PROTERIAL

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NEWSLETTER

Infinite expansion with the principle of addition

— Clad Metals —

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Proterial, Ltd.

About Proterial NEWSLETTER

The Proterial Newsletter is published to introduce and provide wider and deeper understanding of the signature products and technologies of the Proterial Group. Proterial hopes that this communication tool will help you gain a better understanding of the Group.

For many years, Proterial, Ltd. (hereafter, "Proterial") has been engaged in its mainstay business, manufacturing and selling the high-grade specialty steel*[1] of the Yasugi Specialty Steel (YSS) brands. Revenue from the specialty steel business is approx. 30% of the overall revenue of the Proterial Group. The products are produced mainly at the Yasugi Works (Yasugi City, Shimane).

Among these products, clad metals are driving force of Proterial’s business and are believed to be promising materials that are going to open the way to the future. Clad metals are products from Proterial Metals, Ltd., a Group company.

The word *clad* means *clothed* or *covered*. It also means bonded metal. As its name implies, clad metals are metal materials created by bonding two or more different metals without any adhesives or similar materials, thus creating a material with multiple properties that cannot be obtained from a single-metal material, using the principle of addition.

Clad metals are expected to further expand the possible applications of metals, which could not be established for single-metal materials, so Proterial Metals is developing them aggressively.

In this issue, the newsletter introduces the expected contributions of clad metals which are materials opening the path to future possibilities, including their features, future uses, and applications that are particularly in-demand.

*1: Specialty steel: A collective term for high-grade carbon steel and alloy steel, which are separated from common steel

What are clad metals? Japanese swords are also clad metals?

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As explained at the beginning, clad metals are high-performance metal materials created by bonding two ore more different metals without using any adhesives or similar materials, thus creating a material with multiple properties that cannot be obtained from a single-metal material, using the principle of addition.

The technique of bonding different metals, which is used to make clad metals, has existed since early times. One example is the Japanese sword, which techniques for manufacturing are believed to have been established in around the 7th century. Low-carbon steel, which is relatively soft, is wrapped in high-carbon steel, which is hard. The principle of addition is applied to create the distinctive properties of Japanese swords, which do not break or bend but cut well. The beautiful *hamon* (edge pattern) is created by skillfully bonding two types of steels with different hardnesses, which is a process of addition.

Tatara ironmaking

A traditional ironmaking method for creating Tama-hagane, the material used to make Japanese swords

What are clad metals used for?

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Existing applications include current breakers and button cells. When an electrical current is applied to a clad metal made by bonding metals with different thermal expansion rates, heat is generated and the clad metals bend in one direction due to the difference between the two metals' thermal expansion rates. A current breaker uses this phenomenon of clad metals. The package material of a button cell is multiple metals combined together, including a highly corrosion-resistant metal and a high-strength metal. The package material is able to endure the button cell's electrolyte while also allowing the material to be deep drawn.*2

■ Examples of Application 1
Clad metals for micro (button) batteries

Copper (Cu)		Stainless steel (SUS)		Pure nickel (Ni)		
Excellent point: Conductivity, Durability against electrolyte	+	Excellent point: Processability, High strength	+	Excellent point: Corrosion resistance, Low contact resistance	=	A material with high conductivity, corrosion resistance and high strength

This combination of metals ensures not only high conductivity and corrosion resistance but also high strength. Therefore it is appropriate as a material for button cells and the like.

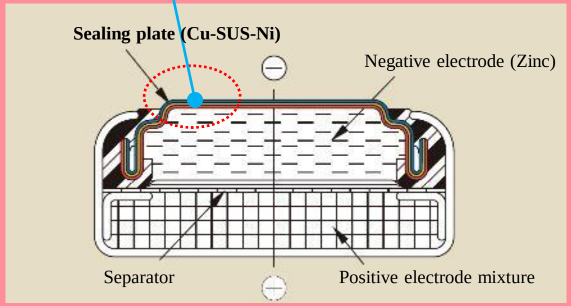
Got it!

Where are they used?

Clad metals are used here.

Application example: Button battery sealing plate

* The function of the sealing plate which contacts the electrode terminals, prevents a short circuit between the terminals and the leakage of the electrolyte.



Pure nickel, which is highly conductive and resistant to corrosion, is used for the outer layer.
Stainless steel is used for the middle layer because the plate strength is necessary.
The inner layer is copper, a highly conductive material able to endure contact with the electrolyte.

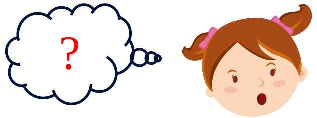
What happens if a single-metal material is used?

Using only copper will ensure high conductivity but there will be problems regarding its strength and corrosion resistance.

Using pure nickel alone will result in a lower conductivity than copper.

In this way, clad metals have been long-used in familiar products. Recently, however, their applications are changing and expanding greatly. Clad metals today have material appropriate for a wider range of higher-performance applications. greater bonding strength, which are made possible by interatomically bonding the metals without using a binder or other adhesive, through a combination of cold rolling and heat treatment, etc. As a composite metal, it is possible to process them using techniques such as punching, bending, and deep drawing, so the effects of the addition make this material appropriate for a wider range of higher-performance applications.

*2: Deep drawing is a processing method in which pressure is applied to a metal plate to make it made into a concave, container shape.



What are clad metals used for?

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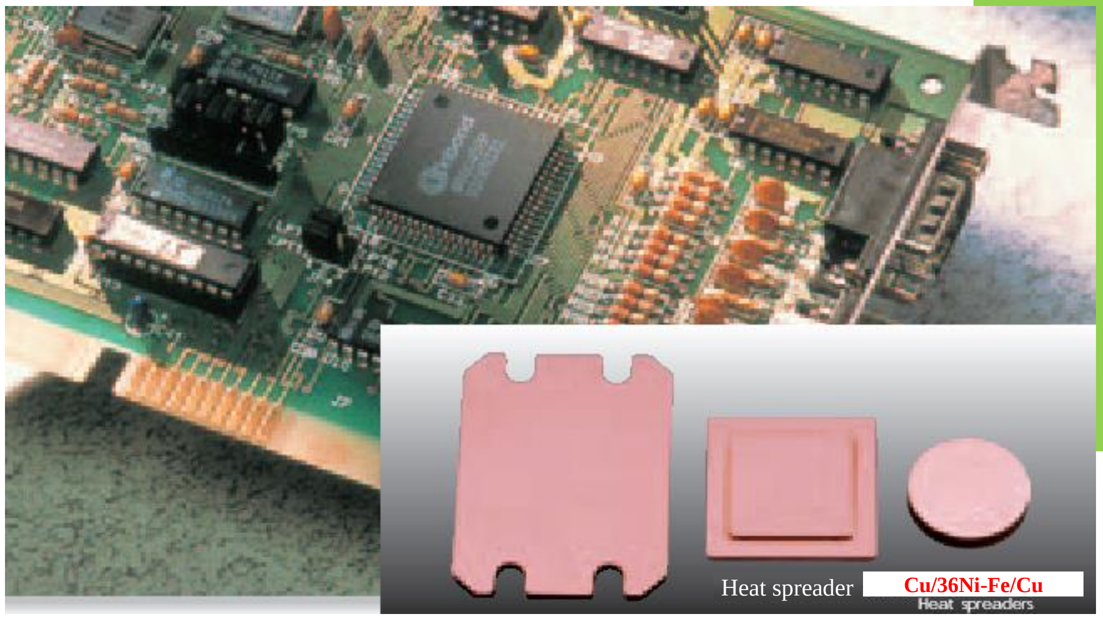
For example, they are used as a lead*3 material or a heat spreader in power semiconductors, which are used in the power control inverters of xEVs, industrial machines and other equipment. Clad metals for heat dissipation are used in various power devices, smartphones, LEDs and other devices. While a metal with high thermal conductivity, that transfer heat quickly, is used as the base material to release heat quickly, the metals combined with that base metal differ according to the product that the part will be used for.

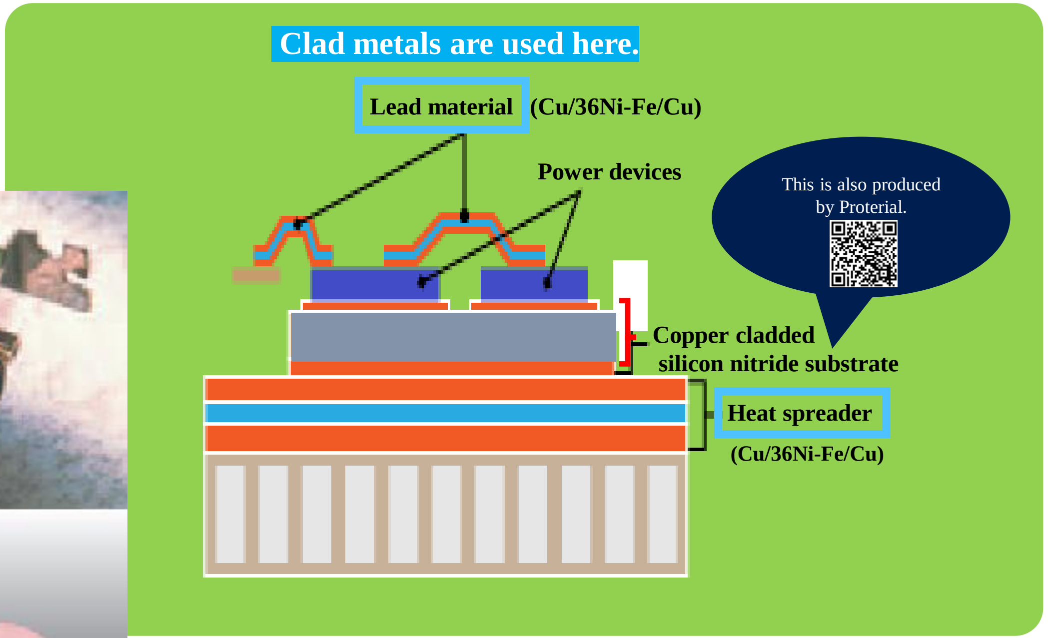
■ Examples of Application 2
Clad metals for lead materials and heat spreaders

High thermal conductivity + Low thermal expansion + Low resistance → **Cu/36Ni-Fe/Cu** *

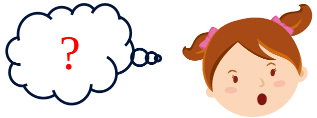
A material that transfers heat smoothly, has low thermal expansion, and also conducts electricity efficiently

* Cu: Copper, Ni: Nickel, Fe: Iron





*3: Lead is a terminal that conducts electricity.

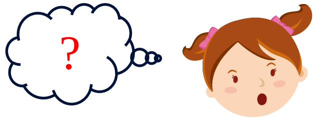


How are clad metals made?

Although they are all called clad metals, the materials are actually made in various ways. Proterial manufactures clad metals using a unique method combining cold rolling, heat treatment, etc. without using an adhesive.
Explosion bonding, with which great pressure is generated momentarily using gunpowder, is applied to bond metals with greatly different properties, such as steel sheet and titanium. Multi-layered clad metals which are created using explosion bonding feature high strength. They are used for products of which high airtightness is required, such as plant reaction tanks and heat exchangers. Further, steel pipe for oil drilling or the transportation of natural gas is made by bonding steel sheet, nickel-based alloy, etc. using a large rolling mill, to make the pipe resistant to corrosion and heat. Other than the above, wire products such as copper-cladded steel wires and aluminum-cladded steel wires, which are made by coating the steel wire base material with copper or aluminum, are also considered as clad metals.

■ Clad metals produced by Proterial Group

Clad metals produced by Proterial Group have greater bond strength, which is made possible by interatomically bonding the metals without using a binder or other adhesives, through a combination of cold rolling and heat treatment and other methods. They are used for a wide field of familiar, high-performance products, including automotive heat exchangers, heat-dissipation and chassis components of smartphones and various other devices, the heat-dissipation, support and flexible materials of displays, the electrodes and internal leads of secondary batteries and package materials and brazing materials in various devices.



How are clad metals made?

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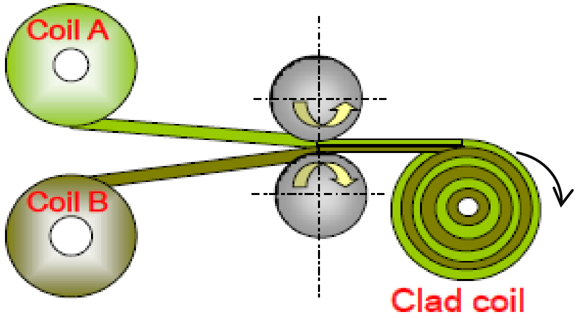
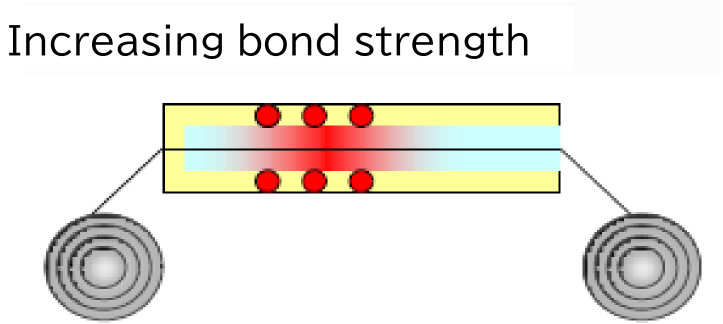
Greatness of materials + the technological capabilities of Proterial = the creation of new product value

The unique technological capabilities of Proterial contribute to improving the performance of automotive parts, industrial equipment, electronics materials, and other products.



Cold Rolling



Heat Treatment

Clad metals from Proterial have the following features:

1. **Manufacturing of long materials**
   Multiple rolled metal materials can be made into a continuous, long material by bonding them through cold rolling and heat treatment.
2. **Materials development**
   Various specialty metals and copper materials as base materials are melted internally. This enables the study of the pursuit of various properties and functions starting from the material development stage.
3. **Precise processing**
   Owning a dedicated precise rolling plant, Proterial can deliver world-leading ultra-thin, wide, multi-layered, high-precision clad metal products.

Above all, these features can be leveraged to make clad metals for the negative electrode tabs of automotive lithium-ion batteries (LIBs), which are essential in the current trend of shifting to xEVs. The next page explains the demand related to LIBs, which is now a hot potential market for clad metals.

What is the background behind the clad metals market?

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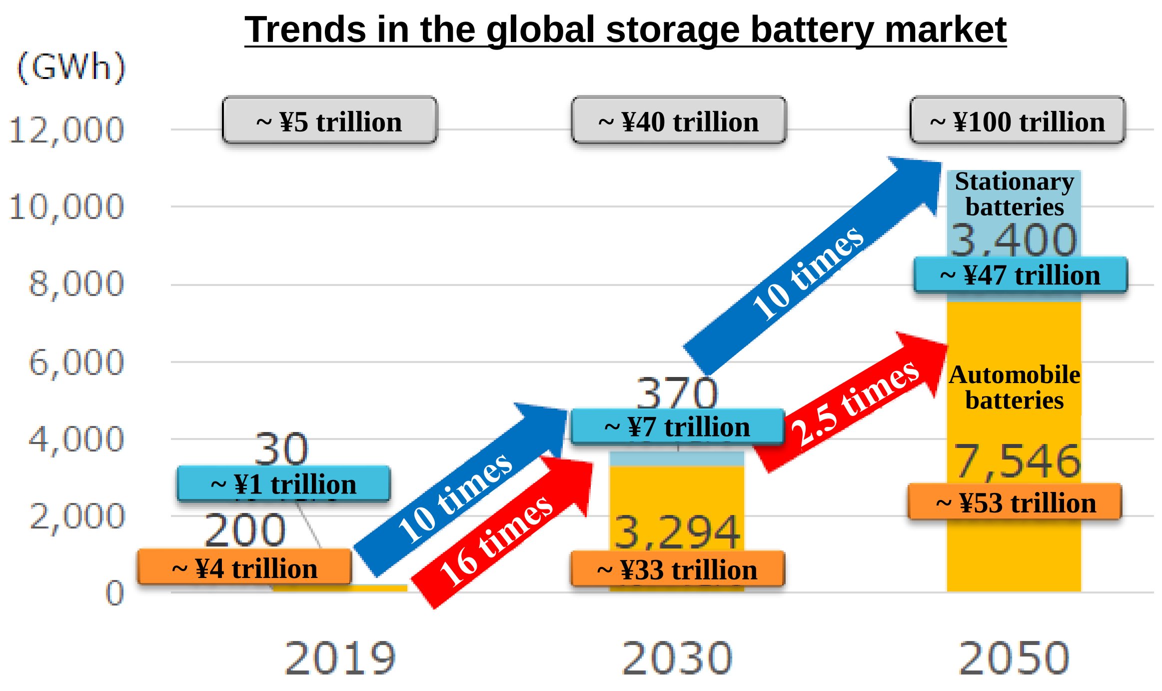
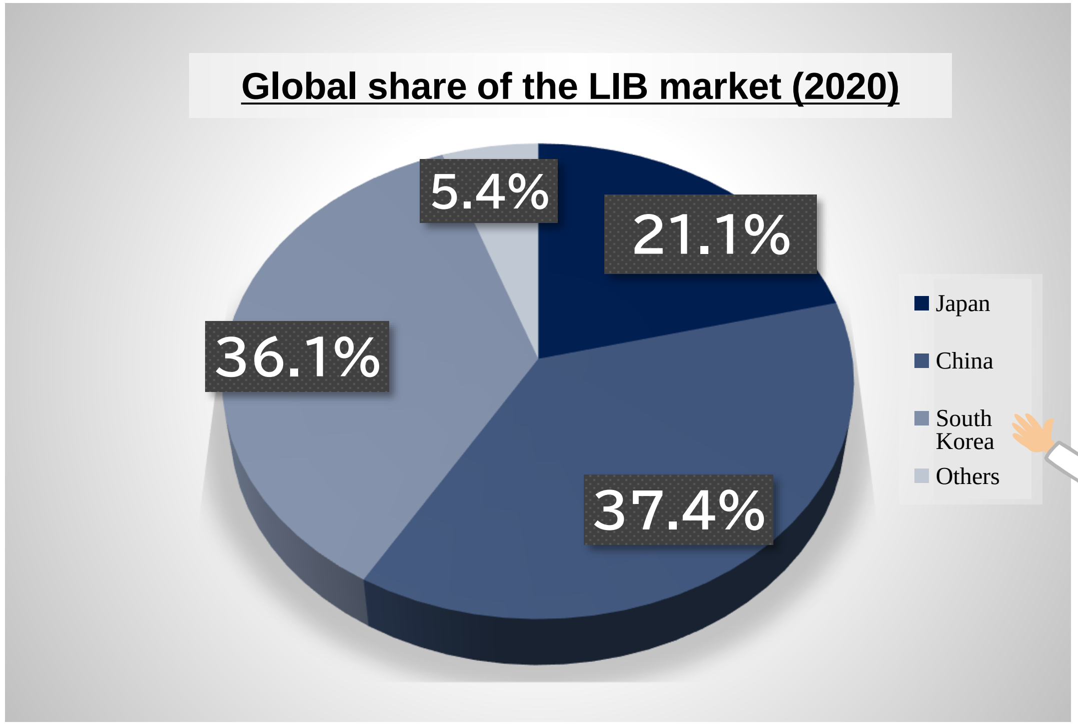
As described already, clad metals have many applications. A typical example of why they are used is the effects of the additive process, including a combination of high performance and low cost that has been not previously achieved. Combinations of various metals enable applications with many benefits.

Therefore, instead of offering clad metals to a specific market, Proterial will develop new applications in areas where additional properties are required, such as low electrical resistance, heat dissipation, strength, processability and weldability, as new solutions that were impossible before, by changing the combination and component ratio of metals. Among the many applications for clad metals, the market that is currently attracting the most attention is the LIB market. Most notably, the market of automotive LIBs is expanding rapidly.

■ Forecast trend in the xEV LIB market



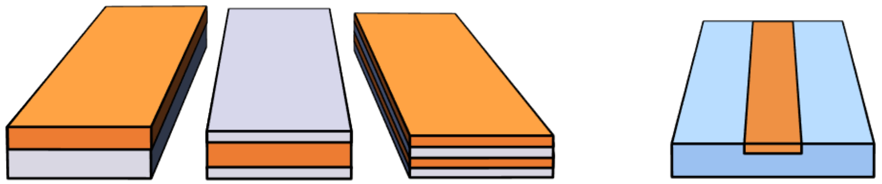


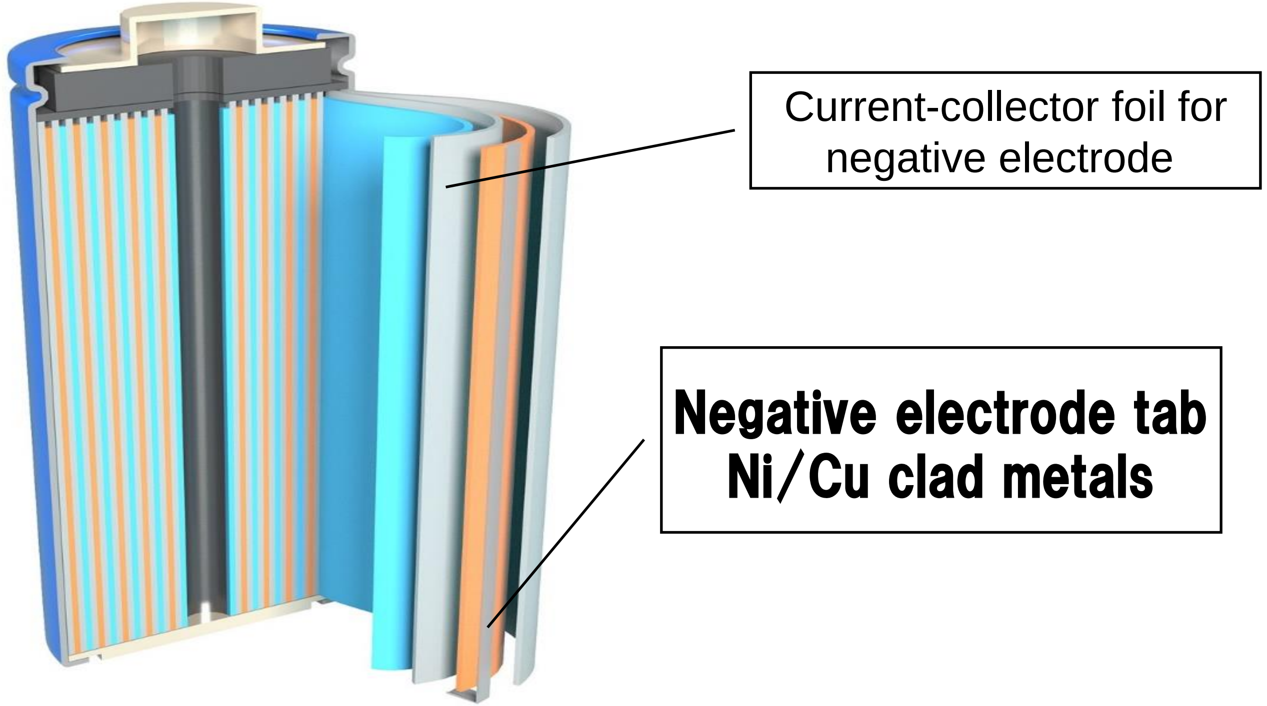
Source: Excerpt from *Jidosha Bunya-no Carbon Neutral-ni Muketa Kokunaigai-no Doukou-tou-ni Tsuite* (trends in Japan and other countries towards carbon neutrality in the automotive field) from the Ministry of Economy, Trade and Industry (April 5, 2023).
Created by Proterial as reference data.

For xEV LIBs, clad metals will be used for negative electrode tabs and terminals, contributing to their conductivity, strength, heat dissipation, processability and weldability. As terminal materials, clad metals are available in various combinations depending on the battery structure. They include Cu-inlay-cladded Al materials (Al materials embedded with Cu), Ni-inlay-cladded Al materials, and Ni-cladded Cu materials.

The negative electrode tab is attached to the current-collector foil for the negative electrode and used to electrically connect the current-collector foil with the bottom. The clad metals from Proterial introduced here are used for negative electrode tabs and contribute to lowering the internal resistance of LIBs.

Proterial manufactures two types of clad metals





▲ LIB structure (for illustration purposes only)

Conventionally, pure nickel, which features excellent weldability, has been selected as the material for the negative electrode tab. However, due to the expansion of applications to xEVs and power tools in recent years, heat generation due to the high current passing through the electrode has been a problem. On the other hand, pure copper enables control over the heat generated by the current passing through the electrode because of its low electric resistance. However, its shortcoming is the difficulty of welding it. Proterial has develops and mass-produces Ni/Cu clad metals which feature both weldability and low electrical resistance.

➢ Contributing to lowering the internal resistance of LIBs! Development of clad metals for negative electrode tabs

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▲ Clad metals for LIB negative electrode tabs

A negative electrode tab is ultrasonically welded using the current-collector foil, resistance welded*4 or laser welded to the bottom, and used to electrically connect the current-collector foil of the negative electrode with the bottom. Because the electricity from the current-collector foil concentrates on the negative electrode tab, heat generation needs to be controlled when current is passing through the negative electrode tab. Accordingly, it is necessary for it to be a low electrical resistance material. At the same time, its weldability to the current-collector foil and the battery case is also a necessary feature. Proterial's clad metals are made by bonding Ni, which features excellent weldability, and Cu, which has low electrical resistance. With the combination of superior weldability and low electrical resistance, the clad metals minimize the heat generated by the negative electrode tab, where the electrical current is concentrated. Because welding methods and burr*5 control are different depending on the structure of the battery, Proterial offers the following lineup of products suited to different battery designs. In the case of Ni/Cu clad metals with low electric resistance, which have only one weldable surface, burrs are generated on both the Ni and Cu surfaces. Burr control is not needed for the Ni/Cu/Ni clad metals, which feature a symmetrical shape with the Cu sandwiched between highly weldable layers of Ni.

Composition	Thickness ratio	Electrical resistivity ($\times 10^{-8}\Omega\cdot m$)	Weldability (◎: Excellent, ○: Good, △: Poor)			Controllability of burrs
			Ultrasonic	Resistance	Laser	
Ni/Cu	25:75	2.1	◎	○	Ni surface: ◎	No
Ni/Cu/Ni	25:50:25	2.8	◎	○	◎	Yes
Ni/Cu/Ni	33:34:33	3.6	◎	◎	◎	Yes
Ni only	-	8	◎	◎	◎	Yes
Cu only (for comparison)	-	1.7	◎	△	△	-

▲ Proterial's lineup of clad metals for negative electrode tabs (figures for properties are reference values.)

*4: Resistance welding is a welding technology that uses resistance heat generated when current is applied to a metal.

*5: Burr means raised edges that are generated on one or both surfaces of a material, such as a metal, when it is cut.

■ Interview with a development engineer (Yoshimitsu Oda, Engineering & Development Department, Proterial Metals)

>> What is the system developing and producing the clad metals, which attract attention?

Proterial Metals, which manufactures these products, is a manufacturer of electromagnetism metal products, specialty metal products, and medical devices. In addition, the company also manufacturers various raw materials semi-products, processed products and accessories for the above products.
These products are both developed and produced at the Suita factory of Proterial Metals. Development began in 2000. Material design was completed in 2004, and then commercial production started. At that time, Proterial was manufacturing only Ni/Cu clad metals. The lineup has been enhanced in accordance with the ways that customers use the clad metals.

>> What were the key points and difficulties in the development of clad metals?

One event occurred when we were developing a soft material as a part of our efforts to enhance our lineup. With a soft metal, a lot of metallic powder is generated when it is cut vertically. The generation of metallic powder needs to be prevented because it could cause a fire if it remains in the battery. Accordingly, the key point was how to prevent the generation of metallic powder while also ensuring softness. The entire manufacturing department including myself worked enthusiastically to solve this issue. A product which met these conflicting requirements was developed by repeatedly reexaming the manufacturing process and through countless experiments. We spent two years on those trials.

>> We hear that clad metals will be launched onto the market following the discovery of new applications. What way of thinking led you to discover their application as negative electrode tabs?
The clad metals lineup includes other products. What is difficult about finding applications for products?

There is also a seed-oriented approach, where Proterial Metals finds an application and develops a product for that application. However, we believe that a needs-oriented approach is more likely to lead to mass production. Therefore, we devote ourselves night and day to discovering applications based on customer needs. Regarding LIB negative electrode tabs, we solved a customer's problem using clad metals, and the customer adopted the solution. This is exactly a typical example of the needs-oriented approach. We believe that identifying customers' problems by communicating closely with them is essential in finding new applications. The products are created through the relationships between people, and I feel that it is very rewarding to be involved in the process.

>> What points of the products are excellent and how has the market evaluated them? In terms of safety, what are the excellent points of the products compared to the conventional materials for negative electrode tabs? What effects are produced when the clad metals are applied in LIBs?

I think that Proterial Metals is able to maintain its high competitiveness because of its ability to work on the manufacturing process from materials design through melting, rolling, cladding and thin foil rolling of materials, which is its strength. Various combinations of the company's technologies enable Proterial Metals to meet to diverse customer needs.

When applied in LIBs, the materials improve usability and reliability in terms of the LIB's service life. This is enabled by the low electric resistance and weldability that ensures the superior safety of the product, something not achievable with conventional materials. These achievements are enabled by the company's strengths in manufacturing, which enable Proterial Metals to meet to the detailed needs of customers.

>> What tasks does Proterial face in the automotive LIB market? What are Proterial's R&D and sales expansion strategies?

At present, the shift to EVs is accelerating in China and other countries all around the world. Reducing cost is the highest priority task. Proterial is considering the upsizing of small batteries. There is also a technological trend toward the simplification of the battery structure. In response, Proterial will pursue even more combinations with multiple functions, to provide customers with comprehensive benefits for batteries even if the cost of parts increases, further solidifying its position as a reliable partner. The company will continue to lead the industry in product development that is ahead of customer needs, thereby contributing to the development of society. This is what I hope.

Clad metals have infinite possibilities through the principle of addition. Proterial pushes forward with the development of solutions for unknown domains, which would be impossible with conventional single-metal materials, such as by creating product value with new ideas and innovating in the product process. Proterial will continue to help society develop by working seriously to strengthen its technologies and by leading manufacturing on a global scale.

[Contact] Corporate Communications Department, Proterial, Ltd.
https://www.proterial.com/e/contact/

Note: Yasugi Specialty Steel and YSS are registered trademarks of Proterial, Ltd.

■About PROTERIAL

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“Proterial” reflects the essence of our corporate philosophy, which consists of three elements: Mission: “Make the best quality available to everyone;”Vision: “Leading sustainability by high performance;” and Values: “Unfaltering integrity” and “United by respect.” It combines “pro-” with the word “material.”

“Pro-” represents our “three pros”:

・Professional — work that exceeds expectations ・Progressive — a spirit that keeps challenging ・Proactive —an enterprising attitude

“Material” refers to the high-performance materials that our original technologies produce and underpinned by the three pros. With our focus on solving customer issues and bringing new levels of value, we promise to contribute to the realization of a sustainable society through the products and services that embody our philosophy.

■Proterial, Ltd. — Company Overview

Established: April 1956
Head office: Toyosu Prime Square, 5-6-36 Toyosu, Koto-ku, Tokyo 135-0061, Japan
Capital: 310 million yen (as of March 31, 2023)
Representative: Representative Director, Chairman, President and Chief Executive Officer(CEO) Sean M. Stack
Sales revenue: 1,118.9 billion yen (Term ended March 2023)
History: 1910: Founded as Tobata Foundry Co.
1937: Merged with Hitachi, Ltd.
1956: Established separately as Hitachi Metals Industries, Ltd.
2023: Company separated from the Hitachi Group, and renamed from Hitachi Metals, Ltd. to Proterial Ltd.

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