# Electrical Performance Characteristics of MLCC's With Low Laydown AgPd Powders


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AgPd electrodes still see widespread use in passive component applications, even with the conversion to using base metal replacements such as nickel and copper. As a consequence of design and cost, MLCC's using AgPd alloys as electrodes must meet the demands of high performance, small case sizes, and low costs. This paper reports the electrical performance characteristics of MLCC's made with 70%Ag30%Pd electrodes and 95%Ag5%Pd electrodes as a function of MLCC case size and metal laydown.


## Introduction

Current MLCC industry trends show the majority of MLCC electrodes are base metal, namely nickel [**1**]. Figure 1 shows the MLCC consumption trend and future projection for three principle electrode types; AgPd, Ni, and Cu. The rapid growth trend for Ni electrodes began in 2000 when sufficient infrastructure was in place for Ni processing kilns, powder and dielectrics, and when Pd prices were exorbitantly high.

The trends shown in Figure 1 do not show the evolution of high silver content AgPd powders. However, a significant emphasis was put onto producing AgPd alloys with very low content Pd [**2**]. In addition to manufacturing high Ag content AgPd powders, MLCC fabricators pushed to reduce the laydown of electrode powders and dielectric thicknesses while trying to maintain desirable X7R, Y5V, NPO, and low fire MLCC performance characteristics

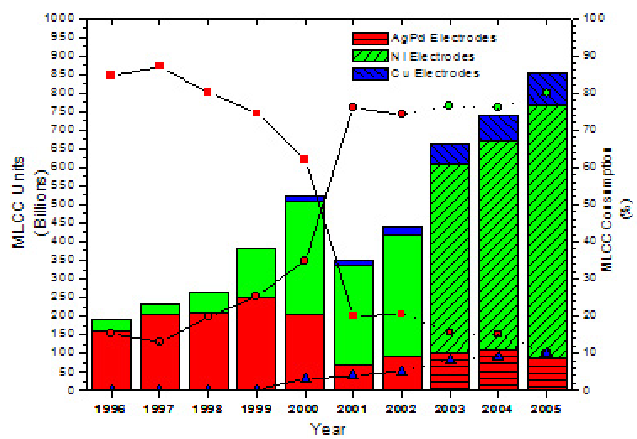


Figure 1. Past MLCC consumption trends and future projection for devices made with AgPd, Ni, and Cu electrodes.

such as high capacitance, low dissipation factor, good ESR, high part yield, and ever smaller case sizes.

Although Ni has become the predominant electrode material for MLCC's, AgPd electrode compositions are still widely used and are continually improving. This paper discusses the current status of two AgPd electrode compositions being widely used in MLCC manufacturing.

## Electrode Laydown and Thickness

Several factors affect metal electrode laydown and consequently electrode thickness. Among these are the reactivity to the dielectric, the ability to fire to a smooth sheet with good conductivity, and the ability to 'wet' the dielectric. Also important has been the development of finer dielectric particle size and size distribution. It is important for the dielectric to have at least one and preferably two grain boundaries between electrodes to maintain good performance characteristics. History shows about a 50% improvement in lay-down and dielectric thickness each decade in the precious metal systems.

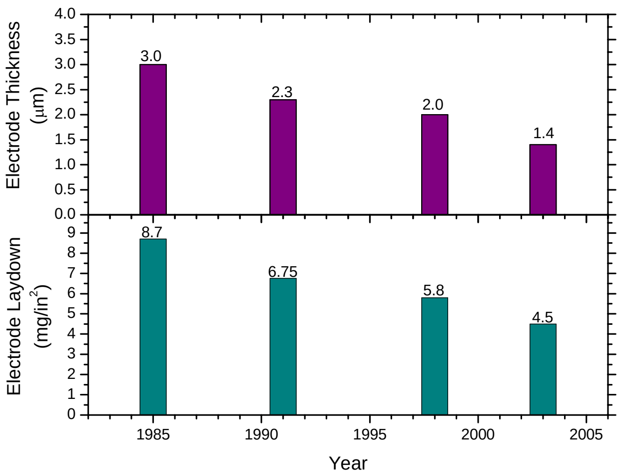


Figure 2. Historic MLCC trends for AgPd electrode laydown and thickness.

## 70%Ag30%Pd – 0402 (X7R) 47nF

Figure 3 shows the typical SEM image of Metalor CP3004 (70%Ag30%Pd), which has been widely used in MLCC devices around the world for over 30 years. Distinguishing characteristics of the Metalor CP series powders are good dispersion characteristics for paste manufacture, particle size control, degree of alloying and

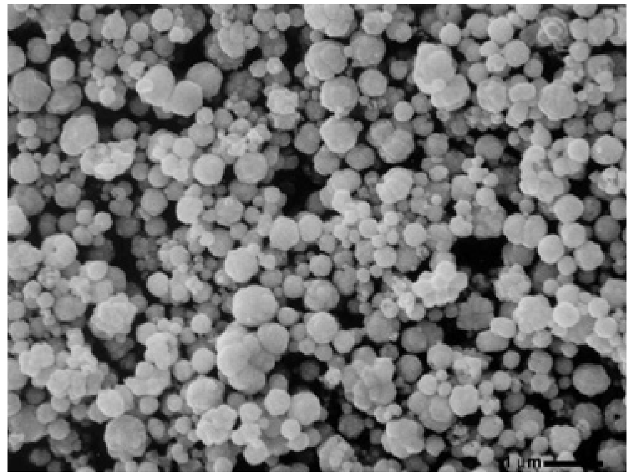

Figure 3. Typical SEM image of Metalor CP3004 (70%Ag30%Pd).

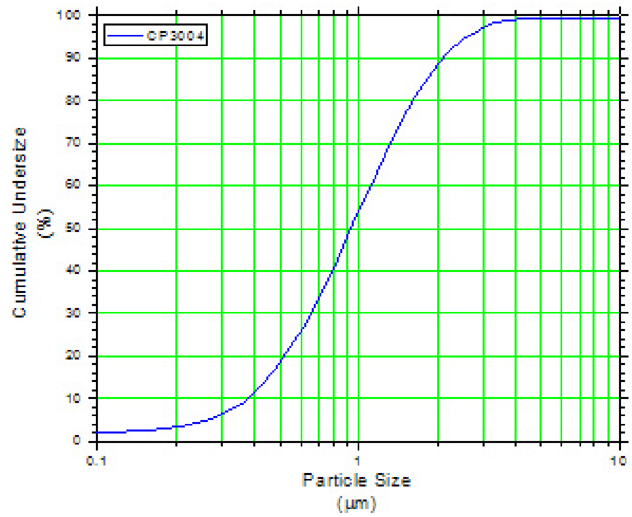


Figure 4. Typical PSD image of Metalor CP3004 (70%Ag30%Pd)

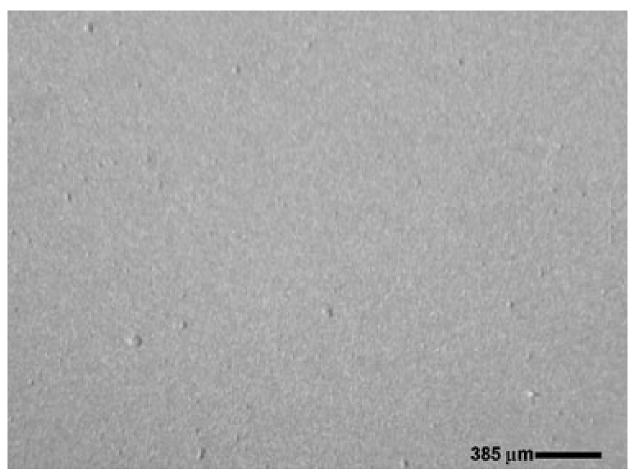


Figure 5. Typical LAL of Metalor CP3004 (70%Ag30%Pd)

dispersion. As can be seen from the above low angle light (LAL) picture of a paste at 2 μm thickness, Figure 5, the CP3004 powder disperses easily in a simple cellulose vehicle and 3-roll milling. This allows the powder to produce a good smooth and conductive electrode, even when printed very thin.

Figures 6 & 7 show the magnified cross sections of an 0402 case (X7R) made with Metalor CP3004 electrode powder. A laydown of 3.82 mg/in$^2$ was achieved with a dielectric thickness of 5 μm.

These cross-sections show the smooth electrodes and good end termination connections necessary in today's high performance parts. These characteristics are important in maintaining the TCC curve, DF, IR, ESR and breakdown voltage for MLCC parts.

The break down voltage testing of the 0402 (X7R) parts was conducted using 1000 parts at 125°C with twice the rated voltage for 100 hours. The failure rate at the test conditions is $2.3 \times 10^{-5} \cdot hr^{-1}$. Under standard operating conditions, the failure rate is 3.5 x $10^{-10} \cdot hr^{-1}$ for Metalor CP3004. The capacitance distribution for the 0402 – 47 nF nominal part is shown in the lower graph of Figure 8.

As can be seen from these results, the Ag/Pd with higher Pd content can make high layer counts, in excess of 400 layers and can handle thin dielectric layers without a degradation of the electrical characteristics. This ability to handle thin layers and firing conditions involving air allow design and production of high performance MLCC parts in small case sizes with excellent electrical performance characteristics.

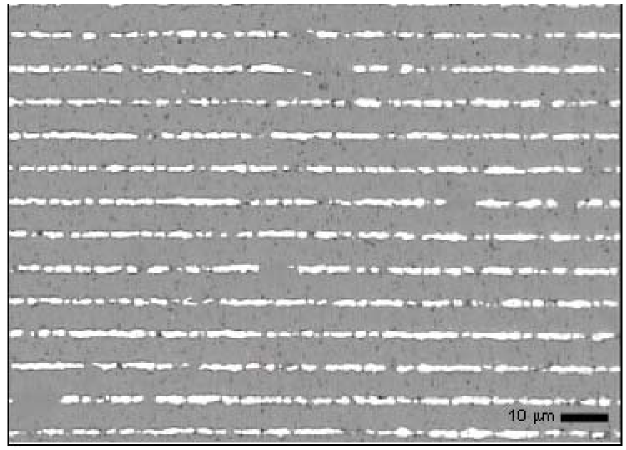


Figure 6. Cross section of 0402 (X7R) MLCC for a 47 nF device with a 10 V operating voltage made with Metalor CP3004 electrode powder.

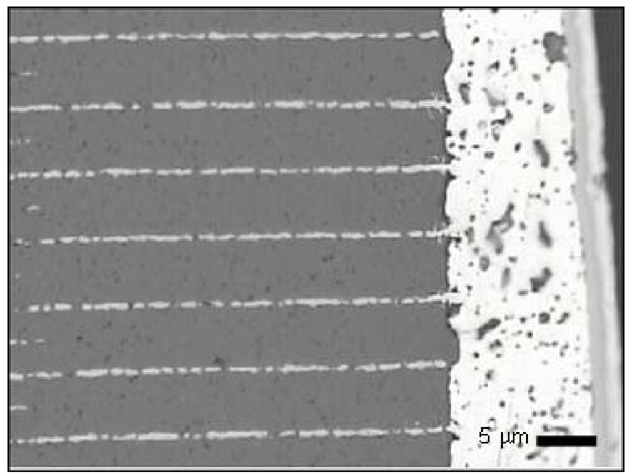


Figure 7. Cross section of 0402 (X7R) MLCC showing good connection between electrode and termination.

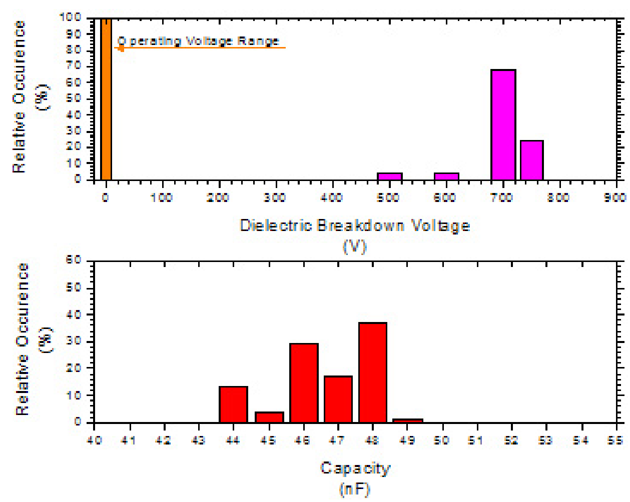


Figure 8. Electrical results for an 0402 (X7R) MLCC part made with Metalor CP3004 electrode powder.

**95%Ag05%Pd – 0804 (X7R) Cases**

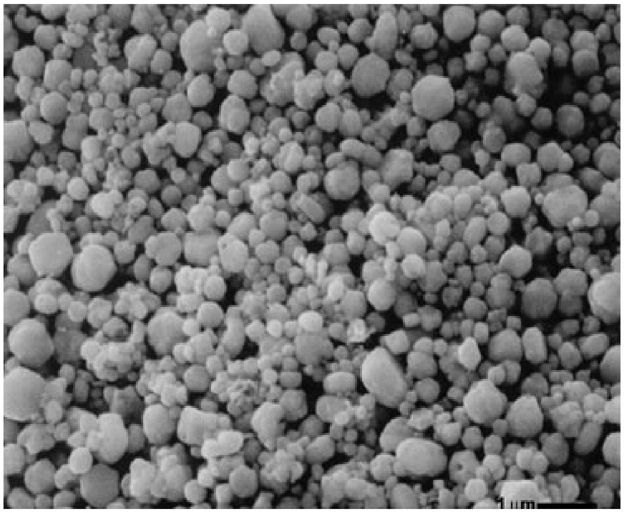


Figure 9. Typical SEM image of Metalor CP0504 (95%Ag05%Pd).

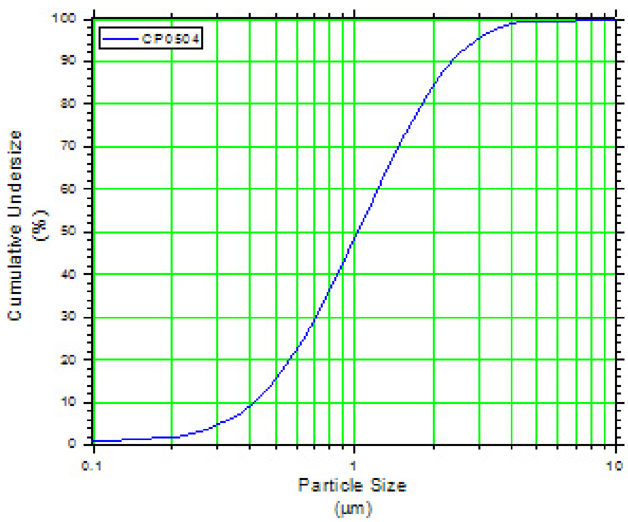


Figure 10. Typical PSD of Metalor CP0504.

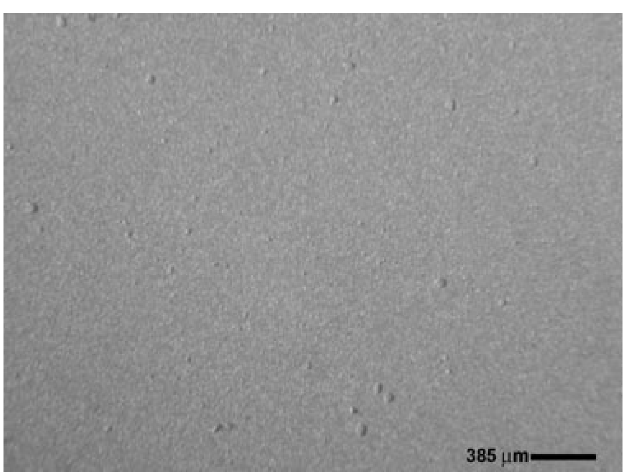


Figure 11. Typical LAL of Metalor CP0504.

As seen from the previous figures (Figure 9 – 11), the high silver CP0504 produces a good smooth electrode when printed with a simple cellulose vehicle.

A critical feature of high Ag content AgPd alloys is good phase composition as well as standard physical properties. A poorly alloyed AgPd powder will soften or even melt under the firing conditions of MLCC manufacturing. Ag migration and melted Ag will cause MLCC part failure.

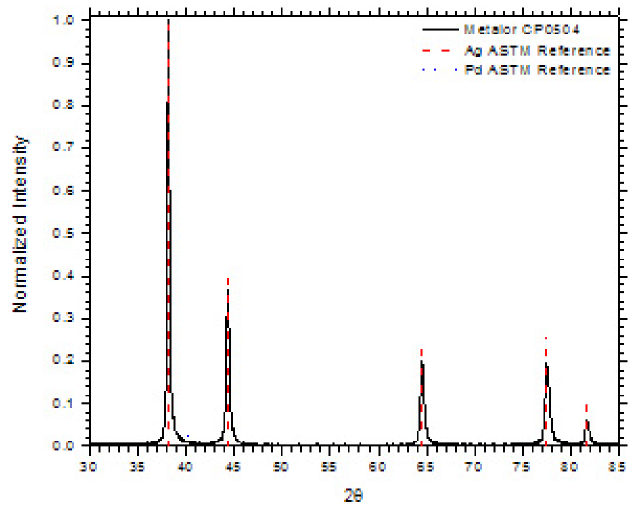


Figure 12. XRD spectrum of Metalor CP0504 (95%Ag05%Pd) electrode powder.

Figure 12 shows a typical x-ray diffraction spectrum of CP0504. The XRD spectrum shows excellent alloy characteristics and is typical for Metalor CP electrode powders. The peaks are well defined and Rietveld analysis shows a high degree of alloying near the target of 95/5.

The cross-section in Figure 13 shows a 0804 X7R 470 nF device with a 10 V operating voltage made with Metalor CP0504 electrode powder. A lay-down of 4.65 mg/in$^2$ was achieved with a dielectric thickness of 6 µm. Smooth and continuous electrodes are seen with dense dielectric layers.

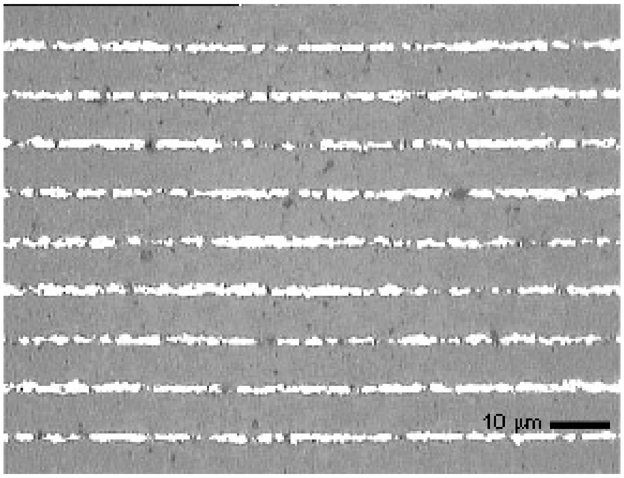


Figure 13. Cross section of 0804 (X7R) MLCC.

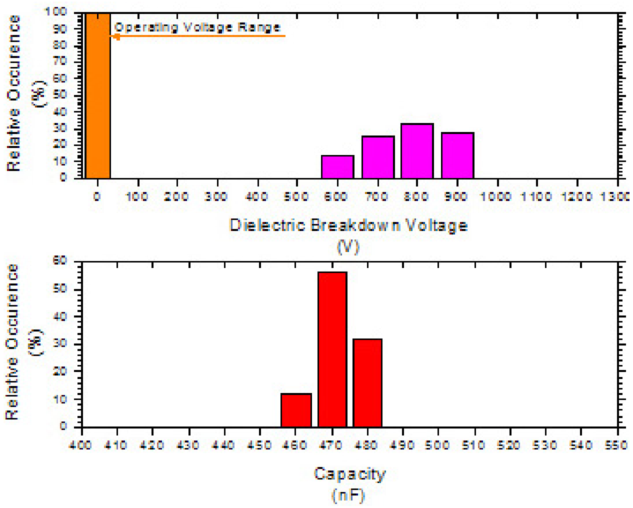


Figure 14. Electrical results for a 0804 (X7R) MLCC part made with Metalor CP0504 electrode powder

The break down voltage testing of the 0804 (X7R) parts was conducted using 1000 parts at 125°C at six times the rated voltage for 250 hours with the following results. The failure rate at the test conditions is 6.7 x $10^{-5} \cdot hr^{-1}$ for the Metalor CP0504. Under standard operating conditions, the failure rate is 3.8 x $10^{-11} \cdot hr^{-1}$.

The capacitance of the 0804 (X7R) part was designed for 470 nF. As can be seen from the graph in Figure 14, a tight distribution was maintained with this electrode.

**Conclusions**

The usage of Ag/Pd electrodes will always be with the industry. These electrodes have an advantage in many applications in being non-magnetic, having good dielectric compatibility and having good stability when fired in air. Many high reliability applications have thousands of hours of testing and usage with the precious metal systems.

The metal powder industry has greatly improved its ability to tailor powders to have good alloying, to be coated with materials to greatly lower the reactivity of fine particles and to improve dispersion characteristics while maintaining standard industry printing techniques.

The Metalor powder has a long history of growing with the industry, having evolved from the Engelhard-CLAL powders with its acquisition by Metalor. The evolution of the higher silver compositions and the low lay-down thicknesses has allowed the Metalor powder to find new markets.

**References**

1. R. Stephenson, "*Use of Copper for Base Metal Electrode Applications*," Trends and New Technology, CARTS EUROPE 2003.
2. R. Stephenson, W. Peng, "*Improvements in Electrode Technologies*," CARTS EUROPE 2002.