# Electronics-Related Metal Products of Furukawa Electric Group

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**ABSTRACT** As the IT industry reaches new heights of prosperity in recent years, the electronics markets in such areas as digital home appliances and mobile equipment continue to grow, together with the automotive onboard equipment market spurred by automotive electronics. Accordingly, the Metals Company of Furukawa Electric in conjunction with other group companies, with their business mainstays founded on copper and copper alloy strips, functional surface-treated products, wires and bars, copper foil products and special metal products, are focusing on the technology and product development of raw materials and components targeted at the electronics markets. We intend to expand our production capacity and sales amount by establishing a suitable system for these strategic products.

## 1. INTRODUCTION

As the IT industry reaches new heights of prosperity in recent years, the electronics markets in such areas as digital home appliances and mobile equipment continue to grow, together with the automotive onboard equipment market spurred by automotive electronics. Accordingly, the Metals Company of Furukawa Electric in conjunction with other group companies, with their business mainstays founded on copper and copper alloy strips, functional surface-treated products, wires and bars, copper foil products and special metal products, are focusing on the technology and product development of raw materials and components targeted at the electronics markets. The characteristics and technology involved with the representative products in these business fields will be presented in this paper.

## 2. STRIP PRODUCTS

Main strip products for electronics-related fields include copper alloys for leadframes and those for connectors. While the Metals Company focused on the development of leadframe copper alloys until the middle of the 1990s, the focus has been shifted to the development of connector copper alloys in the early 2000s.

As the electronic equipment have reduced in size and weight in recent years, ICs and connectors used in these equipment have become smaller in size, lower in height and narrower in pitch. This trend has been clearly reflected in the performance requirements for the raw materials, resulting in a more demanding requirement in terms of strength, electrical conductivity and workability. High-performance copper alloys developed in response to the market needs will be described below.

### 2.1 Copper Alloy for Leadframes

Figure 1 shows the forecast quantity of semiconductor devices production issued by Electronic Trend Publication Inc. in 2005. It can be seen that, whereas packages that do not use leadframe represented by BGA and WLP show a strong growth, non-lead type packages such as DFN and QFN, among those that use leadframe, display a very steep growth trajectory. Conventional QFP shows a steady increase as well. Since EFTEC-64T, one of our

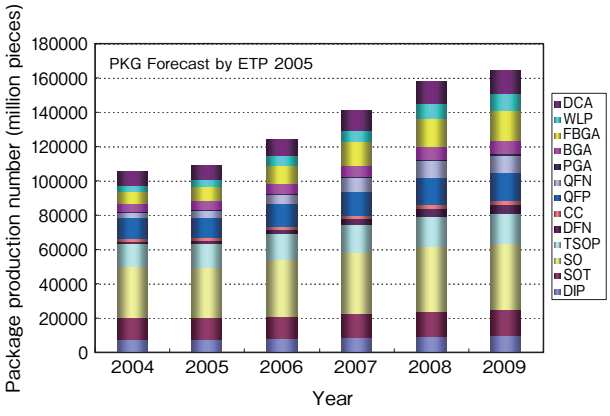


**Figure 1 Forecast of IC package production by package family.**

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main products, has a large share in the QFP and QFN markets, it is expected that the demand for the alloy will grow in the future also.

Figure 2 shows the relationship between hardness and electrical conductivity of various copper alloys for leadframe. In the figure the alloys in red are Furukawa Electric's developments.

1) EFTEC-64T and EFTEC-64T-C

These Cu-Cr-Sn-Zn system alloys are characterized by medium strength and high electrical conductivity (see Figure 2). Due to their well-balanced properties, they maintain a close to 40 % share in the QFP market, thus being recognized as one of the de facto standards for leadframe stocks. They offer not only medium strength and high electrical conductivity, but also superior mounting reliability such as electro-platability, oxide film adhesion and solderability, and thus are applicable to a variety of packages.

Moreover, they would not curl during the leadframe production process of QFN even if half etching is heavily used, since the residual stress in the material is reduced by means of a proprietary manufacturing technology. Furthermore, in the dicing process to cut the molding resin, they exhibit cutting property far superior to other alloys.

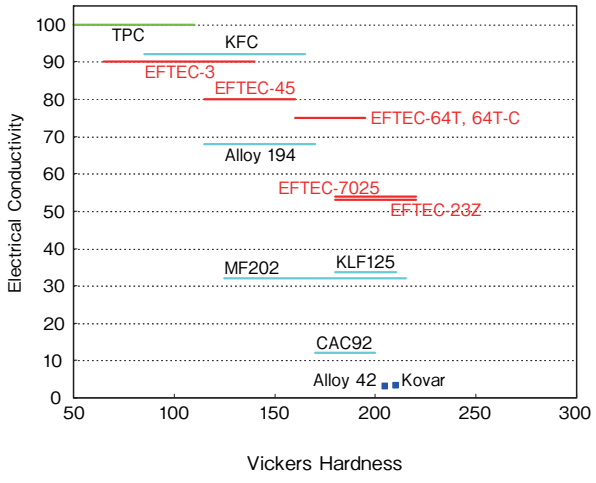


**Figure 2 Relationship between Vickers hardness and electrical conductivity of various copper alloys for leadframe.**

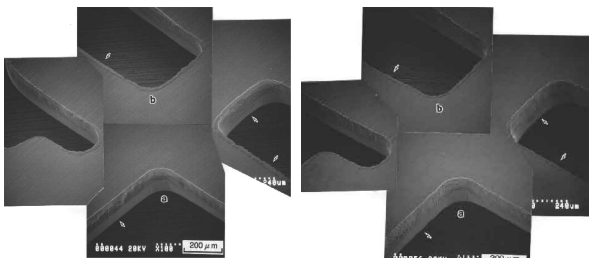

**Figure 3 Status of burrs after stamping for EFTEC-64T and EFTEC-64T-C.**

EFTEC-64T-C has a small amount of Si added to the composition of EFTEC-64T, achieving an improvement in the disadvantageous stamping formability of EFTEC-64T while preserving the fundamental property of EFTEC-64T. By utilizing our proprietary technology for heat treatment control, Cr-Si particles of the sub-micron order are dispersion precipitated, thus improving stamping formability. Figure 3 shows the leadframe surface after stamping. As can be seen, EFTEC-64T-C gives smaller burrs at the cut section, demonstrating improved stamping property.

2) EFTEC-7025 (C7025)

We have entered into the market for C7025, a de facto standard in the leadframe industry, after establishing its production system.

EFTEC-7025 is characterized by its top-ranked strength as for leadframe stocks, as well as by its medium electrical conductivity (see Figure 2). This alloy is mainly used in extra-high pin count packages such as QFP.

The development program was targeted at improving the disadvantages of conventional products. More specifically, we have made efforts to, and succeeded in, achieving the optimum performance balance in terms of expansion and contraction property at stamping, Ag electroplatability and adhesion property of oxide film. Table 1 shows the results of evaluation of oxide film adhesion characteristics. Good adhesion properties can be seen when compared with other materials.

## 2.2 Copper Alloy for Connectors

With the growing demand for digital home appliances including mobile phones, digital cameras, LCD TVs, DVD recorders and game machines, the connector market for

**Table 1 Adhesiveness of oxide film.**

| | Furukawa | A company | B company | C company |
|---|---|---|---|---|
| Peeling temperature of oxide film (℃) | 370 | 300 | 340 | 360 |

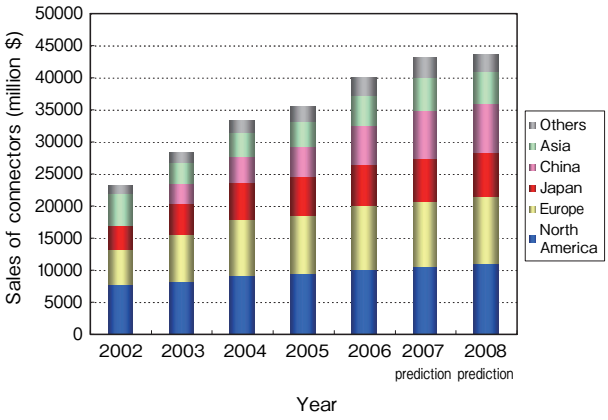


**Figure 4 Trends in the world's sales of connectors (Bishop Report 2006).**

electronic equipment is also expanding rapidly (see Figure 4).

Electronic connectors are becoming significantly smaller in size, lower in height and narrower in pitch. As shown in Figure 5 which plots the trend in connector pitch, connectors having a pitch narrower than 0.3 mm are brought into the market in these days, leading to the demand for a material that has higher strength and better workability.

Moreover, in recent years, there is a growing momentum to avoid beryllium in consideration of the environment, resulting in a requirement for developing a substitute copper alloy. Figure 6 shows the relationship between tensile strength and electrical conductivity of various copper alloys for connectors. In the figure the alloys in red are Furukawa Electric's developments.

1) EFTEC-97 and EFTEC-98S

EFTEC-97 and EFTEC-98S are based on the Cu-Ni-Si system that is characterized by balanced property between strength and electrical conductivity, thus realizing high strength, medium electrical conductivity characteristics (see Figure 6). And since a small amount of elements are added, they have made improvements in the bending and stress relaxation properties.

EFTEC-97 is mainly targeted at the low-concentration beryllium copper market, and is expanding its applications centering on CPU sockets and FPC connectors. On the other hand, EFTEC-98S has achieved improving the strength of EFTEC-97 by increasing the amounts of Ni and Si additions, so that the alloy is suitable for replacing not only low-concentration beryllium copper, but also high-concentration beryllium copper. Since these alloys are provided with an outstanding modulus of elasticity of as high as approximately 130 GPa, they allow for obtaining a high contact pressure with a small displacement, achieving high reliability of contact even when used in downsized, small-height connectors. Figure 7 shows the relationship between material strength (yield strength) and minimum bending radius (R/t) of selected copper alloys, in which the bending workability of EFTEC-98S is seen to be equivalent to that of low-concentration beryllium copper.

2) F5218 and F5248

F5218 and F5248 have modified 8 % phosphor bronze for springs and 10 % phosphor bronze for springs, respectively, by adding a small amount of Fe and Ni, thereby improving the strength and bending workability while preserving the elastic spring performance of the conventional

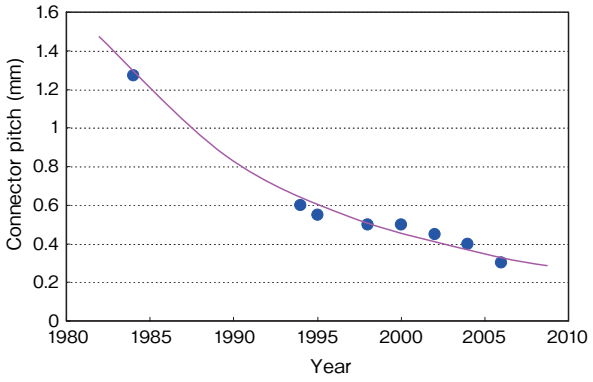


**Figure 5 Trends in connector pitch.**

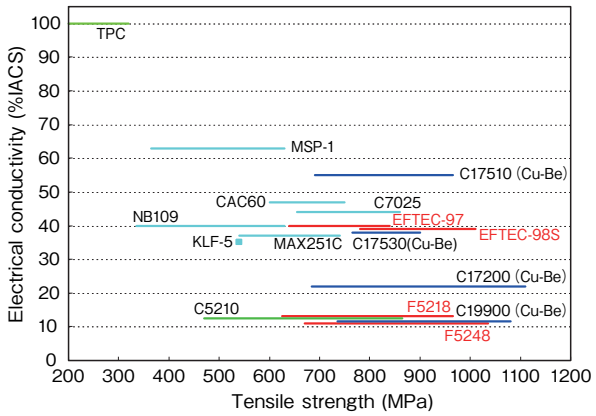


**Figure 6 Relationship between tensile strength and electrical conductivity of various copper alloys for connectors.**

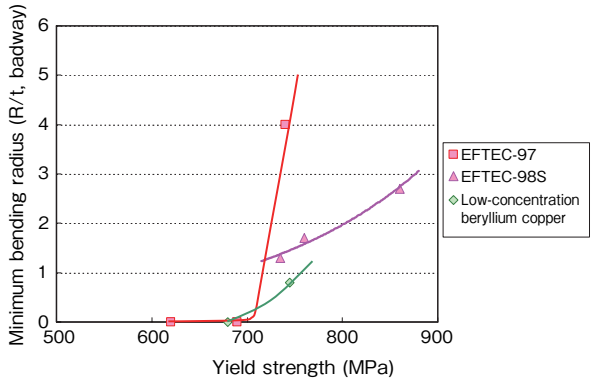


**Figure 7 Relationship between yield strength and minimum bending radius of selected copper alloys (I).**

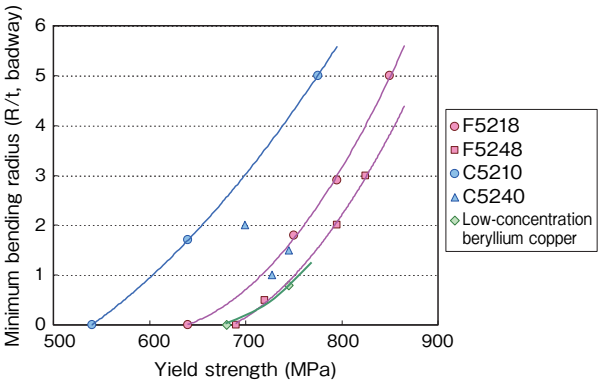


**Figure 8 Relationship between yield strength and minimum bending radius of selected copper alloys (II).**

phosphor bronze for springs (i.e., modulus of elasticity is approximately 110 GPa).

Figure 8 shows the relationship between material strength (yield strength) and minimum bending radius (R/t) of selected copper alloys including F5218 and F5248. It can be seen that, compared with the conventional 8 % phosphor bronze for springs, and assuming the same level of minimum bending radius, F5218 allows for using a material that is higher in yield strength by approximately 100 MPa, and as for F5248 by approximately 150 MPa, thereby significantly upgrading the design flexibility.

## 3. FUNCTIONAL SURFACE PRODUCTS

Our representative functional surface products include plated alloy strip products having plated surface layers, and resin coated metal strips "Furukawa F-Coat" products having electric insulating and heat-resistant resin coatings. The strong point of Furukawa Electric is that we can manufacture these functional surface products in an integrated manner from the raw materials such as copper and copper alloy strips to the final products. This makes it possible for us to offer very quickly a variety of cost-efficient high-quality products that meet the customers' needs.

These products are targeted at two major markets: the IT and electronics market and the automotive market. Below will be presented our functional surface products targeted at these markets that are expected to expand significantly in the future.

### 3.1 Plated Strip Products

Most of the copper and copper alloy strips for electronic and electric equipment are used as plated, and they may be categorized into "pre-plating" stocks where strips are plated before being press worked into parts, and "post-plating" stocks where strips are plated after press working. For example, connector stocks for wire harness mainly for in-vehicle use are largely pre-plated with Sn, while those for electronic components are mainly post-plated with precious metals. In these days, as the domestic automobile manufactures and automotive parts manufacturers make great strides worldwide, the demand for these plated products is rapidly expanding. Accordingly, Furukawa Electric is not the last to making and implementing plans to increase the production of these plated products.

Figure 9 shows the trends in the worldwide sales of automobiles. Whereas the number of sales in Japan goes sideways, that in the developing countries is still growing headed by China. On the other hand, in the electronics market both connectors and semiconductor devices are growing.

1) Ag-Plated Stainless Steel Strip

As mobile phones become sophisticated in functions and the strokes on the tact switches increase in number, there arises a requirement for improved reliability of contacts. This is particularly true for domestic mobile phones where electronic mails and games have rapidly proliferated. Conventionally for their contacts, stainless steel strips with or without Ni plating were broadly used. But, Ag-plated stainless steel strip came gradually into use to improve the contact reliability. Whereas the use was at first adopted only by domestic manufacturers which intended to rapidly advance in sophistication of mobile phones, it is recently gaining momentum among mobile phone manufacturers overseas, resulting in a rapid growth of demand for Ag-plated stainless steel strip. Furukawa Electric accordingly has been actively investing in plant and equipment aimed at expanding its production capacity.

Figure 10 shows the sales amount and rate of increase of mobile phones in the world.

It has been reported that stainless steel has very poor plating properties, so that it is allegedly difficult to form a plated coating of excellent adhesion. We have developed an Ag-plated stainless steel strip provided with superior adhesion, taking advantage of our proprietary technology based on the long-accumulated plating technology. Thanks to its high reliability, our products enjoy a domestic market share of more than 80 % accounting for a worldwide market share of more than 50 %.

2) Partially Precious Metal-Plated Strip

Partially precious metal-plated strips, in particular those

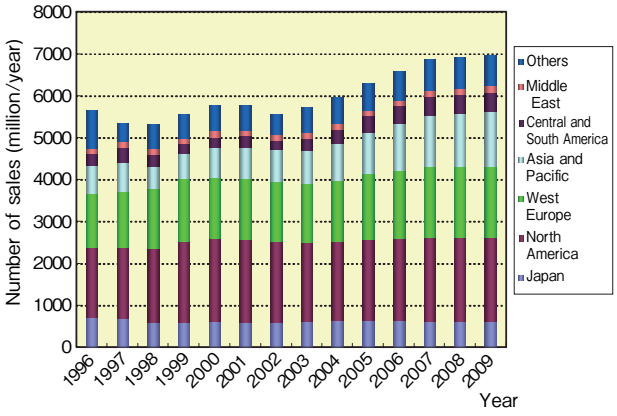


**Figure 9 Trends in the worldwide sales of automobiles.**

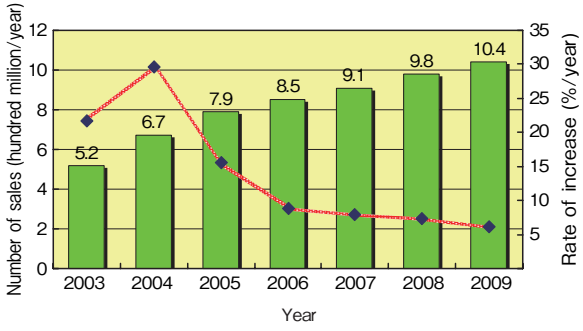


**Figure 10 Sales amount and rate of increase of mobile phones in the world.**

using Au, have been heavily used in heavy-duty electronic connectors for their high reliability. Recently, connectors based on Au plating are gradually being applied, due to their stabilized connection characteristics, to automotive safety systems such as ABS and air-bag equipment where Sn plating still constitutes the mainstream. Thus the use of Au-plated parts and connectors is rapidly growing because of the accelerated computerization of automotive equipment as well as of the worldwide business expansion of domestic automobile manufacturers.

Since precious metal plating is expensive, most of the products employ partial plating instead of whole plating, and in addition, since the price of precious metals is soaring in recent year, the shift from the stripe plating where metals are plated in stripes to the spot plating where plating is applied on contact points is being accelerated in order to save precious metals by minimizing the amount of use.

Furukawa Electric begins considering an increased production system for precious metal plating to cope with such an accelerated market growth. Furukawa's strong point is its consistent production system involving the raw materials and plating, which has resulted in the excellent bending workability of our products as shown in Figure 11.

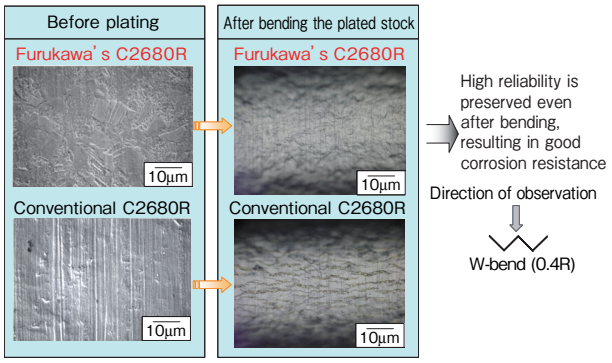


**Figure 11 Improvement in the minimum bending radius of C2680R.**

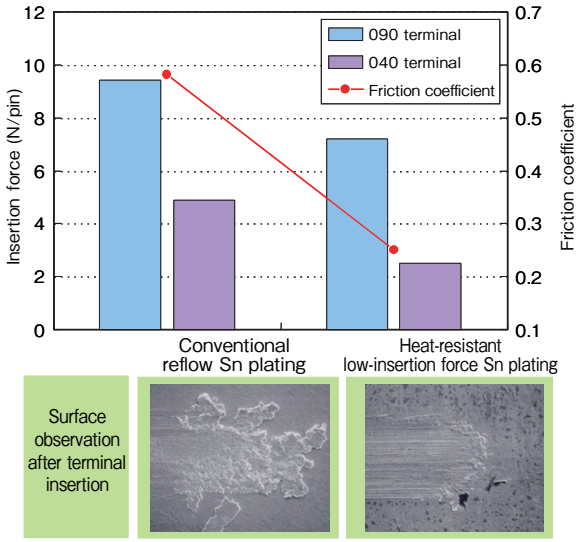


**Figure 12 Low-insertion force characteristics of typical materials.**

3) Sn-Plated Strip

Nearly all Sn-plated strips are currently used as a material for automotive terminals. The demand for this automotive terminal stock is expected to grow in future as the production of automobiles expands, while the need is anticipated to diversify as the computerization of automobiles proceeds along with the power hybridization.

Pb-free plating and reduction of insertion force are two major technological trends in Sn-plated strips. As for Pb-free plating, the shift from conventional solder plating to reflow Sn plating is being accelerated. With regard to insertion force reduction, there is an increasing requirement for reducing the surface friction coefficient as the terminals become downsized and multi-poled.

In anticipation of demand increase in the future, Furukawa Electric is planning to expand the production facilities for reflow Sn plating. As for the low-insertion force material, we have developed heat-resistant low-insertion force Sn plating, in which the insertion force is reduced and yet heat resistance is improved. Figure 12 shows the low-insertion force characteristics of typical materials.

### 3.2 Resin Coated Alloy Strip "Furukawa F-Coat"

As mentioned earlier, mobile phones are increasing in production volume worldwide. Domestically, despite the fact that they show a rather slow increase in number, they are improving in terms of functions and reduction in size and height. As a result, there is an urgent requirement for reducing the height of electronic parts in mobile phones.

A modular metal casing is used in every mobile phone to shield the noise generated by the electronic components used in phones. Conventionally, a sufficient clearance was provided between the casing and the components, posing no particular problems of insulation. Recently, however, the clearance became narrower, making it difficult to ensure ample electric insulation. Accordingly, a solution was proposed to coat a strip stock with resin, which was subsequently press-formed into a

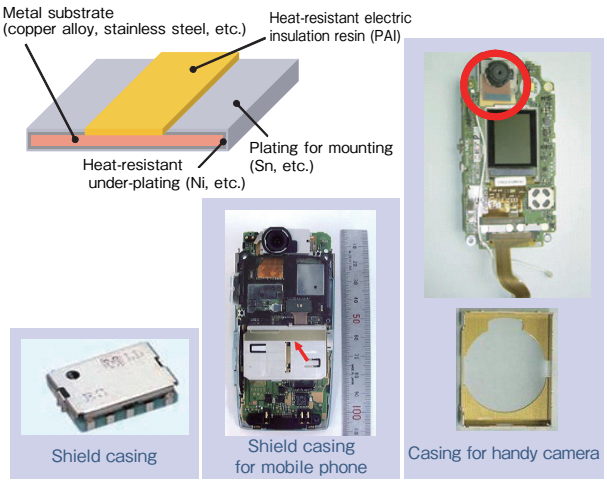


**Figure 13 Structure and typical applications of F-COAT.**

casing. In this way, a resin coated metal casing can be obtained readily, resulting in eliminating the clearance between the casing and the components, and hence realization of a low-profiled mobile phone.

Furukawa Electric has developed, using a proprietary technology that the Company has cultivated for the adhesion between metal and resin, a composite strip stock that offers sufficient resin adhesion against press forming. Moreover, taking advantage of our strong point as a material manufacturer, we can consistently manufacture from raw materials to final products, thereby making it possible to offer various products that are excellent in terms of quality, lead time and cost. The demand for the product is expected to grow in the future.

Figure 13 shows the schematic structure and typical applications of this product.

## 4. WIRE AND BAR PRODUCTS

Main products of wire and bar are experiencing some changes. For example, the copper-plated steel wire for lead wire use with a product name "EF wire" and the electrode wire for electric discharge machines with a product name "FULLACE" have decreased in the market price due to the inflow of low-priced products from overseas and the domestic overproduction. We have withdrawn from the domestic production of EF wire in 2001 on the occasion of a business merger with our affiliated company. As for FULLACE, we have introduced surface washing facilities for removing adhesive particles, in an effort to differentiate our products by reducing shutdown troubles of electric discharge machines.

We are strengthening our efforts to enter into the electronics fields for our wire products, by improving material properties and upgrading functions such as plating. With regard to property improvement, we are developing various precipitation-type alloys utilizing our alloy design technology that we have accumulated in the development of strip products. For example, EFTEC-194 W to be mentioned later has been adopted in a CPU of personal computers, making itself one of the main products of wire. In addition, whereas conventionally the wire for connector pins were used as solder-plated, we are specializing in tin-plated products in line with the Pb-free trend, and the products have been adopted as a pin stock for multi-pin connectors in various electric and electronic equipment.

As the electric and electronic equipment develop in performance decreasing in size and weight in the future, the materials used will advance toward smaller diameter and reduced thickness, raising requirements for materials of high strength and high electrical conductivity. We plan to develop materials that meet the market needs, thereby strengthening our business development into electronics-related fields. In terms of the cross-section shape of wires also, we plan to manufacture rectangular and specially shaped wires as well as conventional round and square wires in order to cover wide ranges of applications.

Our main products of bar include rectangular bars of tough pitch copper, oxygen-free copper and copper-silver alloy, together with round bars of copper-chromium alloy. Rectangular bars are used for bus bars, anodes for magnetron and rotor coils for motors. Copper-chromium alloy is mainly used for electrodes of resistance welding machines, and there is an emerging need for rectangular bars for rotor coil members of high-performance motors, exploiting the high-strength and high-conductivity property of the alloy. We are now promoting entry into the new market by launching various precipitation-type alloys in the same manner as for wire products.

We manufacture raw materials for both the wire and bar products in-house through melting, billet casting and hot processing. This makes our strong point because, while control of alloy components and structures at these upstream processes is essential for improving the properties of precipitation-type alloys, few manufacturers are able to implement these processes consistently.

Figure 14 shows the relationship between tensile strength and electrical conductivity of alloys for wire and bar products. Our main products of today and their applications will be described below.

### 4.1 Wire Products

1) EFTEC-194

EFTEC-194 W wire of our product 0.3 mm in diameter has been adopted as lead pins for the PGA package that is widely used in personal computer CPUs. This is a precipitation-type copper-iron alloy, where high bendability and high electrical conductivity is obtained due to the finely dispersed precipitates. Although Kovar (Fe-Ni-Co alloy) was conventionally used in such an application, a new material with higher electrical as well as thermal conductivity was needed as the operation speed of CPUs increased, and, accordingly, CDA19400 alloy with an established track record as a leadframe strip came to be used in this wire application. Since, in this application, demanding requirements are imposed not only for

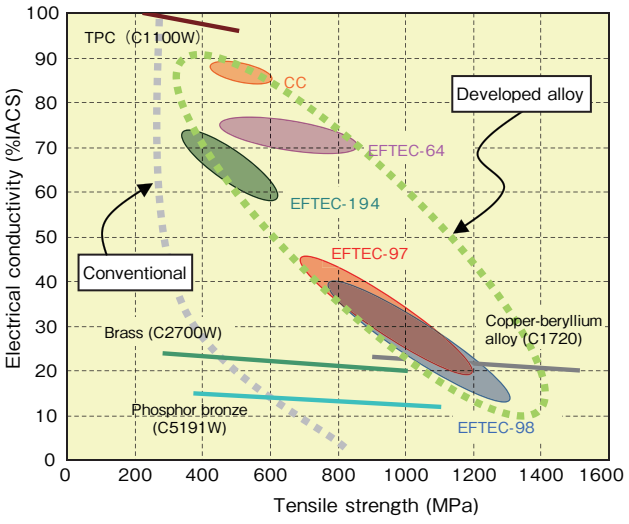


**Figure 14 Relationship between tensile strength and electrical conductivity of the developed wire and bar.**

strength and electrical conductivity characteristics but also for wire surface properties, we are developing manufacturing technologies such that the shape of the capstan in the drawing machine is designed in our proprietary way so as to prevent possible generation of minute defects during wire drawing.

2) EFTEC-98
Our EFTEC-98 BD wire 2～6 mm in diameter has been adopted as pins in the SMA female coaxial connector that is used in microwave communications. EFTEC-98 BD is our original alloy with a small amount of additive elements to the Corson alloy (i.e., a Cu-Ni-Si-based precipitation-type alloy with Ni-Si precipitates). Conventionally, free-cutting copper-beryllium alloy (CDA17300 alloy based on the Cu-Be-Pb system) and free-cutting phosphor bronze (JIS C5441 alloy based on the Cu-Pb-Sn-Zn-P system) were widely used for their superior properties in spring characteristics aging as well as in ease of fine cutting, but, since they contain hazardous Pb or costly Be, these alloys have been replace by EFTEC-98BD that is provided with the advantageous characteristics mentioned above in addition to strength and electrical conductivity.

3) Reflow Sn-Plated Square Wire
Reflow Sn-plated square wire is used as a connector pin stock. The base material is mainly brass or phosphor bronze, and the cross section is square 0.3～1.0 mm on a side. Reflow is intended for suppressing generation of whiskers specific to Sn plating, where the plating is melt once and subsequently solidified. A uniform distribution of plating has been obtained thanks to our proprietary reflow technology.

### 4.2 Bar Products

1) Copper-Chromium Alloy
Our rectangular bar of chromium-containing copper has been adopted in the rotor coil of the motor for the N700 Shinkansen. Copper-tin alloy and copper-silver alloy conventionally used have been substituted by copper-chromium alloy with superior electrical conductivity and fatigue properties.

2) EFTEC-98
EFTEC-98 BD 13 mm in diameter has been adopted in the bushing for the needle sliding shaft of an industrial high-speed sewing machine. Conventionally, since the bushing is oil-free to keep the sewn clothes clean, copper-beryllium alloy (CDA17200 alloy based on the Cu-Be system) has been used for its superior seize resistance against steel shaft and wear resistance. EFTEC-98 BD is superior to the CDA17200 alloy in terms of thermal conductivity and heat-dissipating property in addition to seize resistance due to its dense metallographic structure, and it has been confirmed that the shaft and the bushing have achieved a longer service life.

## 5. ELECTRODEPOSITED COPPER FOIL PRODUCTS

Copper foil is one of the major constituting materials for printed circuit boards, and it comes in two types: electrodeposited type and rolled type.

Electrodeposited copper foil is manufactured in such a way that a cylindrical titanium drum is used as the cathode, and its surface is copper plated during rotation, the resultant plated layer of copper is continuously peeled off to be taken up in a roll. In contrast, rolled copper foil is manufactured by repeatedly rolling a rectangular ingot of copper a number of times.

The electrodeposited copper foil is, due to such a difference in the manufacturing methods and in comparison with the rolled copper foil, characterized by its ease of manufacturing relatively thin foils and is manufacturable in large widths exceeding 1 meter, so that it is widely used in the printed circuit boards in a variety of applications.

With its history of more than 30 years as an electrodeposited copper foil manufacturer, Furukawa Circuit Foil Co., Ltd. is developing and releasing various new applications of copper foil targeted at flexible circuit boards, build-up multilayer boards, semi-additive circuit boards and circuit boards with embedded passive components, as well as conventional rigid printed circuit boards.

Moreover, the company is expanding its sales targets at different industries including not only printed circuit boards but also negative electrode copper foil for lithium ion batteries and electromagnetic shielding copper foil for PDPs.

Table 2 summarizes our main products of electrodeposited copper foils and their technological characteristics.

## 6. Ni-Ti ALLOY

### 6.1 Ni-Ti Alloy Products

It is well known that Ni-Ti alloy has the shape memory and super-elastic characteristics, so that a variety of applications have been developed so far. On the other hand, with its rather short history of around 40 years, it may be called a very young alloy when compared to other ordinary alloys. Its transformation temperature can be arbitrarily changed between a range of 0～100°C by controlling the atomic composition of Ni-Ti around a point of 50:50. Products whose transformation temperature is below room temperature and which are used at room temperature are super-elasticity products, while those whose transformation temperature is above room temperature and which take advantage of the shape recovery effect when heat is applied are shape memory products.

The Ni-Ti alloy is superior to other shape memory alloys in terms of shape memory properties, workability and corrosion resistance, so that it dominates in practical applications.

It may be said that Ni-Ti alloy products belong to a class of typical development-oriented products, where it is essential how to make its new functions develop into new applications. This presents a challenging problem for

**Table 2 Types and characteristics of electrodeposited copper foils.**

| Category | Main uses | Surface treatment | | Foil type | Thickness (μm) | Features and advantages |
|---|---|---|---|---|---|---|
| Printed circuit board copper foil | Two-layered flexible circuit board<br>Package circuit board | One side | F0<br>F1<br>F2<br>F3 | WS | 9<br>12<br>18 | ・Low surface roughness resulting in ease of fine pattern forming<br>・High adhesion with resin<br>・Superior bending resistance |
| | LCD polymer circuit board<br>High-frequency circuit board | One side | FWL | WS | 9<br>12<br>18 | ・Low surface roughness resulting in ease of fine pattern forming<br>・High adhesion with resin<br>・Superior radio frequency characteristics |
| | Chip on film (COF)<br>High-frequency circuit board | One side | U | WZ | 9<br>12<br>18 | ・Lower surface roughness than F-WS foil resulting in ease of fine pattern forming and superior high-frequency characteristics<br>・High adhesion<br>・Superior bending resistance |
| | Multilayer circuit board<br>High-density multilayer circuit board<br>Build-up circuit board<br>Tree-layer flexible circuit board | One side | GTS | STD<br>MP | 9<br>12<br>18<br>35<br>70 | ・High adhesion with resin<br>・Superior heat resistance |
| | Large current circuit board<br>Heat-dissipative package circuit board<br>Automotive circuit board | One side | GTS | STD | 105<br>140<br>175<br>210 | ・High adhesion with resin<br>・Superior heat resistance |
| Copper foil for build-up multilayer circuit board for mobile phones | Any Layer Interstitial Via Hole (ALIVH †) substrate | Both sides | GLD | STD | 9<br>12<br>18 | ・Both sides roughening treated achieving high-reliability bonding<br>・ Both sides roughening treated suppressing copper powder dropping |
| Ultra-thin peelable copper foil with copper carrier | Package circuit board<br>Fine pattern circuit board | With carrier | F<br>U<br>FWL | DP<br>HP<br>HP | 1<br>3<br>5<br>9 | ・Ultra-thin peelable layer 1~9 μm in thickness is formed on carrier copper foil<br>・Ultra-fine pattern can be formed<br>・Stabilized carrier peel strength<br>・HP type is peelable even after hot processes of 300°C |
| Copper foil with resistance layer | Mobile electronic equipment circuit board for mobile phones, etc. | One side | FR | WS | 12<br>18 | ・Copper foil with electrical resistance layer on the surface<br>・Used in circuit boards with embedded passive components eliminating conventional external resistors |
| Negative electrode copper foil for lithium ion batteries | Negative electrode for lithium ion batteries | – | NC | WS | 6<br>8<br>10<br>15<br>20 | ・Smooth surface for both sides<br>・Large elongation<br>・Superior bending resistance |
| Electromagnetic shielding copper foil for PDPs | Electromagnetic shielding for PDPs | One side | B | WS | 10 | ・Black surface treatment for luxury goods<br>・Low surface roughness resulting in ease of grid pattern forming |

† ALIVH is a registered trade mark of Matsushita Electric Industrial Co., Ltd.

manufacturers, which is a source of concern, i.e., the short life cycle of products. Thus, our main products in the past 20 years went through changes from core wire for women's brassiere to whip antenna for mobile phones. Currently, we are promoting product development specifically targeted at our new entry area of medial applications while pushing forward the sales of spring stocks and eyeglass frame stocks.

### 6.2 Problems at Manufacturing Processes

1) Property Control

The composition of Ni-Ti alloy exerts a strong influence on the transformation temperature, such that a variation of 0.1 at % in alloy composition results in a transformation temperature difference of about 10°C. Since the causative factors include fluctuation in composition ratio and impurity levels such as carbon and oxygen, it is essential to control the casting conditions including degree of vacu-

um. We use a vacuum induction furnace melting (VIM) furnace in the melting and casting process for Ni-Ti alloy, thereby managing the alloy compositions depending on application.

2) Workability

Since Ni-Ti alloy is an intermetallic compound, its workability is very low thus presenting many manufacturing problems. During cold working, the reduction ratio between annealing has to be held at approximately 40 % since the workability is deteriorated due to work hardening. A 12-stand hot rolling machine based on three-roll mill that was introduced in 1997 helped us a great deal to improve the productivity, significantly contributing to the sales promotion of the mobile phone antennas mentioned before.

In addition to this low workability, the shape memory and super-elastic properties also cause manufacturing problems, whereby the materials once processed try to recover their original configurations. This causes many problems such as difficult drawn wire size control, poor machinability and configuration changes during annealing. For these reasons, dedicated facilities are used in the production line, excluding general Ni products.

### 6.3 New Applications of Super-Elasticity in the Medical Treatment Area

It can be said that the applications of Ni-Ti alloy in the medical treatment area are the best suited ones, since the applications utilize the body temperature within the human body, being simultaneously helped by the superior biocompatibility and corrosion resistance of Ni-Ti alloy. Recent years have seen various application developments of this superior super-elasticity in the medical treatment area centering on Europe and the United States. Their social background comprises hardened arteries caused by high-calorie meals and piled-up stress from the modern society, in addition to the medical treatment developments for vascular diseases represented by brain infarction. Recently, the medical treatment has made a remarkable progress making a shift from the abdominal operation-based techniques conventionally used to the modern interventional techniques with improvements in health impact and biomedical impact, which include guide wire, catheter, stent, etc. Biomedical treatment devices using the super-elastic effect of Ni-Ti alloy are under development also outside of vascular diseases, so that it is expected that the technology develops further.

On the other hand, there have been concerns about the biomedical safety of Ni-Ti alloy such as nickel allergy and the fact that nickel is a target substance of environmental regulations. However, with its low solubility comparable to that of stainless steel, the biomedical safety of Ni-Ti alloy is known to be sufficiently high. In Europe and the United States, in case of medical applications, compliance validation to the new standard ASTM-F2063 is oftentimes required. Thus, study on the biomedical safety of Ni-Ti alloy is advancing.

1) Guide-Wire for Medical Treatment

Guide-wires for medical treatment utilizing super-elasticity are required to provide stiffness, straightness and torque transmitting abilities in order to smoothly pass through the complicated vascular system of the human body. Ni-Ti alloy wires have heretofore been employed since they outperform stainless steel wires in these respects. A new product called FHP-NT (see Figure 15-1) that does not show stress plateau has been developed to achieve higher pushability and superior torque transmitting abilities.

We have developed in-house the manufacturing equipment for FHP-NT, and this has led to acquiring new customers. Moreover, we have additionally installed the same type of equipment, thereby successfully increasing the product variations in size and strengthening the production capacity. With regard to the guide-wire of conventional super-elasticity type (see Figure 15-2), we are strengthening our unique technologies since we are having more advanced product requirements as the medical treatment technology advances in recent years.

2) Ni-Ti Alloy Tube

Although Ni-Ti alloy is generally described as less workable, tubes $\phi$ 10 ~ $\phi$ 0.3 in diameter have come to be manufacturable in recent years (see Figure 16). And, using Ni-Ti alloy tubes, various medical treatment devices have

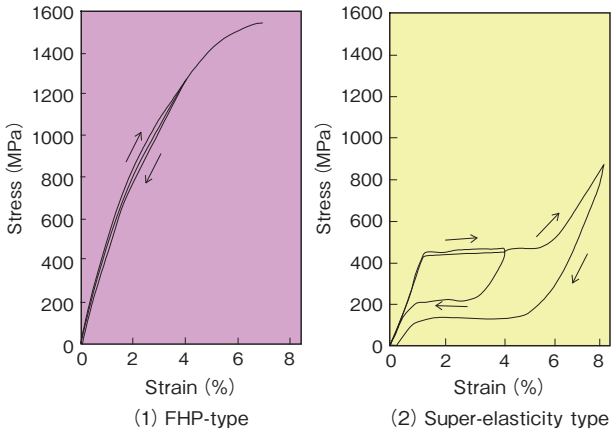


**Figure 15 Property of guide-wires.**

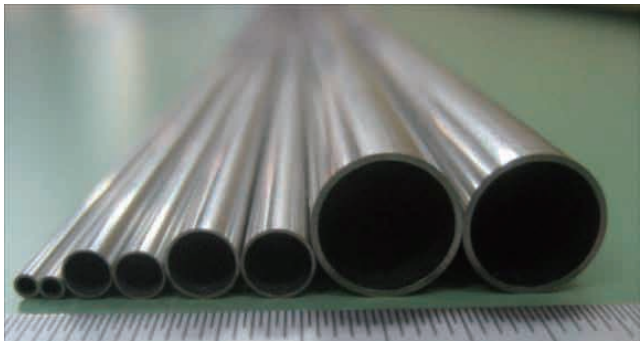

**Figure 16 Ni-Ti tubes.**

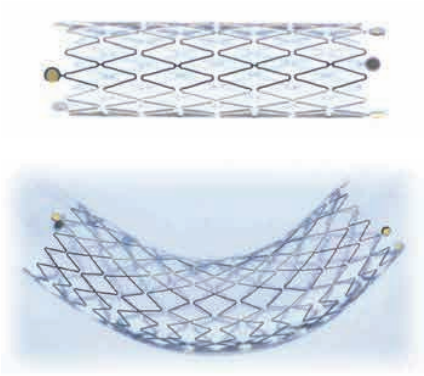

**Figure 17 Appearance of stent made of Ni-Ti tubing. (By courtesy of Biotronik GmbH&Co)**

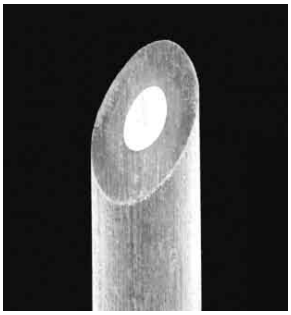

**Figure 18 Cored wire.**

been developed and released including catheter, stent (see Figure 17), reamer, etc. In order to meet the stringent requirements for Ni-Ti tubes with respect to the wall thickness uniformity and the outer- and inner-diameter tolerances, process management that is more complicated than that for wires is needed, and this leads to overcoming the manufacturing difficulties due to super-elasticity property. To cope with such problems mentioned above, it is indispensable to introduce new facilities and to develop new technologies. We are also proactively introducing the improvement promotion activities, which contributes a great deal to productivity improvement.

3) Cored Wire

When a doctor performs an external operation using an X-ray display as is the case with catheter operation, the transmissivity of the guide-wire has to be high as much as possible. For this purpose, an alloy wire containing additive elements for transmissivity improvement has been developed together with the cored wire having a core of platinum or gold, an application of tubing technology, as shown in Figure 18.

## 7. CONCLUSION

We have presented here electronics-related metal products of Furukawa Electric Group.