steel) provide superior wear and abrasion resistance, at considerable cost savings over solid alloys offering similar properties



D718-TV

19 February, 2016

FROST & SULLIVAN

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Metal Hard-facing Innovations

Advances in Plasma Thermal Spray Hard-facing

Oerlikon Metco, Westbury, New York, USA

Unmet Needs/Trends

- Uncoated and unprotected metal surfaces in many severe situations may suffer premature wear and exhibit poor durability in the field.
- Not all hard-facing solutions (which apply wear-resistant metals to the base material's surface) are suitable, depending on the specific service conditions.

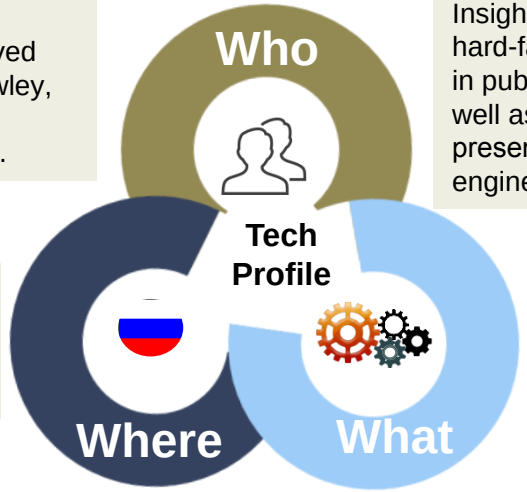
Potential Applications

- Gas turbine components, such as hot blades and vanes
- Exhaust systems (ceramic surface on metal exhaust pipes)
- Aluminum-block engine cylinder bores

Analyst Insights

The advanced research on plasma thermal spray involved the leadership of David Hawley, Director of R&D for coating equipment in Westbury, NY.

Metco HQ is located in Westbury on the west end of New York's Long Island, in Nassau County.



Insights on plasma thermal spray hard-facing technology are found in published technical papers as well as technology conference presentations authored by Metco's engineering professionals.

Innovation Attributes

The key innovation is the super-hot (10,000 degrees Kelvin) *plasma-assistance* to the thermal spray hard-facing, with benefits such as: faster metal coating, better surface integrity, more coating durability, and the ability to handle hi-temp Ni (nickel) Co (cobalt) and refractory metal deposition.

Future Plans

The Metco engineers want to expand options regarding hard-facing materials and improve the application equipment to draw less electric power (improve efficiency).

This process is commercialized and on the market now.

Funding

The development work was funded internally by Oerlikon Metco and its predecessor company (Sulzer Metco).

TechVision believes that such sophisticated high-tech coating processes have a place in the industry, along with other hard-facing solutions.

Improved Weld Overlay Hard-facing Materials

NanoSteel, Providence, Rhode Island, USA

Unmet Needs/Trends

- Despite best efforts, ordinary weld overlay applications do wear out, especially in brutal field applications
- Thus, replacement or touch-up of the failing welded hard-facing may be required, which is annoying and raises operating costs.

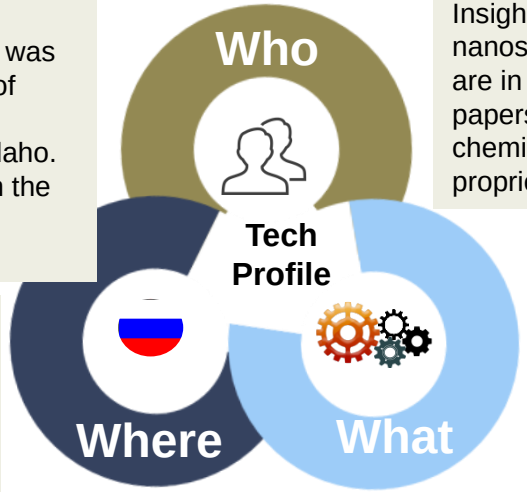
Potential Applications

- Oil & gas down-hole steel tubulars (rotating drill pipe collar joints)
- Construction equipment
- Farm equipment
- Mining equipment
- Cement plants

Analyst Insights

The advanced research on nanostructured hard steels was done under the leadership of Daniel Branagan at the NanoSteel R&D center in Idaho. Branagan was formerly with the US DOE Idaho National Laboratory (INL).

The Idaho Falls NanoSteel R&D lab is located near the INL in southeastern Idaho, just west of the Wyoming border.



Insights on the development of nanostructured steels at the INL are in publicly accessible technical papers. However, the exact chemical compositions are proprietary and patented.

Innovation Attributes

The key innovation is the company's patented nanostructured steel composition, imparting exceptional mechanical properties to the weld overlay, at reasonable cost (no exotic metal alloys involved).

Future Plans

The NanoSteel professionals want to expand the market appeal of its cored nanostructured welding rod to a broader set of industrial applications.

This welding rod material innovation is on the market now and licensed for sale by Lincoln Electric.

Funding

Development was funded by NanoSteel, based on licensed US DOE (Department of Energy) research from the Idaho National Lab.

TechVision finds such material innovations worthwhile and a good example of a successful laboratory-to-marketplace transition.

Metal Hard-facing via Laser Cladding

Praxair Surface Technologies, Indianapolis, Indiana (IN) USA

Unmet Needs/Trends

- Some hard-facing processes have technical shortcomings, generate too much heat, and draw too much electric power.
- Some processes have slower deposition rates
- In any event, candidates for hard-facing have to be well proven with years of favorable field experience.

Potential Applications

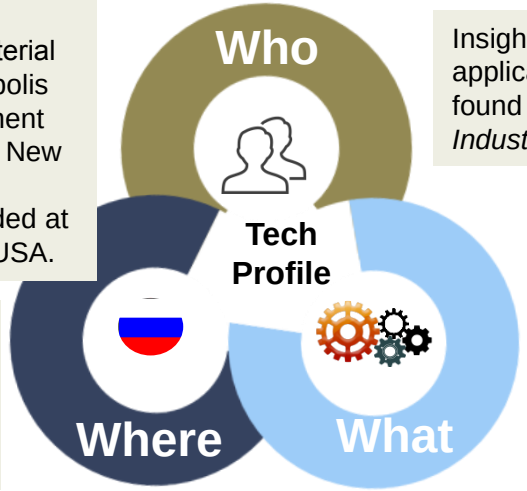
- Oil & gas production equipment
- Construction equipment
- Farm equipment
- Mining equipment
- Cement plants

Analyst Insights

TechVision is impressed by modern higher-tech surface coating methods, such as laser cladding, that raise the bar in materials technology progress.

The advanced research on Praxair's laser cladding material is performed at the Indianapolis HQ and commercial equipment development is in Concord, New Hampshire. Merchant laser cladding services are provided at many locations across the USA.

Concord is located in south central New Hampshire, north of the city of Manchester, in Merrimack County.



Insights on laser cladding applications and processes are found in trade journals, such as *Industrial Laser Solutions.*

Innovation Attributes

The key innovation is a laser cladding process which sinters a powder-based hard-facing material on metal objects with high integrity and precision with a smaller heat affected zone (HAZ) and less power consumption than rival processes.

Future Plans

The Praxair engineers want to expand the applications for laser cladding and reduce the fairly high capital cost of equipment.

This laser cladding is available now, but is in early market development, compared to thermal sprays.

Funding

The research was funded internally by Praxair.

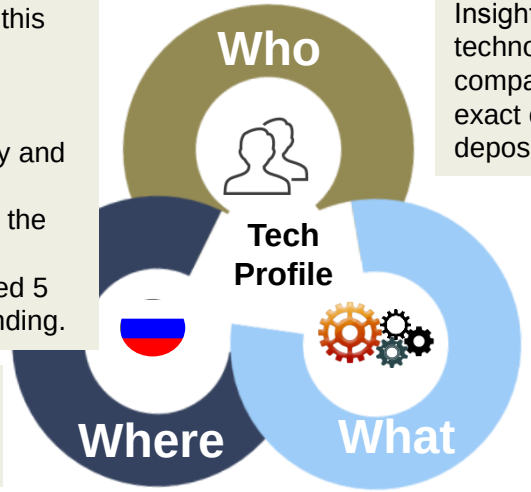
Nanostructured Electroplated Hard-facing
Modumetal, Seattle, Washington (WA), USA

Unmet Needs/Trends

- Some hard-facing processes are so hot that they can damage the underlying metal workpiece, as by de-tempering heat treatment.
- A largely unmet need is for a cooler and kinder hard coating process.

The advanced research on this novel nano-structured electroplating process was directed by Modumetal co-founder Christina Lomasney and originally conceived during graduate physics studies at the University of Washington. Modumetal has been granted 5 US patents with 4 more pending.

Modumetal is located on the north side of downtown Seattle



Insights on Modumetal's technology are found on the company website, however the exact composition of the deposited coating is not disclosed.

Potential Applications

- Oil & gas production equipment
- Construction equipment
- Farm equipment
- Mining equipment
- Cement plants

Innovation Attributes

The key innovation is a proprietary wet-bath room-temperature electroplating method that deposits a nanolaminated wear-resistant and corrosion –resistant coating that competes with rival high-temperature hard-facing technologies.

Future Plans

The Modumetal team would like to further develop its proprietary plating technology and improve process economics to encourage displacement of a wide variety of competing hard-facing technologies.

This invention is now in beta field-testing and could be commercially available via license to electroplaters by 2018.

Funding

The research was funded by Modumetal investors (primarily "angel" investors and venture capital firms).

Analyst Insights

TechVision finds this approach to be novel and interesting, worth tracking. However, plating bath chemical disposal can be a challenge, if toxic.

Strategic Insights

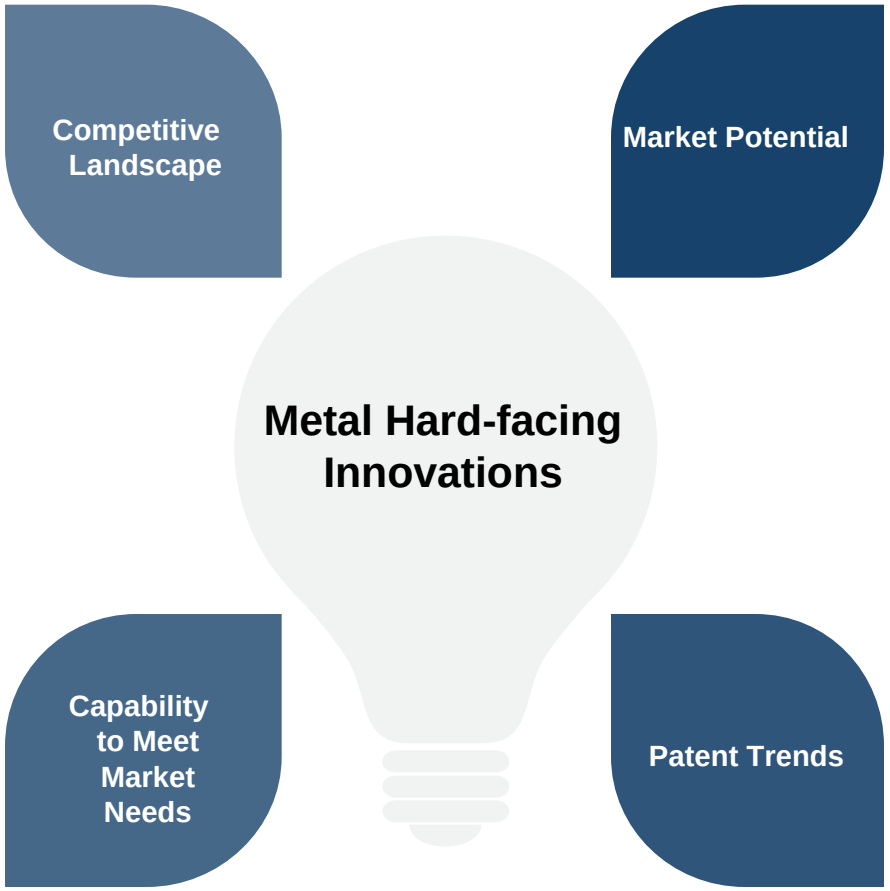
Strategic Insights

Various Research Rivals

A great many global research organizations and metal hard-facing participants are involved in pushing the state-of-the-art.

Little Ability to Serve Market

R&D organizations, start-up companies, and universities typically have no ability to manufacture hard-facing equipment or materials, but industry participants do that every day, and may license intellectual property of value.



Market Potential is There

Analysts are optimistic about the market for hard-facing on metals, which is already a substantial global business. The market growth rate outlook, however, in the mature end-user industries is not especially high. A well-accepted new technology could potentially experience high growth, but new hard facing materials or methods must undergo years of favorable field trials; and machine downtime due to failing hard facing or premature wear is unacceptable.

Patent Activity Growing

Global patents related to metal hard-facing, applied for and granted, are growing. That reflects a robust level of research activity and a growing interest in securing IP in this field, such as proprietary hard-facing materials compositions.

Strategic Insights

Drivers

- ✓ Offers substantial cost savings over solid heat-treated wear- and abrasion-resistant alloys
- ✓ Hard-facing is often field repairable, quite convenient
- ✓ Wide industry acceptance

Challenges

- Ẋ Sometimes, hard-facing can separate from the metal substrate (fail in the field)
- Ẋ Most hard-facing processes are notoriously slow
- Ẋ Appearance of the finished hard-facing can be unattractive (but then again, industrial functionality is more important than looks)
- Ẋ Some processes (such as laser cladding) can be capital intensive.

R&D Focus Areas

- Further development of metal hard-facing technologies that can raise the confidence of potential investors
- Conducting proof-of-principle experiments
- Moving from laboratory to functional field applications in hard-facing
- Documenting results in peer-reviewed welding, thermal spray, and laser cladding technical papers

Funding & Market Potential

- Substantial amounts of annual funding have been directed toward hard-facing development over time
- The annual global market potential for metal-hardfacing equipment, materials and merchant application services is quite large, on the order of $5 billion to $10 billion.

The 2020 Scenario

- ❑ The 2020 scenario for commercialization is varied
- ❑ There is a well-established metal hard-facing market now, but acceptance of truly advanced innovations takes time, plus years of favorable field experience as a reference.

Key Patents

Key Patents - Russia

No.	Patent No.	Publication Date	Title	Assignee
1	**RU 0002560604**	20.08.2015	Method of hard facing of metal part	Artemov Igor I.
	FIELD: machine building. SUBSTANCE: invention relates to machine building, namely to hard facing of the part surface layer, and can be used to manufacture machine parts out of ferrous and non-ferrous alloys by cutting methods. Lubricating-cooling liquid is prepared by preparation of semi-finished product of the lubricating-cooling liquid containing the following components in wt %: surface-active substance - 0.5-1.0, mineral oil - 1.0-3.0, distilled water - rest, aeration of said semi-finished product by multi-jet radial flow of the compressed air, addition to it of the nanopowder of the hard facing metal by means of the tangential jet of the compressed air with simultaneous agitation of the said semi-finished product of the lubricating-cooling liquid and nanopowder of the hard-facing powder with the obtained mixture turbulence. Then the said mixture obtained as liquid flow is subjected to the hydrodynamic cavitation treatment by constriction of this liquid flow with creation of the cavitation bubbles in the liquid volume. Nanoparticles are implemented in the part surface by the nanoparticles delivery from the bubbles surface in the microcracks and dislocation of the hard faced part surface upon "collapse" of the said bubbles. The implantation process is performed at concentration of the cavitation bubbles in the lubricating-cooling liquid within range 45-60 vol %. EFFECT: high mechanical and operation properties of parts are provided in combination with simplification of the process, increasing of its capacity and reduction of the prime cost of parts manufacturing. 2 dwg			
2	**RU 0002548847**	20.04.2015	Hard-facing of steel parts	Krushenko Henry G.
	FIELD: process engineering. SUBSTANCE: invention relates to tool production and can be used for hard-facing of wearing parts. Hard-facing effect is brought about by processing of the surface with plasma jet whereto fed are vapours of organo-silicon compound, that is, Si(OCH3)4. EFFECT: efficient hard-facing. 1 dwg			

Key Patents- USA

No.	Patent No.	Publication Date	Title	Assignee
3	**US 20150211305**	30.07.2015	Use of tungsten carbide tube rod to hard-face PDC matrix	Charles Daniel Johnson
	A hardfaced infiltrated matrix downhole tool and a method for hardfacing such items is provided. The hardfaced infiltrated matrix downhole tool includes a body, an intermediate base coat coupled to at least a portion of the surface of the body, and a hardfacing material coupled to at least a portion of the intermediate base coat. The body is composed of at least a carbide material and an infiltrating binder material. The intermediate base coat bonds to the surface of the body and to the hardfacing material. The method includes obtaining an infiltrated matrix downhole tool, applying and bonding the intermediate base coat to at least a portion of the surface of the infiltrated matrix downhole tool, and applying and bonding the hardfacing material to at least a portion of the intermediate base coat.			
4	**US 20150122552**	07.05.2015	Hard-facing for downhole tools and matrix bit bodies with enhanced wear resistance and fracture toughness	National Oilwell DHT, L.P.
	A composite material and a methods of making and using the composite material, wherein the composite material provides improved wear resistance and fracture toughness to hard-facing and matrix materials for down hole drilling tools.			

Key Patents- World

No.	Patent No.	Publication Date	Title	Assignee
5	**WO/2014/056031**	17.04.2014	A method of producing a hard facing material	Callidus Process Solutions Pty. Ltd.
	There is disclosed a method of producing a hard facing material comprising the steps of pre-heating a work piece to a working range of temperatures; attaching at least one resistance heater to maintain the work piece at a desired temperature; applying a TiN surface layer to a surface of the work piece; heating the work piece to a desired temperature for a desired period prior to allowing the work piece to cool to ambient temperature.			
6	**WO/2012/004292**	12.01.2012	Hard face structure, body comprising same and method for making same	Element Six GmbH
	A body comprising a steel substrate and a hard face structure fused to the steel substrate, in which the hard face structure comprises at least 1 weight percent Si, at least 5 weight percent Cr and at least 40 weight percent W and substantially the balance of the hard face structure consisting essentially of an iron group metal M and C, M being selected from Fe, Co and Ni or an alloy thereof; the hard face structure including a plurality of elongate or platelike micro-structures having a mean length of at least 1 micron, a plurality of nano-particles having a mean size of less than 200 nanometres, and a binder material; the micro-structures comprising more than 1 weight percent Cr and a phase having the formula MxWyCz, where x is in the range from 1 to 7, y is in the range from 1 to 10 and z is in the range from 1 to 4; the nano-particles comprising more than 20 weight percent W, the metal M, and C; and the binder material comprising more than 3 weight percent W, more than 2 weight percent Cr, more than 0.5 weight percent Si, the metal M and C.			

Industry Contacts

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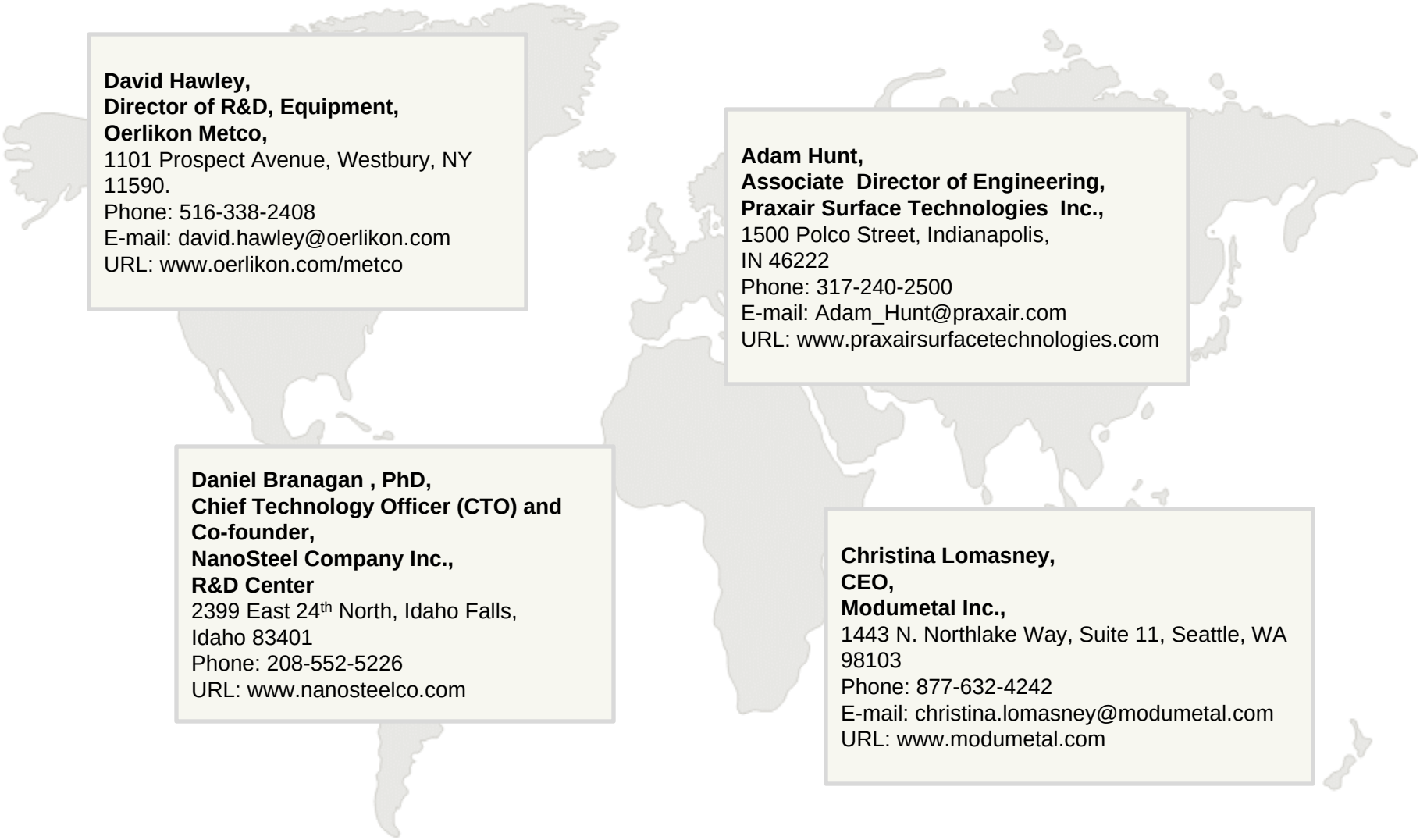

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