Technical Report

Newly Developed High Reliability Bonding Wire for Semiconductor Packaging

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Abstract

The electrical interconnection between semiconductor chip and outer lead is commonly made by bonding wire. For the past fifteen years, the shift from Au to low-cost materials such as Cu and Ag wires has progressed considerably. Especially, Pd coated Cu (PCC) wire is widely used in consumer devices now. However, the PCC and Ag wires are still not widely used in the automotive industry due to the reliability limitations under high temperature conditions. We have developed the new PCC wire (EX1R) and Ag alloy wire (GX2s) with long-term bond reliability under severe high temperature conditions.

1. Introduction

As personal computers, LCD TVs, and smartphones have shown, electronic devices are becoming smaller, thinner, more sophisticated, and more multifunctional. Consequently, there is mounting demand for larger and more highly integrated large scale integrated circuits (LSIs), which are essential for the progress of electronic devices, and for smaller electronic components, multi-layered boards, and higher density packaging of entire mounting boards, such as ultrafine copper wiring. In addition, hybrid electric vehicles (HEVs), electric vehicles (EVs), and new automobile technologies such as autonomous driving are rapidly evolving. In-vehicle LSIs that electronically control these vehicles are expected to lead to greater electronic component demand and higher reliability.

Figure 1 schematically illustrates the internal structure of an LSI package. The LSI package is mainly composed of metals (bonding wires, electrodes, solder balls), resins (substrates and sealing resins), and ceramics (fillers contained in sealing resins). Among these materials, bonding wires are used to transmit the functions of semiconductors to the outside. Wire bonding technology is extensively applied as the packaging technology for semiconductors. The wire bonding process is shown in **Fig. 2** and is explained below according to the numbers in the figure.

(a) Ball formation
The tip of the bonding wire is melted by arc discharge, and the action of surface tension produces a spherical ball.

(b) Ball bonding
The formed ball is thermally bonded to an Al pad on the chip by using a cylindrical bonding tool called a capillary and by applying ultrasonic waves and load. At this time, the Al pad is heated to about 150 to 250°C using the heating stage below. In this step, the ball and Al pad are bonded by solid-phase diffusion.

(c) Looping
The capillary rises to the height of the loop and moves to the external terminal side. This movement of the capillary curves the bonding wire and forms a loop, as shown in Fig. 2 (c).

(d) Wedge bonding
The capillary pushes the bonding wire against the external terminal. Then, ultrasonic waves and load are applied to thermocompression bond (wedge bond) the ball to the external termi-

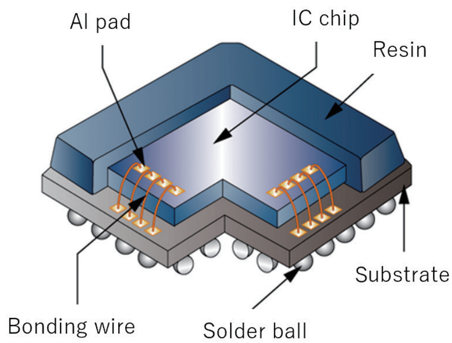

Fig. 1 LSI package

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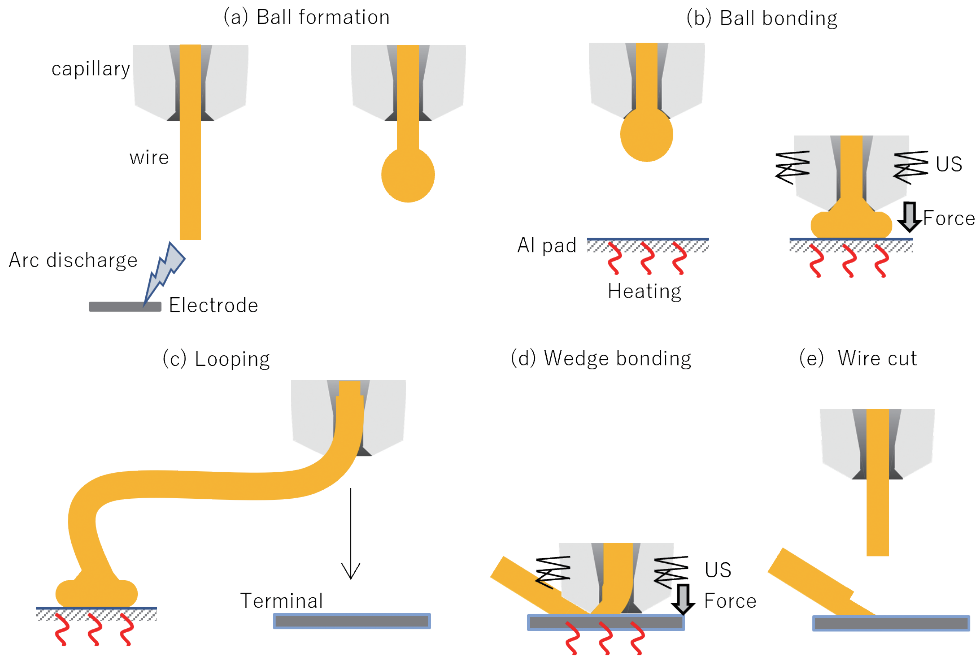

Fig. 2 Wire bonding process

nal.

(e) Wire cutting

The wire clamp closes, and the capillary rises to cut the bonding wire. After that, a new ball is formed at the fresh end of the bonding wire that is sheared by arc discharge, and the bonding wire moves to the next bonding process.

This series of steps is repeated at a high speed of less than 0.1 s per wire. When we consider mass production technology for bonding wires that can withstand such a complex process, it is essential to have property control technology for controlling the sphericity of the balls and the diffusion and metal bonding conditions of the mutual constituent materials at the bonding interface, ensuring both the stable bending deformation and alignment of wires during high-speed loop formation, and controlling the failure rate to an order of less than several tens of ppm.

Since the development of wire bonding technology, chemically stable gold (Au) has been used as the material for bonding wires. Against the background of skyrocketing Au prices, however, the trend of moving away from Au has accelerated significantly over the past 15 years. In 2007, Au wires accounted for almost 100% of the total bonding wire shipment volume by type of wire material. In 2022, this share significantly dropped to 29%.[1] This disuse of Au is mainly accounted for by the technological innovation of copper (Cu) wires, especially palladium (Pd) coated Cu (PCC) wires. Compared to Au, Cu is lower in cost and has higher electrical conductivity and thermal conductivity. For these reasons, Cu wires have been studied from the beginning as the first candidate material to replace Au wires. However, single-phase Cu wires (hereinafter referred to as bare Cu wires) have the weakness of being easily affected by oxidation during storage in the atmosphere and the bonding process. Furthermore, it was not easy to ensure their long-term reliability after mounting together with various other components. PCC wires were developed to solve these technical issues.[2,3] **Figure 3** shows cross-sectional SEM backscattered electron images of a typical PCC wire. Figure 3 (a) shows the entire cross-section of the wire. Figure 3 (b) shows an enlarged image of the top surface region of the wire as enclosed in the red frame in Fig. 3 (a). The white contrast in Fig. 3 (b) corresponds to Pd. The PCC wire is characterized by a Pd coating layer several tens of nanometers (nm) thick on the surface of the Cu wire with a diameter of several tens of micrometers (μm). The EX series PCC wires of Nippon Micrometal Corporation have excellent oxidation resistance, bondability, and long-term reliability. They are already being used in consumer electronic and information devices such as cutting-edge personal computers and smartphones. Also, PCC wires themselves have been improved and refined. Compared to the first generation (EX1) of PCC wires, the second generation (EX1p) of Au PCC wires or PCC wires coated with extremely thin Au to improve their bondability are now used as principal bonding wires. In this report, PCC wires and Au PCC wires are collectively referred to as PCC wires. **Figure 4** schematically shows the main wire structures.

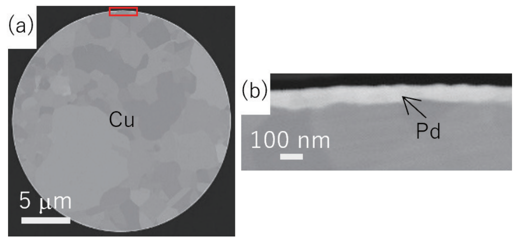

Fig. 3 (a) Cross-sectional SEM images in PCC wire, (b) Enlarged image for coating layer

In addition, the use of Ag wires and Cu wires is also prevalent to support the shift away from Au. Compared to Cu, Ag has a lower Young›s modulus, lower hardness, and higher reflectance in the short wavelength range. Taking advantage of these excellent properties, Ag has now become a principal candidate material to replace Au in memory device and LED applications. In order to increase the capacity of memory devices, multiple chips thinned to several tens of micrometers are laid in multiple stacks. The stacked structure

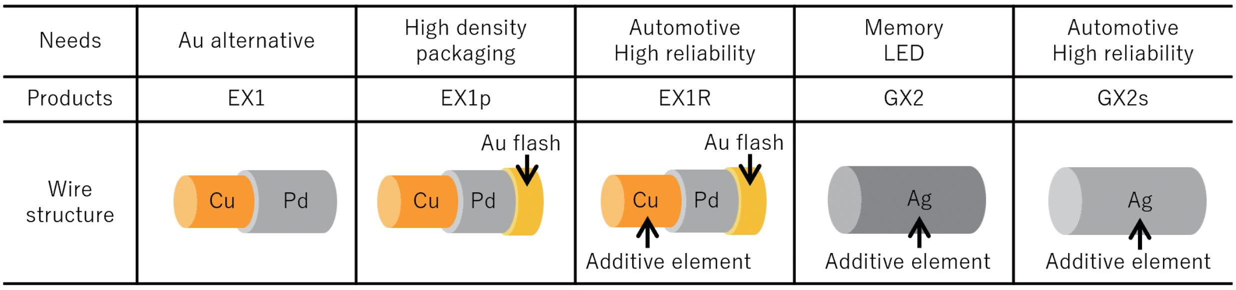

Fig. 4 Schematic images of wire

contains some partially hollow chips. Wires must be bonded to such unstable chips continuously and without damaging the chip (**Fig. 5**).[4)] Ag wires are softer than Cu wires and are more easily deformed when they are bonded to the chips. Therefore, they can be bonded under conditions similar to those of Au wires and minimize the impact of damage to the semiconductor chips. However, pure Ag wires have the disadvantage of poor corrosion resistance in high-temperature and high-humidity environments, making it difficult to put them to practical use in such environments. Conventional technology improved the corrosion resistance of pure Ag wires by alloying them with an element in a high concentration of 5 to 12 atomic%. At the same time, this alloying is accompanied by an increase in electrical resistance, making it difficult to apply pure Ag wires to cutting-edge memory devices that require high-speed communication. The application of pure Ag wires was limited accordingly. Nippon Micrometal Group worked on new alloy designs and developed and mass-produced new Ag wires (GX series) that combine low resistivity equivalent to that of Au wires with long-term reliability in high-temperature and high-humidity environments.[5)]

As described above, the use of PCC wires and Ag wires as alternatives to Au wires in consumer and information equipment LSI semiconductor packages is rapidly progressing. On the other hand, many Au wires are still widely used in the mounting technology of in-vehicle semiconductors. In recent years, the number of semiconductors installed per vehicle has been increasing with the trend toward the vehicle electronification. Obviously, even if the number of in-vehicle semiconductors increases, the failure rate of semiconductors must be kept as close to zero as possible because they must be responsible for human lives in the severe operating environment of vehicles exposed to high temperature, high humidity, and high vibration. Consequently, the replacement of Au with stable characteristics by other materials has not advanced much in in-vehicle applications that require high quality and long-term reliability.

In order to improve the reliability of semiconductor packages, we must improve their resistance to external stress, increase their tolerance, and clarify and counter the factors that lead to their failures. Most semiconductor packages are long-lasting under normal use conditions, so it takes years to check their lifespan and determine the causes of their failures. Therefore, measures are taken to prevent failure modes by increasing the above stresses, accelerating the occurrence of potential failures, and facilitating the identification of the causes of failures. Measures are consequently implemented to prevent the identified failure modes. Typical accelerating factors for semiconductor packages are temperature and humidity. Environmental stress tests are performed under such accelerated conditions. In the environmental stress test standards for automotive electronic components (AEC-Q100 and AEC-Q006), the operation guarantee temperature is divided by grade, and environmental stress test conditions are set according to the respective operating temperature grades. For Grade 0 (−45 to 150°C) with the highest guaranteed temperature, the example of the high-temperature storage life (HTSL) test is used to determine long-term reliability under high-temperature conditions. In the HTSL test, 2000 h high temperature and long-term conditions are set under the 175°C heat treatment. As such, environmental stress tests become longer in time and higher in temperature, and bonding wire failure modes that have not previously appeared in environmental stress tests for consumer semiconductor applications have been reported.

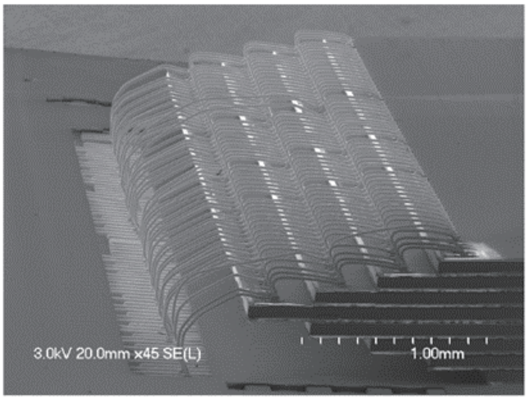

Fig. 5 SEM image of wire bonded multi-stack die[4)]

In order to satisfy the stringent requirements for in-vehicle semiconductor packages, Nippon Micrometal Group has established unique technologies for alloy design, coating design, and manufacturing process optimization. It has succeeded in the development of new PCC wires EX1R[6, 7)] and new Ag alloy wires GX2s[8)] that ensure long-term reliability. The performance of these new wires is introduced below.

2. Highly Reliable Pd-coated Cu Wires EX1R

2.1 Evaluation method

For performance evaluation, three types of wires were used: the newly developed EX1R wires, and the conventional PCC wires and bare Cu wire for comparison. The main feature of EX1R is that it contains an additive element in the Cu core material to improve the bonding reliability (Fig. 4). The addition of the additive element to the Cu core material may increase the resistivity, increase the wire hardness, deteriorate the free air ball (FAB) sphericity, and worsen the wedge bonding performance. The additive element of EX1R was selected on the premise that it would not degrade the practical performance. On that basis, the additive element content is adjusted so that the resistivity of EX1R becomes 3.0 $\mu\Omega$cm. This resistivity is the same as the 3.0 $\mu\Omega$cm resistivity of 2N (99% pure) Au wires used in the in-vehicle application and is acceptable for substitute use. Test element group (TEG) test chips were used. The composition of Al pads on the TEG is Al-1%Si-0.5%Cu, and their thickness is 1.5 μm. The package type was a 144-pin quad flat package (QFP), and a Ni/Pd/Au plating was selected for the lead frame surface to ensure stable reliability. A general automatic wire bonder (ProCu, Kulicke & Soffa) was used for wire bonding. As the environmental stress test for evaluating high-temperature and high-humidity resistance, a highly accelerated stress test (HAST) was conducted at 130°C, 85% RH, and 3 V bias. In the HAST, wire-bonded samples were sealed with an epoxy resin containing a large amount of Cl, which is one of the causes of defects, for the purpose of accelerating the test conditions (pressure extraction analysis: Cl^- = 21 ppm, SO_4^{2-} < 1 ppm, pH = 6.7). As the environmental stress test for evaluating high-temperature resistance, the HTSL test was performed at 175°C. A conventional sealing resin (pressure extraction analysis: Cl^- = 4 ppm, SO_4^{2-} < 1 ppm, pH = 6.8) was used.

2.2 High-temperature and high-humidity resistance

Figure 6 shows the change in the bond strength of Cu ball/Al pad joints in the respective samples every 48 h of the HAST. The wire diameter is 18 μm for each of the three evaluation levels. A ball shear test measured the bond strength after removing the sealing resin using a laser and a mixed acid. The bond strength of the bare Cu wires rapidly decreased immediately after the start of the test. A clear decrease in the strength of the conventional PCC wires was confirmed after 192 h, indicating the superiority of the conventional PCC wires over the bare Cu wires, as in a previous study.[2)] The average bond strength of the EX1R wires after 240 h remained at more than 80% of the initial value. This result indicates that the bond reliability is significantly improved compared to the conventional PCC wires. **Figure 7** shows the cross-sectional SEM images and Pd ele-

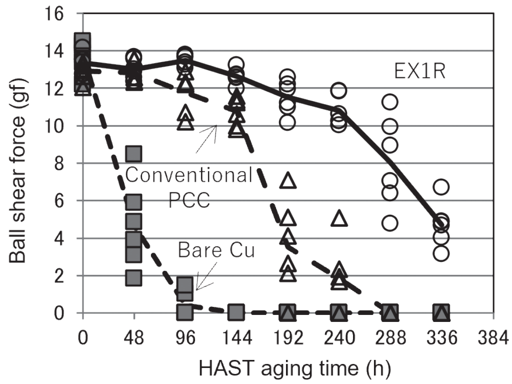

Fig. 6 Change of ball shear force at Cu ball/Al pad in HAST

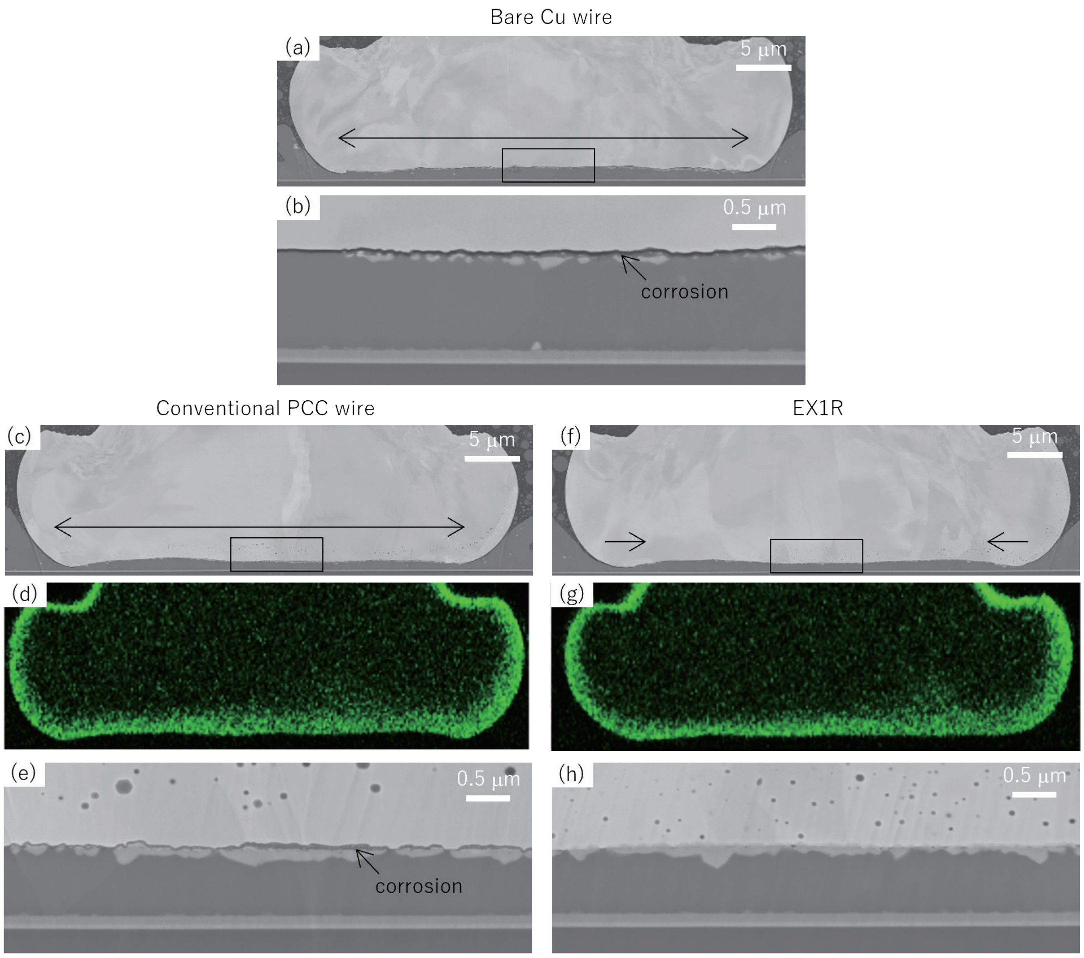

Fig. 7 Cross-sectional SEM images and corresponding Pd EDS mappings at Cu ball/Al pad area, and enlarged SEM images (b), (e), and (h) for area indicated by area in (a), (c), and (f) after HAST 192 h

ment mapping images of the Cu ball/Al pad joint for each sample after 192 h of the HAST. The arrows in Figs. 7(a), (c), and (f) indicate the width of the corrosion that had progressed in the joint. Figures 7(b), (e), and (h) are enlarged images of the regions enclosed in quadrangles in Figs. 7(a), (c), and (f), respectively. The bare Cu wire and conventional PCC wire had a corrosion layer formed over the entire joint at the Cu ball/Al pad interface, and Cl was detected from the corrosion layer. On the other hand, the EX1R wire had some corrosion confirmed at the outer periphery of the joint, but a good joint condition was maintained at the center of the joint. **Figure 8** shows a TEM image of the corrosion region at the outer periphery of the joint of the EX1R wire and element mapping images of the corresponding region.[9, 10] Pd tended to concentrate slightly in an inter-metallic compound (IMC). The additive element added to the Cu core of the EX1R wire was detected in a higher concentration near the interface between the Cu-Al IMC and the Cu ball than in the surrounding region.

Why PCC wires are superior to bare Cu wires in a high-temperature and high-humidity environment is described in a previous study.[3] Pd is concentrated in the IMC formed at the Cu ball/Al pad joint. This concentrated Pd layer suppresses the interdiffusion of Cu and Al and forms corrosion-resistant Cu-Al-Pd compounds and CuPd solid solutions, thereby improving joint reliability. On the other hand, as shown in Fig. 7, there is no significant difference in the Pd distribution at the joint between the conventional PCC wire and the EX1R wire. Still, significant differences are confirmed in the shear strength reduction and corrosion progress. This finding suggests that not only Pd, but also the additive element added to the Cu core material, which is a feature of the EX1R wire, are effective in inhibiting the corrosion reaction. The additive element added to the EX1R wire was detected at a higher concentration near the IMC-Cu ball interface than in the surrounding region near the interface between the IMC and Cu ball (white arrow in Fig. 8). The region where the added additive element is concentrated coincides with the tip where corrosion progresses at the Cu ball/Al pad joint interface.[11] It is considered that the additive element added to the Cu core of the EX1R wire forms a stable oxide film containing the added additive element that has Cl resistance during the corrosion process of the IMC (selective dissolution of Al) and improves the corrosion resistance by suppressing the dissolution of Al. EX1R wires were confirmed to have excellent high-temperature and high-humidity resistance even in resins that contain a relatively high concentration of Cl.

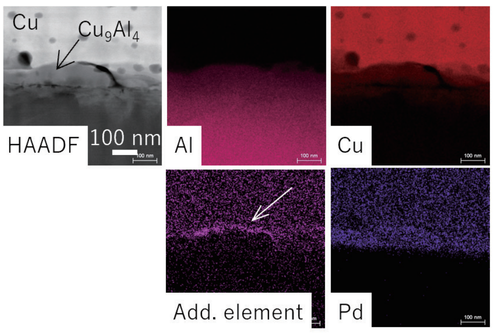

Fig. 8 Cross-sectional TEM image and corresponding EDS mappings obtained from Cu-Al IMC in EX1R

2.3 High-temperature resistance

Figure 9 shows changes in the bond strength of the Cu ball/Al pad joint for the respective samples at 175°C and every 1000 h in the HTSL test. The wire diameter is 20 μm for each of the three evaluation levels. The bare Cu wires exhibited a clear decrease in strength after 2000 h. After 3000 h, a ball lift or the separation of the ball from the Al pad occurred when the resin was removed. The conventional PCC wires maintained their initial bond strength even after 2000 h, but their bond strength was confirmed to decline gradually after 3000 h. The EX1R wires maintained sufficient bond strength even after 4000 h. It was confirmed that the EX1R wires can maintain the long-term reliability of the Cu ball/Al pad joints not only in the high-temperature and high-humidity environment described in the previous section, but also in a high-temperature and long-term environment.

Figure 10 shows cross-sectional SEM images of wedge joints at 175°C and after 3000 h in the HSTL test. Figures 10(c) and (e) show enlarged images of the corresponding boxed regions in Figs. 10(b) and (d), respectively. As shown in Fig. 10(a), no peculiar structure was observed in the bare Cu wire. In the conventional PCC shown in Fig. 10(c), the formation of voids several micrometers in size was confirmed near the outermost surface of the region where the wire was significantly deformed by wedge bonding. On the other

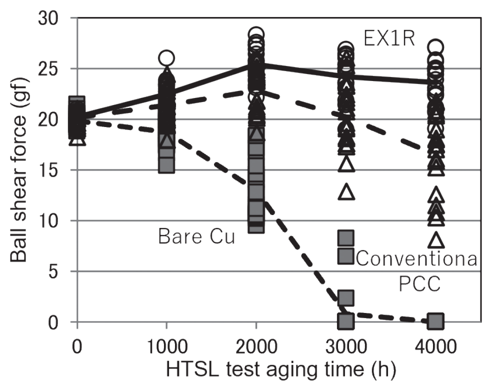

Fig. 9 Change of ball shear force at Cu ball/Al pad in HTSL test at 175°C

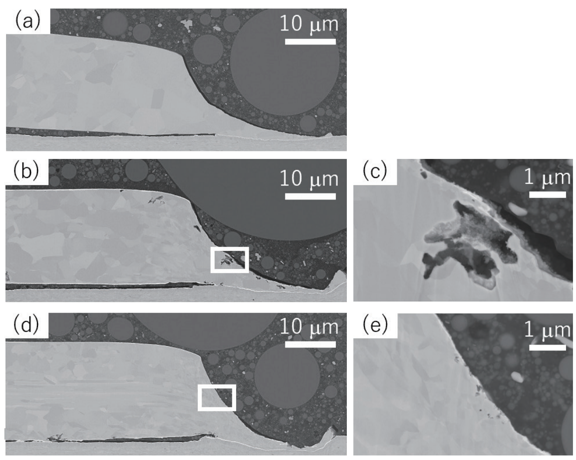

Fig. 10 Cross-sectional SEM images (a) bare Cu wire, (b) conventional PCC wire, (c) enlarged SEM image indicated by area in (b), (d) EX1R, (e) enlarged SEM image indicated by area in (d) after HTSL test at 175°C for 3000 h

hand, in the EX1R wire, very small voids were confirmed at the wedge bond, but no coarse voids were confirmed in a wide field of view across the wire region (Figs. 10(d) and (e)).

The void formation shown in Fig. 10(c) has not been reported for PCC wires in HTSL tests conducted at 150°C or less for consumer electronic and information device package applications. On the other hand, similar void formation has been reported for PCC wires in HTSL tests for automotive applications.[12, 13] Nippon Micrometal Group has evaluated the effects of the presence or absence of the sealing resin and of the HTSL test atmosphere (air or vacuum) in greater detail, identified the factors influencing the formation of Cu voids, and considered the failure mechanism.[7, 14] The corrosion process involved is schematically illustrated in **Fig. 11** and summarized below.

(a) In the PCC wire, the Pd layer is partially lost in the wire drawing and wedge bonding processes, and the underlying Cu is exposed.

(b) In a high-temperature environment, H_2O, O_2, and S-based gas are released from the sealing resin and are condensed to form a water film. The water film electrically connects the exposed Cu region and the Pd layer.

(c) The cathodic reaction by oxygen reduction occurs on the surfaces of both Cu and Pd. However, because Cu is less noble than Pd, the underlying Cu is selectively dissolved by the anodic reaction.

(d) As the Cu void deepens, Cu^{2+} ions are concentrated in the deepest region, and the pH decreases due to hydrolysis. Furthermore, the S gas released from the resin as outgas dissolves in the water film and forms SO_4^{2-}. The SO_4^{2-} ions are concentrated in the Cu void and generate sulfuric acid. Sulfuric acid inhibits the formation of an oxide film, accelerates the dissolution of Cu, and enlarges the Cu void.

At temperatures below 150°C, the amount of sulfur outgas from the sealing resin is small, and the reaction rate is also low, so this failure mode is not considered to appear. Unlike the corrosion produced in the IMC at the Cu ball /Al pad interface, this failure mode occurs inside the Cu wire. It does not appreciably affect the electrical properties of the semiconductor itself. Still, there are concerns about reduced bond strength and an appearance problem. The cause of this corrosion reaction or the loss of the Pd layer on the PCC wire surface originates in the wire bonding process and is difficult to address. The reduction of the amount of sulfur compound, which is another responsible factor, is expected to suppress the corrosion reaction. On the other hand, however, there is a concern that the adhesion between the organic components in the sealing resin and the filler or chip/lead frame interface may decrease. Since there is a trade-off between reducing corrosion and improving adhesion, it is necessary to control the amount of sulfur compounds in the sealing resin appropriately. On the other hand, the same failure mode was not confirmed with bare Cu wires. A Cu oxide film exists on the surface of the bare Cu wire, making it difficult for the oxidation-reduction reaction to proceed on the surface. Even if the wire surface is damaged in the wire bonding process, a Cu oxide film is quickly formed and is considered to inhibit the progress of local corrosion into the bulk, even in a high-temperature environment. However, bare Cu wires are poor in corrosion resistance of the Cu-Al IMC formed at the Cu ball/Al pad joint in a high-temperature environment. This condition makes it difficult to practically use the bare Cu wires in applications where high reliability is required (Fig. 9).

As shown in Fig. 10(d), the degree of localized corrosion in the EX1R wires has been improved to the same level as the bare Cu wires. As with the improvement of high-temperature and high-humidity resistance, the EX1R wire is a product that aims to improve the inhibition of Cu localized corrosion from the wire side by adding the additive element to the Cu core material. TEM analysis revealed that the additive element forms a thin corrosion-resistant oxide film as the localized corrosion of Cu proceeds (**Fig. 12**).[10] This action inhibits the dissolution of Cu, leading to improved corrosion resistance.

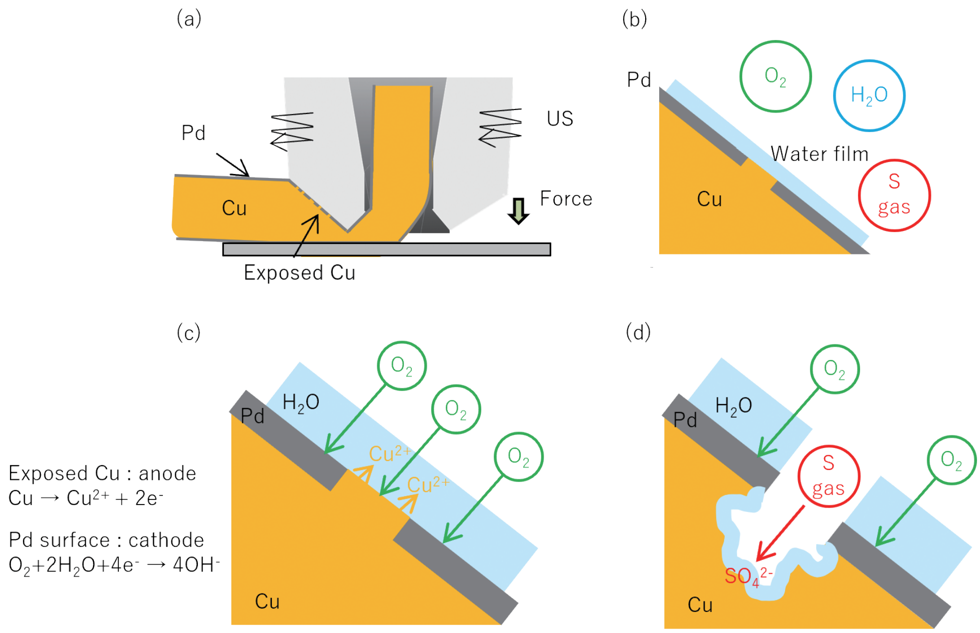

Fig. 11 Schematic images of corrosion process for PCC wire under high temperature

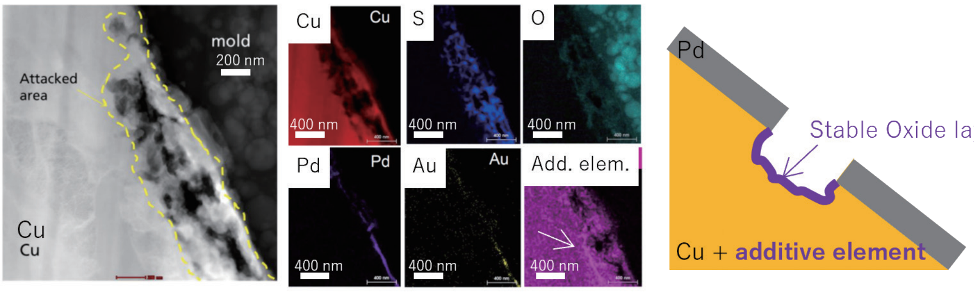

Fig. 12 Cross-sectional TEM image, corresponding EDS mappings, and schematic image obtained from localized corrosion are in EX1R

3. Highly Reliable Ag Alloy Wires GX2s

The chips of some packages are fragile. There is a concern about damage to the chips during wire bonding, making it difficult to use Cu wires. Therefore, we studied the possibility of using soft Ag wires in the in-vehicle application where high reliability is required. Nippon Micrometal Group has developed GX2s wires with enhanced high-temperature reliability on the basis of GX2 wires developed for memories.[8] Like the EX1R wires, the GX2s wires contain an additive element added to improve bonding reliability. Their alloy design is conducted to achieve a specific resistance of 2.4 $\mu\Omega$cm. This value is the same as that of 4N (99.99% purity) Au wires. Low resistance is also achieved. The high temperature and high humidity resistance of GX2s wires are briefly introduced here. For performance comparison, 4N Ag and 4N Au wires were also evaluated at the same time. A conventional sealing resin was used. The wire diameter was 50 μm. **Figure 13** shows cross-sectional SEM images of the ball/Al pad joint after 240 h of the HAST (130°C, 85% RH, 4 V). The arrows in Figs. 13(a) and (b) indicate the width of the corrosion that proceeded over the entire joint region or the joint where corrosion had progressed. For 4N Ag, a corrosion layer was formed over the entire joint region (Fig. 13(a)). Since Cl was detected in the corrosion layer, it is presumed that the corrosion reaction between Ag-Al IMC and Cl occurred. This mechanism is partially the same as the failure mechanism of Cu wires. On the other hand, GX2s had corrosion in a small region near the outer periphery of the bond, as shown in Fig. 13(b). Otherwise, GX2s maintained a stable joint.

Figure 14 shows cross-sectional SEM images of the ball/Al pad joint after 2000 h of the HTSL test at 175°C. The arrows in Figs. 14(a) and (b) indicate the width of corrosion at the joint. A corrosion layer was formed over the entire joint for 4N Ag (Fig. 14(a)). As S was detected in the corrosion layer, it is presumed that a corrosion reaction was caused between the Ag-Al IMC and the S-based outgas from the sealing resin in a high-temperature environment in the same way as observed with the Cu wires. On the other hand, as shown in Fig. 14(b), corrosion only occurred in a very small region around the outer periphery of the joint for GX2s. A stable joint condition was maintained without any reduction in joint strength or poor conductivity. Although no corrosion layer was observed for the 4N Au wire, the growth of the Au-Al IMC progressed significantly, and coarse Kirkendall voids originating from the difference in the interdiffusion rate between Au and Al were formed around the outer periphery of the joint. Uno[15] reported the corrosion of the Au-Al IMC in a high-temperature environment. Still, this corrosion was thought to have resulted from the chemical reaction between the Au-Al IMC and the bromine (Br) contained in the sealing resin. In recent years, sealing resins have become free of Br. This trend presumably explains the absence of significant corrosion reactions.

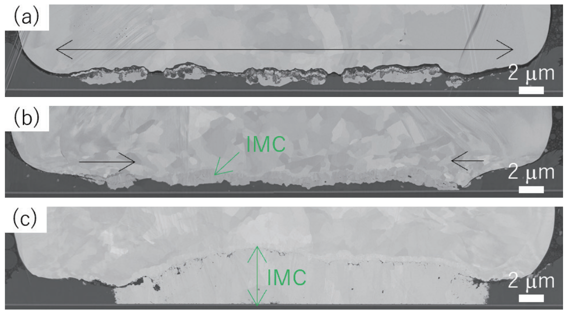

Fig. 13 Cross-sectional SEM images (a) 4N Ag, (b) GX2s, (c) 4N Au after HAST 240 h

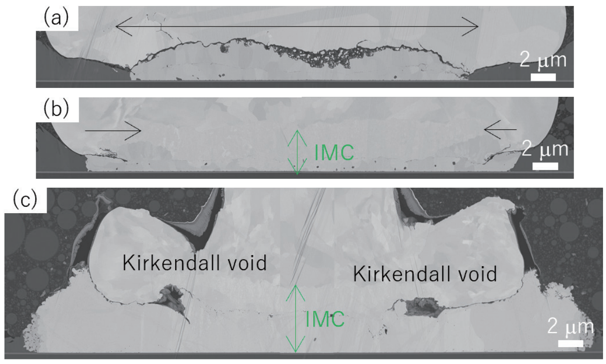

Fig. 14 Cross-sectional SEM images (a) 4N Ag, (b) GX2s, (c) 4N Au after HTSL test at 175°C for 2000 h

As compared to 4N Ag, GX2s is markedly improved in corrosion resistance in high-temperature and high-humidity environments and high-temperature environments by the unique alloy design of Nippon Micrometal Group. The GX2s wires were confirmed to have bonding reliability equivalent to that of the Au wires.

4. Initiatives toward Practical Application

Generally, bonding wires are wound on spools, packaged into coils, shipped, and then fed to a wire bonding machine in the semiconductor assembly process. The bonding conditions and bonding targets using wire bonding machines, as well as the types of sealing resins, vary widely depending on manufacturers. In this context, bonding wires are required to achieve stable bonding, proper loop formation during wiring, and long-term reliability, as mentioned above, at a mass production level. In order to apply new materials to semiconductor packages with strict standard requirements, cooperative development by semiconductor package assemblers and material manufacturers is also considered to be important. From this perspective, Nippon Micrometal collaborated with a semiconductor package assembler and Fraunhofer of Germany as an independent third-party evaluation and analysis organization, fabricated semiconductor packages under mass production conditions, tested the semiconductor packages according to the requirements of AEC-Q006, and evaluated the applicability of the EX1R and GX2s wires developed by Nippon Micrometal Group.[16, 17] Both EX1R and GX2s wires have initial bondability equivalent to that of existing bonding wires and have been demonstrated to satisfy the requirements of AEC-Q006 in environmental stress tests fully.

5. Conclusions

The EX1R and GX2s bonding wires, developed by the unique alloy design of Nippon Micrometal Group, have achieved long-term joint reliability that is sufficiently satisfactory for the harsh high-temperature environments of in-vehicle applications. With respect to technical issues on the market, we have identified factors leading to failures and implemented corrective measures, including the alloy design. Our customers can use the EX1R and GX2s wires without appreciably changing their wire bonding conditions with their existing wires. The mass production of the EX1R and GX2s wires has already begun for some in-vehicle applications. We think that the adoption of our new wire products to replace existing bonding wires at a low cost will reduce the wire bonding cost, reduce the consumption of scarce Au, and greatly contribute to the realization of a sustainable society. In addition, we have registered more than 20 important patents in Japan to turn the developed materials into intellectual properties and have built a global patent network.

Wire bonding is superior in terms of freedom and cost of wiring and occupies the mainstream of semiconductor packaging technology. There is no doubt that wire bonding will continue to be used in various packages in the future. It is predicted that future semiconductor packaging technology will further advance toward higher-density packaging. The bonding wires used as wiring materials will inevitably become thinner and have smaller bonding areas with various materials. In parallel, new issues may become apparent in terms of bonding reliability, looping performance stability, and ball formation stability. In order to solve these issues, we think it is important to deepen our understanding of the causes of defects and feed the knowledge we have gained back into material design and bonding technology. Nippon Micrometal will build a product group that can meet these market needs at the same time.

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