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# Ultrafine Nickel Powder for Multilayer Ceramic Capacitors

## 1. Introduction

Capacitors are an important electronic component which is indispensable for electronic circuits and power supplies, and are used in voltage stabilization and noise filters. Various types of capacitors are made by sandwiching an insulator between two metal plates or metal foils. Among them, ceramic capacitors using a ceramic insulator are compact and have high heat resistance and high accuracy, and demand is growing due to these characteristics. In particular, the compact, high-capacity MLCC (Multilayer Ceramic Capacitor), in which ceramics and metals are alternately laminated as shown in **Fig. 1**, now accounts for about 80 % of capacitor production.

A very large number of MLCCs are used in various applications, including 300 to 1 000 per smartphone, 3 000 to 6 000 pieces per car and 10 000 per electric vehicle (EV). The number of MLCCs installed is also expected to increase in the future with expansion of the field of high-density mounting of mobile devices accompanying the deployment of 5G next-generation communication equipment and increasing demand for large-capacity, high-voltage chips for automobiles in response to expanded use of electrical automotive equipment, as seen in CASE (Connected, Autonomous/Automated, Shared, Electric) automobiles.

The internal electrodes are alternately connected to different terminal electrodes so as not to conduct with upper and lower layers, are formed by applying a thin layer of pasted metal powder on the dielectric layer by printing and then firing. Currently, ultrafine nickel powder with a particle size of about 0.2 µm is mainly used as the metal powder for this internal electrode. JFE MINERAL succeeded in industrial-scale mass production of ultrafine nickel powder by the CVD (Chemical Vapor Deposition) method for the first time in the world, and has contributed to high performance in MLCC since commercialization of this product in 1995[1].

This report first outlines the characteristics required in ultrafine nickel powder as an internal electrode material and the method for producing the powder, and then introduces a top-grade product with an average particle size of 0.2 µm with coarse particles of 0.6 µm or more are reduced to respond to thinner internal electrodes, which have been in high demand in recent years.

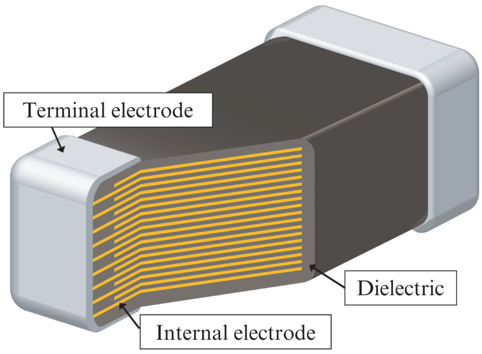


Fig. 1 Cutaway view of MLCC

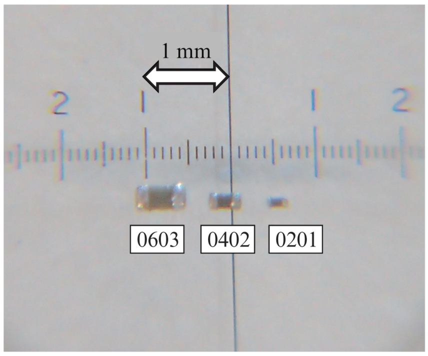


Photo 1 Various sizes of MLCC

## 2. Ultrafine Nickel Powder

### 2.1 Ultrafine Nickel Powder for Internal Electrodes

**Photo 1** shows examples of MLCCs of various sizes. In 2009, the 1005 size (1.0 mm × 0.5 mm) MLCCs had a market share of 50 %, but in 2020, the 0603 size (0.6 mm × 0.3 mm) became the mainstream, and the share of 0402 is also high[2].

In order to achieve both miniaturization and large

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capacity in MLCCs, it is necessary to reduce the thickness of the ceramic layer and the internal electrode layer. The thickness of the internal electrode layer has reached 0.5 µm in the latest products.

However, as the electrode layer becomes thinner, it is essential to reduce the number of coarse particles in the ultrafine nickel powder electrode material, as these particles may penetrate the dielectric layer and cause a short circuit or reduce the durability of the MLCC. High crystallinity is also required to prevent rapid sintering in the high temperature region during firing, and high dispersibility in the paste is necessary to ensure high smoothness and a good filling property when the paste is applied.

### 2.2 Ultrafine Nickel Powder Manufacturing Method

At JFE MINERAL, ultrafine nickel powder is produced by the CVD method, in which solid nickel chloride is introduced into a reactor and vaporized, and the generated nickel chloride gas is reduced with hydrogen gas. In the CVD method, the diameter of the generated particles can be controlled by controlling the residence time during the vapor phase reaction.

**Photo 2** shows scanning electron microscope (SEM) images of powders with an average particle size of 0.4 µm to 0.1 µm, and **Fig. 3** shows their particle size distributions. As can be seen here, the CVD method can produce ultrafine nickel powder having a sharp particle size distribution.

In the CVD method, a small amount of nickel chloride remains in the produced nickel powder, so it is removed by washing with water. For MLCC applications, coarse particles on the ppm order mixed in are then removed by a classification operation using a gravitational field, and the washed and classified powder becomes the final product after drying and packaging processes.

### 2.3 Ultrafine Nickel Powder Product Grade

For ultrafine nickel powders for MLCC applications, the number of coarse particles is an important measure of quality. Coarse particles are particles whose

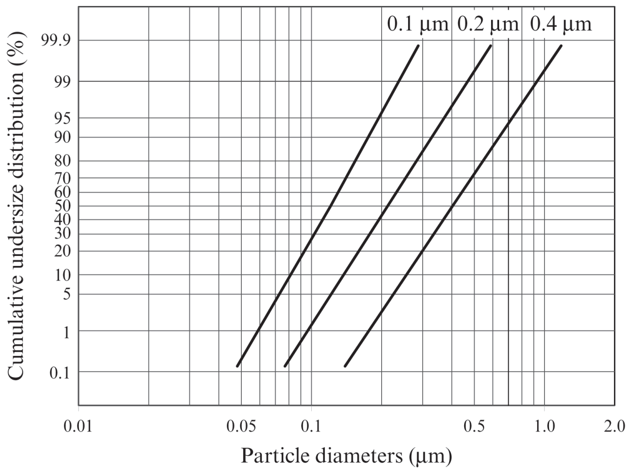


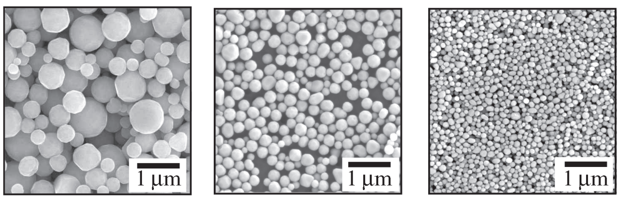

Fig. 2 Cumulative undersize distributions of ultrafine nickel powder with average diameter from 0.4 to 0.1 µm

size exceeds the upper limit of the target particle size distribution, and even a small amount causes deterioration of quality such as the reliability of the MLCC[3].

To realize thinner MLCC internal electrode layers in order to achieve small size and high capacity, it is necessary to reduce the particle size of the nickel particles used. However, as the diameter is reduced, the effect of coarse particles becomes more apparent, so it is necessary to narrow the particle size distribution and reduce the number of coarse particles. When reduction of coarse particles with sizes of 2 µm and more was required in the current mainstream product with an average particle size of 0.2 µm, JFE MINERAL achieved a micron-order classification technology and commercialized the current standard grade product. We also developed a classification technology that enables classification on the submicron order to meet the demand for reduction of coarse particles of 0.8 µm or larger, and commercialized high-grade products by using this technology. As a result of such improvements in classification technology, JFE MINERAL's ultrafine nickel powders are now widely used in small, high-capacity MLCCs.

At present, MLCC manufacturers are further thinning the layers, and the corresponding electrode material powders are also required to have higher quality. To meet this demand, we improved our CVD reaction technology and developed a distributed processing technology to improve classification efficiency, making it possible to commercialize a new top-grade product with an average particle size of 0.2 µm, in which coarse particles of 0.6 µm or more are reduced to the ultimate limit.

**Figure 3** shows the number of coarse particles of 0.2 µm products by grade. It can be seen that the top-grade product has a significantly reduced number of




Particle size 0.4 µm Particle size 0.2 µm Particle size 0.1 µm

Photo 2 Scanning electron micrographs of ultrafine nickel powder with average diameter from 0.4 to 0.1 µm

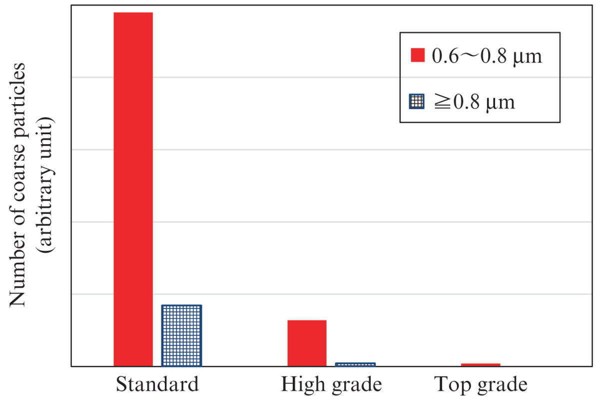



Fig. 3 Number of coarse particles of various grades of ultrafine nickel powder with average diameter 0.2 μm

coarse particles of 0.6 μm or more compared to the standard grade and even high-grade products. This top-grade product is currently highly evaluated by customers.

## 3. Conclusion

This article has introduced JFE MINERAL's top-grade nickel ultrafine powders for MLCC internal electrodes manufactured by the CVD method, especially the 0.2 μm product which is currently the mainstream. JFE MINERAL will continue research and development of higher quality grade products in order to support next-generation MLCCs from MLCC manufacturers.

### References

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2) Roadmap for electronic component technology up to 2028. JEITA, 2019, 430p. (p. 211)
3) Nomura, T. Material and process technology for miniaturization and high capacity and high reliability of multilayer ceramic capacitors. *Johokiko*, 2018, 219p. (p. 78).

### For Further Information, Please Contact:

Sales Dept. I, Advanced Materials Division, JFE MINERAL
Phone: (81)3–5445–5215 Fax: (81)3–5445–5222
http://www.jfe-mineral.co.jp/