

Anodes for the Electronics Industries

copper foil electrodeposition
printed circuit board manufacturing
lithium-ion battery production



Founded in 1923, De Nora is an Italian multinational company listed on the Euronext Milan stock exchange, which specializes in electrochemistry, is a leader in sustainable technologies, and plays a **vital role in the electronics industry production chain**. The Company has a portfolio of products and systems to optimize the energy efficiency of critical industrial electrochemical processes. **The Company's technologies are recognized as high-value enablers that facilitate transformational processes for many industrial applications such as** chemicals production, **electronics applications**, galvanic process to name a few.

De Nora has 24 operating companies in 10 countries, and 5 R&D centers located in Italy, the United States, and Japan, enable continuous improvement and enlargement of its proprietary technologies covered by over 260 patent families with more than 2.800 territorial extensions. With its widespread presence and broad product portfolio, the Company can effectively serve customers in 100 countries, employing more than 2,000 people worldwide.

De Nora is everywhere

Globally, De Nora is the world's largest supplier of activated electrodes, serving a broad portfolio of customers operating in chlorine & caustic soda production, components for electronics, and non-ferrous metal refining. De Nora is among the world's leading suppliers of water filtration and disinfection technologies (for the industrial and municipal sectors) and swimming pool disinfection components. Leveraging its well-established electrochemical knowledge, proven manufacturing capability, and a supply chain established over the years, the Company has developed and qualified a portfolio of electrodes and components to produce hydrogen through the electrolysis of water, which is critical for energy transition.

Anodes for the Electronics Industry

Committed to providing advanced anode solutions in line with electronic industry requirements.

The electronics market is influenced by continuous technological development and consumers' demand that are reflected in the key components.

The trends towards better connectivity, greater device functionality, performance, and miniaturization, are leading to higher complexity in our customers' products, which require advanced technological solutions more than ever before. Furthermore, the energy revolution, and an **increased demand for lithium-ion batteries (LiB)**, have highly impacted the need of strategic material like copper foil.



DSA[®] anodes for Electronics

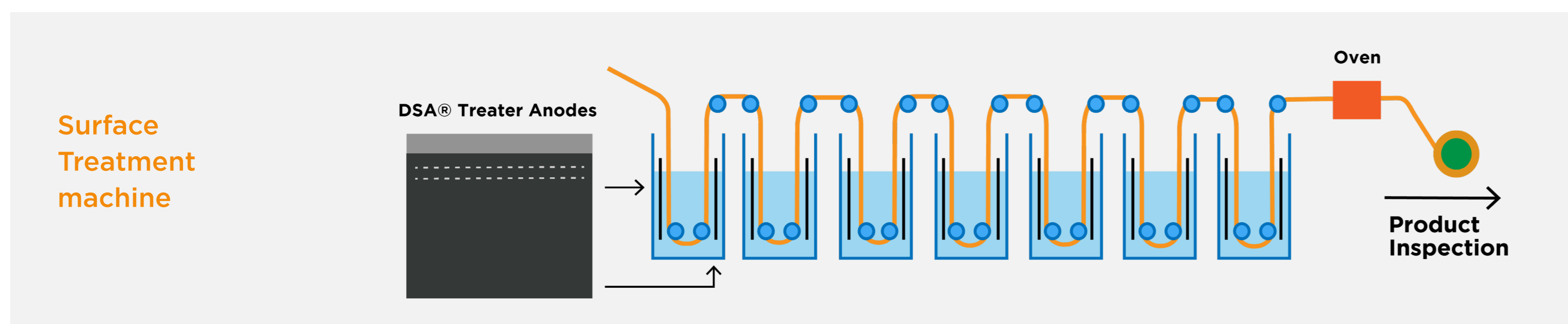
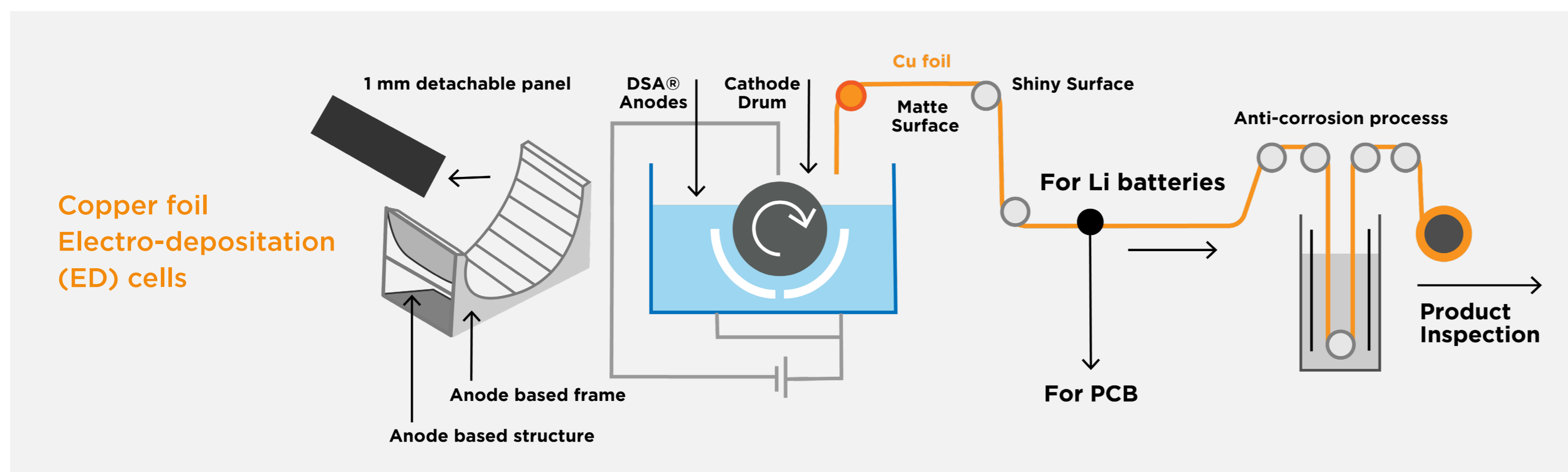
De Nora was the first company to introduce DSA[®] insoluble anodes in the electronics industry for the production of electrodeposited (ED) copper foil and the electrochemical copper plating of printed circuit boards (PCBs).

Over the years, we have continued to invest in research and development by being active participants/partners in the technological progress of the electronics industry. By developing long and trusted relationships with customers, we have been able to

improvetheelectrodepositionprocess andanode/anodestructurecelldesign, allowing for the introduction of new, superior, high-quality products with high functionality.

Ourcustomers,partnersandindustries served:

- main producers of electrolytic/ electrodeposited copper foils
- specialized engineering companies, electrodeposited cell for Copper foil, plating equipment and chemical vendors for PCB Cu plating

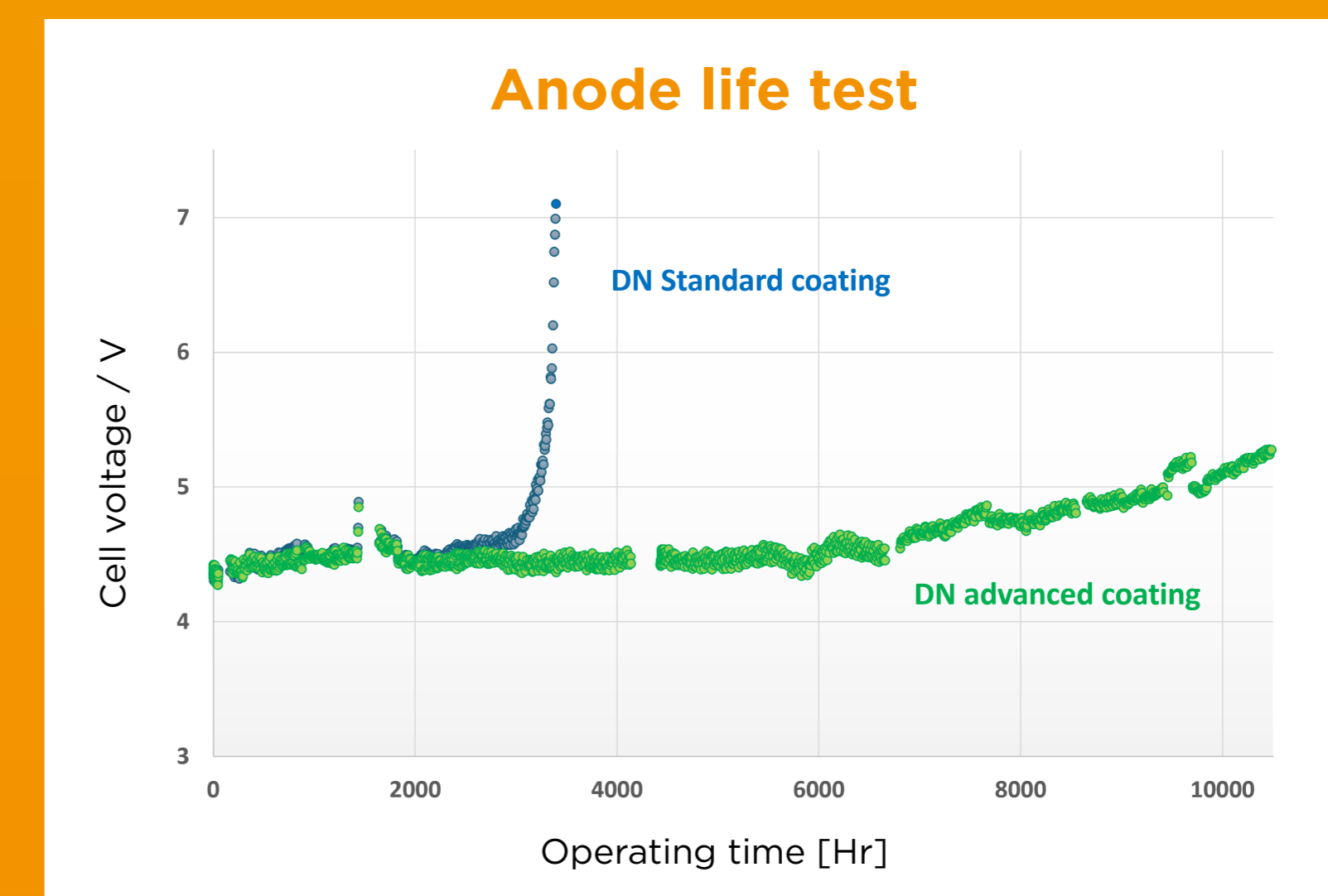


Key features and characteristics of DSA electrodes:

- **Great Stability:** insoluble anodes do not deform or degrade during use, ensuring consistent voltage performance and efficient operation over time.
- **High Efficiency:** electrodes, due to tailored catalytic coatings, facilitate desired reactions with minimal energy consumption and/or ohmic losses, leading to cost savings and improved purity of the products because of an optimal process.
- **Customizable:** Electrodes can be customized to suit different applications and cell configurations - they can be tailored to specific electrolytes, operating conditions, and process parameters.
- **Reusable:** at the end of the catalytic activity, the electrodes may be reactivated- recovering the initial performances without replacing the mechanical structure, hence minimizing the electrodes' total cost of ownership (TCO).

Our products ensure high quality manufacturing of:

- Copper foil for PCB
 - Rigid PCB
 - IC substrate
 - High Density Interconnection (HDI) board
 - Flexible PCB
- Copper foil for lithium ion batteries (LiB)
 - Negative current collector



Copper Foil Electrodeposition (ED) anodes

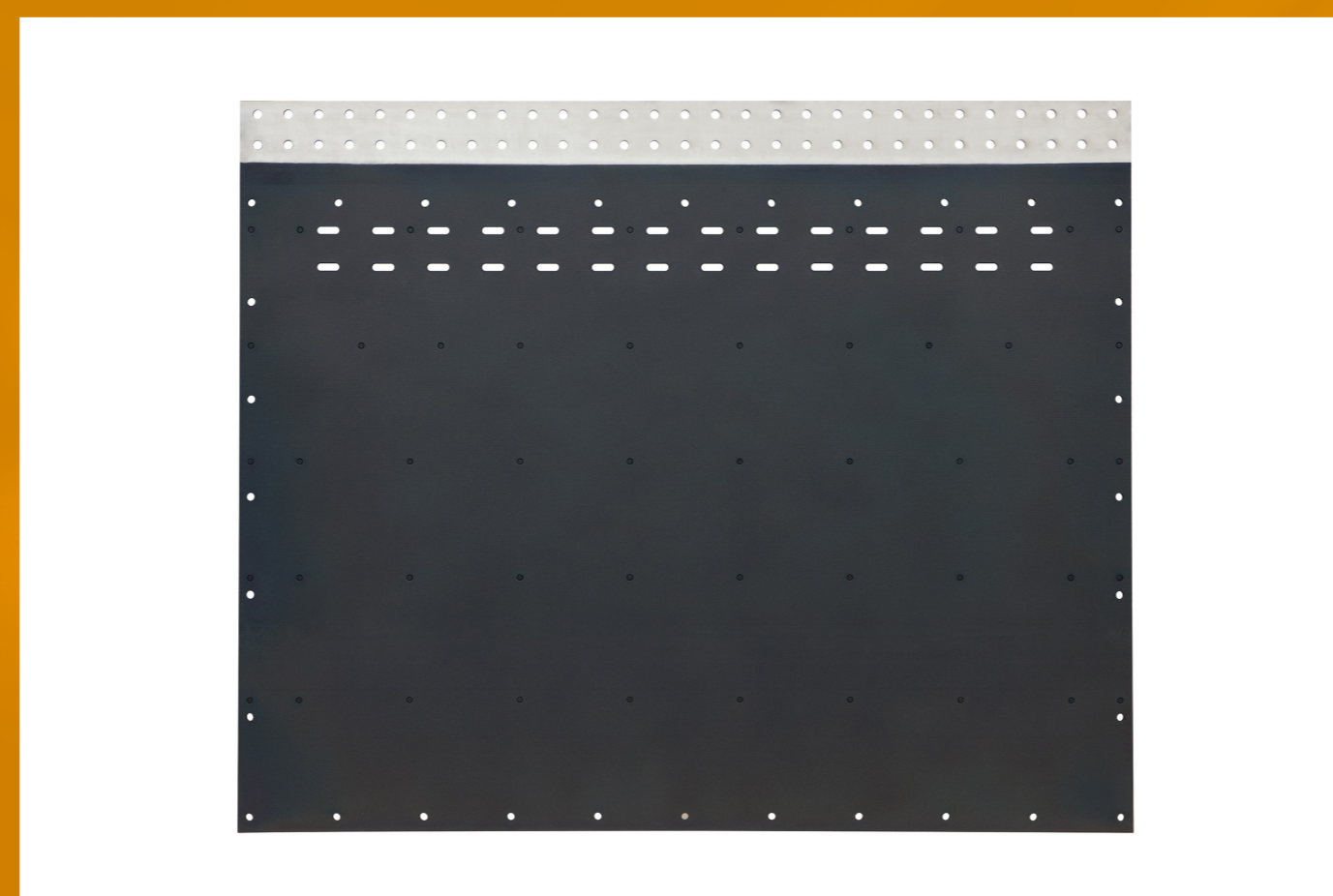
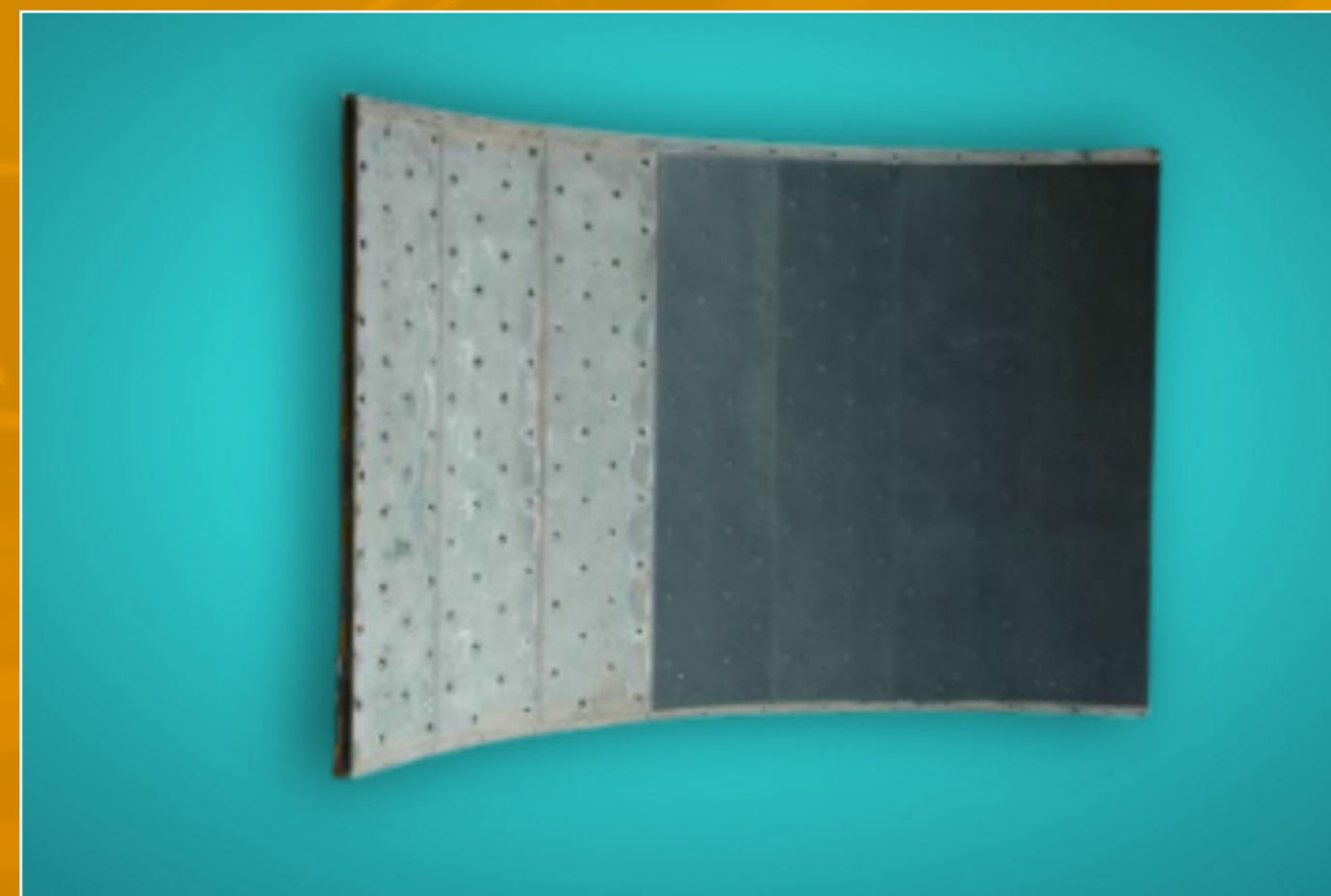
With nearly a century of experience, De Nora can support the copper foil manufacturing industry with electrodeposition anode and anode structure design and electrolytic process optimization, allowing them to operate at a very reduced electrodes gap, and to produce ultra-thin copper foil.

DSA® anodes for **decreased cost of operation** and **increased efficiency** for high-quality copper foil manufacturing.

We offer:

- Patented anode technologies (**detachable panels, based structures, and supporting frames**) for electrodeposition cell designs
- DSA® anodes for **electrochemical surface treatment** of metal foil, to provide the final product attributes
- Highest level of **field service and technical assistance** available due to global presence

- Maintenance agreement for anodes refurbishment, recoating, repair, refreshing service **for lead removal/ washing (Pb washing)**
- Customized offers, including **leasing contracts** and periodic **monitoring of anodes performance**



Why chose DSA anodes for copper foil manufacturing?

Our insoluble anodes allow operation under varied operating conditions to produce a full range of quality foils and thickness (including ultra-thin foil), covering many applications:

- PCB manufacturing, largely diffused in all the electric and electronics equipment we generally use in our daily life
- as negative current collector for lithium batteries that find application in smartphones, notebooks, personal computers and electric vehicles

De Nora is the partner of choice for the copper foil industry.

In addition to all of the above, we offer collaboration and partnership with all of our customers to ensure the ideal solution is achieved.

Technical assistance is available at De Nora's laboratories, and global R&D facilities to allow for collaboration with metal foil companies to optimize operating conditions or qualify new additives influencing anode performances. Additionally, we collaborate to develop innovative electrolytic coatings that are able to achieve the most challenging requirements in terms of surface morphology and internal structure.



Printed Circuit Board Production

As an increasing number of products incorporate computing technology, from personal and Internet-of-Things devices, to cars and 5G infrastructure, the demand for printed circuit boards (PCB) is likewise expanding. PCB manufacturing requires specially designed anodes for the electrolysis process, and the quality of these anodes is critical to producing PCBs that achieve high performance standards and product quality, while also minimizing maintenance, manufacturing costs and downtime.

For excellent PCB electroplating with strong connectivity, the following insoluble anode attributes are ideal:

- **Good plating uniformity**
- **Strong productivity**
- **Less additive consumption**
- **Low required maintenance**

While soluble anodes can be less expensive in the short term, they have a current density (5A/dm²) that is much lower than insoluble anodes (up to 30A/dm²) and a current distribution that is uneven, as compared to the **highly uniform current distribution of**

insoluble anodes. The electrode gap with soluble anodes is typically above 400mm (as compared to 100mm for insoluble), and they have a lower via filling ratio than insoluble anodes.

Also, soluble anodes gradually dissolve during electrolysis, which has several unfortunate results:

- The creation of debris (sludge) in the plating solution, which increases maintenance and decreases product quality
- An anode size and shape that is constantly changing, which impacts performance consistency
- A short operational life, which contributes to frequent and arduous maintenance

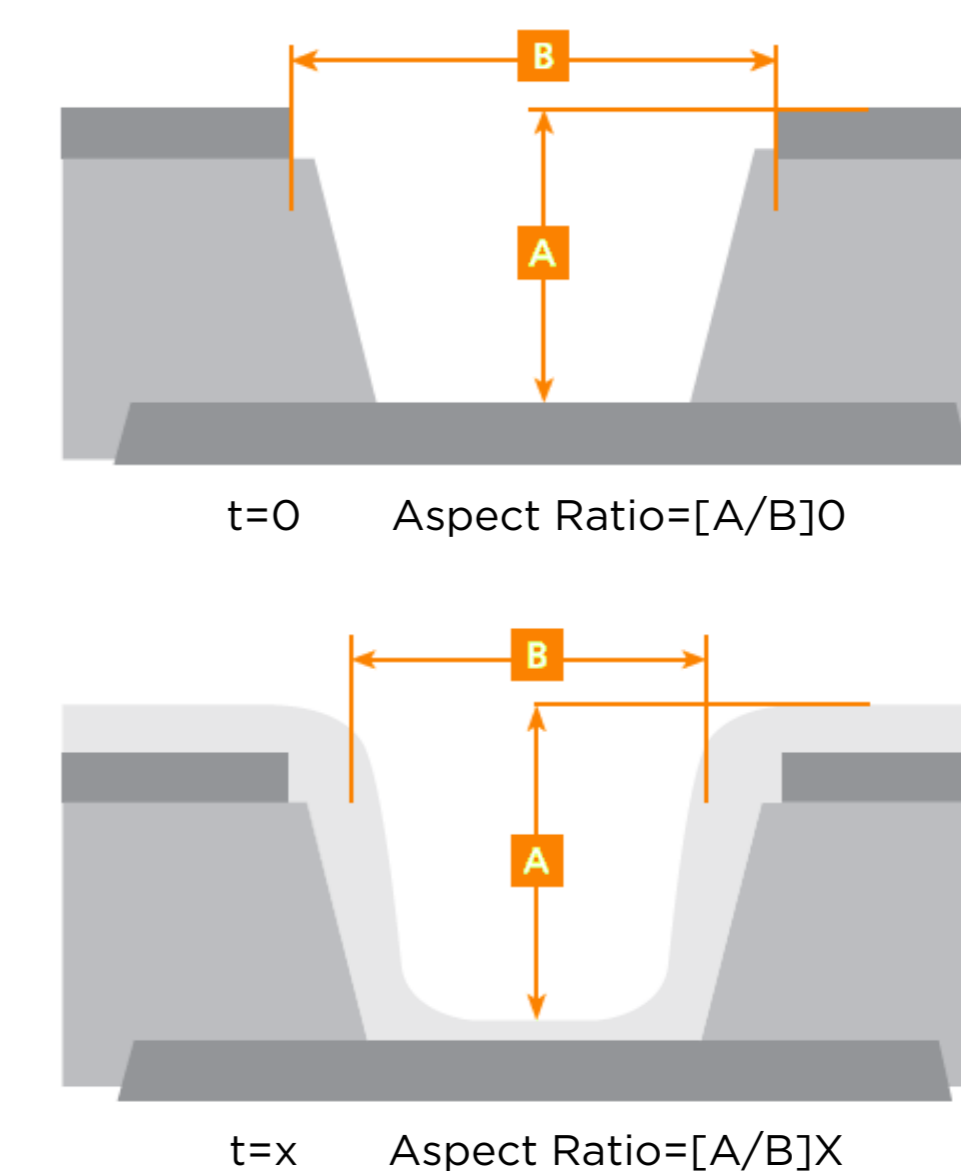
Because insoluble anodes do not dissolve, they overcome all these challenges. Their one downside is that they typically have higher additive consumption than soluble anodes, which can increase operating expenses for manufacturers. **De Nora has overcome this challenge with DENORA DT anodes.**

The De Nora solution

With DENORA DT anodes, manufacturers get the best of both worlds: **Long-lasting anodes that deliver high and consistent performance, do not degrade or introduce impurities, require little maintenance, and offer additive consumption equivalent to soluble anodes.** Our insoluble anodes are used by leading PCB manufacturers and selected by equipment suppliers for their vertical continuous plating (VCP) lines and horizontal electroplating equipment.

While some insoluble anodes depend on an anode box to minimize additive consumption, DENORA DT anodes have a membrane function incorporated into the coating layer, eliminating the need for an anode box while also minimizing additive consumption. This feature also eliminates the cost of an anode box.

Throwing Power as a Function of the Deposition Time



Uniform current distribution plays a role in via filling. Control of the current density profile, possible with DSA® anodes, can help meet via filling requirements in production



DENORA DT plating anodes have become the primary choice in **copper-via-filling and mSAP electrodeposition** processes for manufacturing both HDI printed circuit boards and semiconductor substrates.

Our insoluble anodes are largely applied by leading printed circuit board (PCB) manufacturers and are selected by equipment suppliers for:

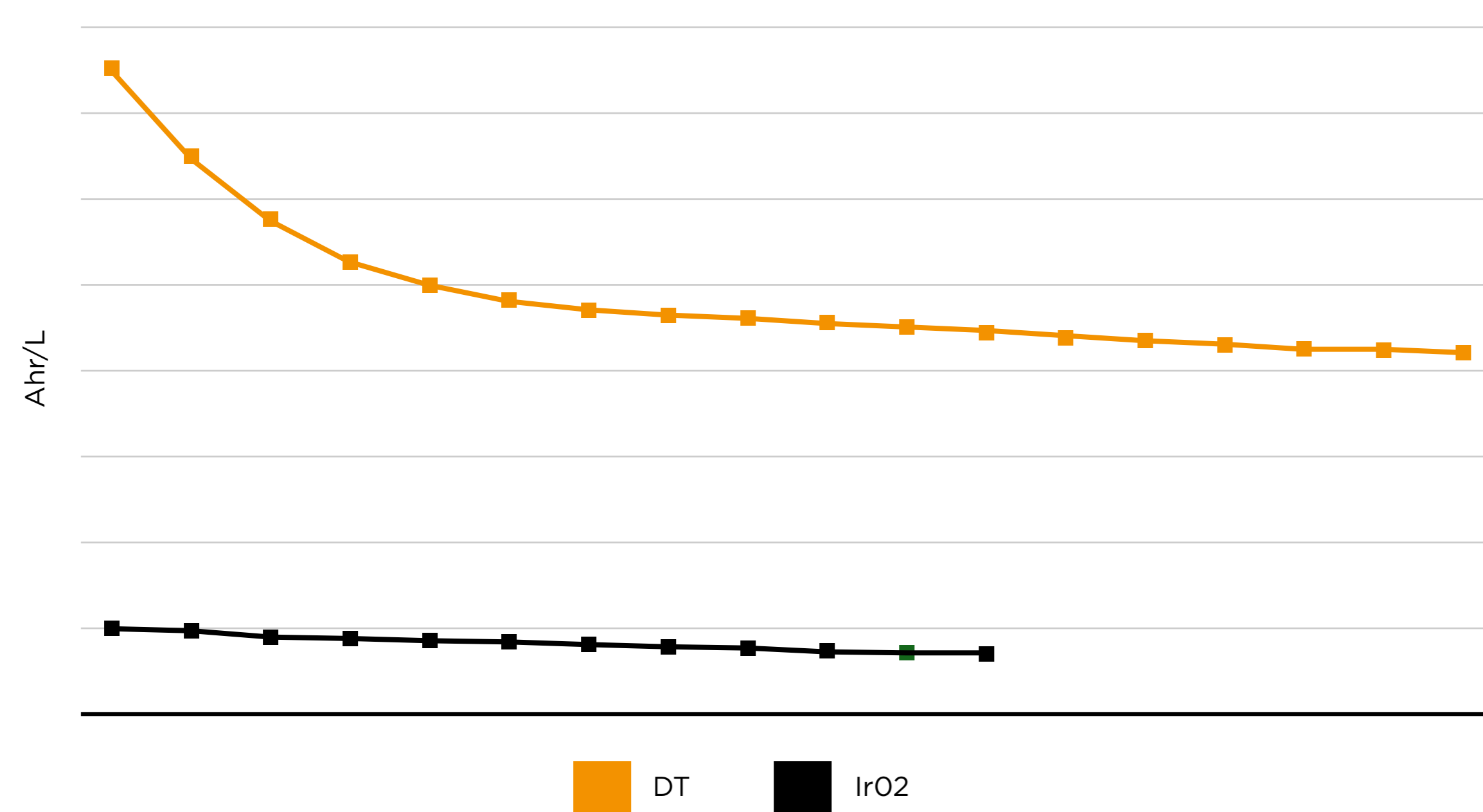
- **vertical continuous plating (VCP) lines and**
- **horizontal electroplating equipment.**

DENORA DT anodes:

- Provide high-quality, long-life performance
- Offered in both standard and custom fabricated designs
- Improve straight line throwing power
- Copper metal plates deep into high aspect ratio holes and blind vias

Performance comparison of iridium oxide electrodes and DT coating in EVF plating bath

Additive Consumption Profile in VCP line



Why industry leaders chose DENORA DT anodes

DENORA DT anodes are offered in standard and custom designs to ensure **optimum performance**.

Performance advantages:

- Improved Copper Plating Distribution
- 1:1 Surface to Through-Hole Uniformity
- Elimination of Nodules & Surface Sanding
- Elimination of Anode Sludge
- Improved Yield
- Eliminates Tedious Anode Maintenance
- Safer Operation with Light Weight Titanium Anodes
- Ability to Operate at Increased Current Density

Uniform copper deposition, reliable via filling ability, elimination of surface roughness, and minimum additive consumption make DENORA DT anodes the solution for today's challenge in the electronics industry. DENORA DT anodes have been specifically **formulated to maintain the stability of organic plating bath additives**. Operation with DENORA DT anodes provides additive consumption equivalent to soluble anodes.

De Nora coatings, marketed under the DENORA DT brand, have been qualified by all main chemical vendors and are compatible with all plating chemicals, including the latest generation.



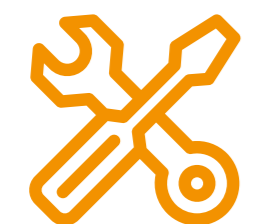
Services

Our expertise enhances the user experience of high-performance products. De Nora supports your business in all product life cycle.

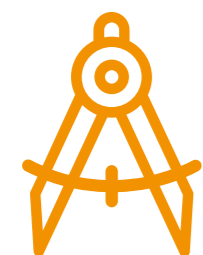
BUSINESS CONTINUITY



Global presence for sales & technical support



Supply, leasing & maintenance agreements

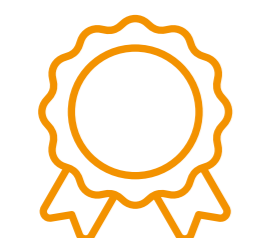


Tailored solutions & engineering design

ADDED VALUE



Performance enhancement



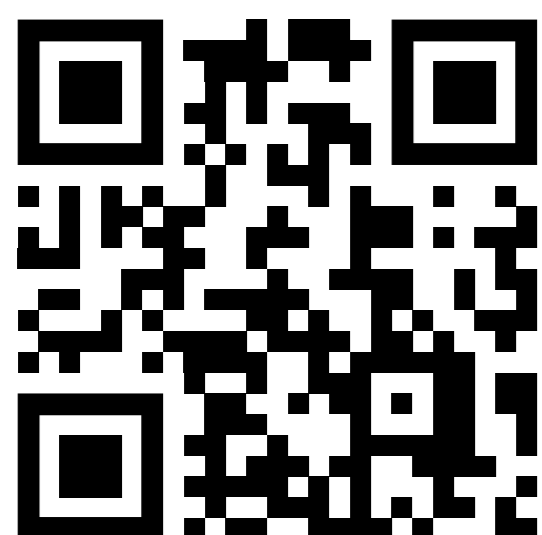
Product quality improvement



Environmental sustainable solution

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**Get in touch
with us**

www.denora.com

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