New Products

Copper Based Resistance Alloy EFCR Series

1. INTRODUCTION

Resistors play roles in current control, sensing, and shunting in electrical and electronic circuits. So it is an essential component for next-generation vehicles and consumer electronic devices. Figure 1 shows a chip resistor and a shunt resistor as representative resistors, as well as an electric/electronic circuit board. As the guaranteed temperature range expands, high reliability and high accuracy are required for resistors, among these, there are various requirements such as downsizing, high power, and energy saving. As a result, characteristics that lead to the stabilization of resistance values in various environments and high quality are required for resistance materials as well.

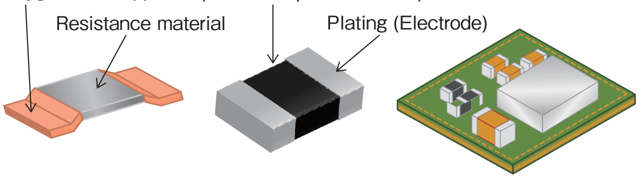

Figure 1 **Resistors and an electric and electronic circuit board.**

Our company has been strengthening its lineup (series) of copper based resistance materials which are optimized not only for resistivity but also for the temperature coefficient of resistance (T.C.R.) and the thermo-electromotive force (EMF) characteristics which are necessary for high-precision resistors. This time, EFCR-100, which has the world's highest-class resistivity among the copper based resistance materials, has been added to the lineup. Advanced features of EFCR series are introduced here.

2. FEATURES

(1) Physical properties

Table 1 shows the main electrical properties and the thermophysical property values of EFCR series. Volume resistivity (resistivity) was measured with the four-terminal method and EMF values show the thermos-electromotive forces generated between the copper and the resistance material, converted into a value per unit temperature. Also, the thermal conductivity and the specific heat are shown as thermophysical property values. By adding "EFCR-100" to "EFCR-30 (HRR)" and "EFCR-44 (CMR)", it becomes possible to address a wide range of resistivity. The newly released EFCR-100, with a high resistivity (98 μΩ·cm), has a resistivity equivalent to high resistivity materials such as FeCr based alloys and NiCr based alloys and is a possible candidate to replace these alloys.

Table 1 **Electrical and thermal properties of EFCR series.**

Products	Volume resistivity μΩ·cm	EMF μV/℃	Thermal conductivity W/(m·℃)	Specific heat J/(kg·℃)
EFCR-30	29	0.1	32.2	393
EFCR-44	43	0.4	21.3	393
EFCR-100	98	0.2	11.7	457

Figure 2 shows the change rate in resistivity of EFCR series, and Table 2 shows T.C.R. over multiple temperature ranges. The change rate in resistivity shows the measurement results using the four-terminal method while changing the temperature. In addition, T.C.R. indicates the difference between each temperature and the slope between the temperatures. As the absolute values of T.C.R. and EMF (Table 1) are small, the resistance characteristic of EFCR does not easily change due to temperature change. This is an important feature for resistors. In particular, since EFCR-30 has a small change rate in

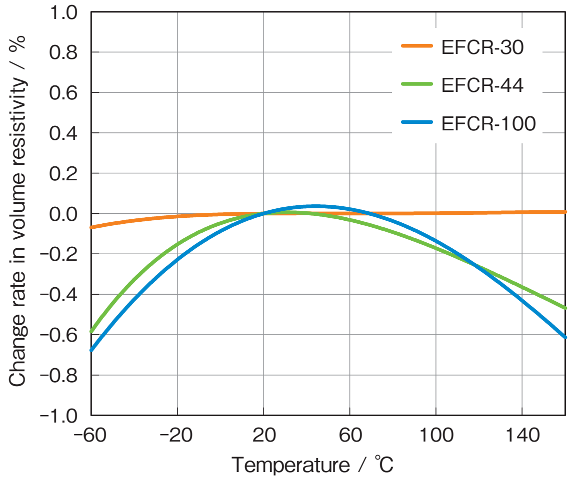

Figure 2 **Change rate in volume resistivity to temperature of EFCR series.**

Table 2 **Temperature coefficient of resistance of EFCR series.**

Products	Temperature coefficient of resistance (T.C.R.) ppm/℃		
	20-60℃	25-125℃	-60-160℃
EFCR-30	3	5	4
EFCR-44	3	−35	5
EFCR-100	5	−35	2

resistivity over a wide temperature range, then exhibits stable resistance values even when exposed to high temperatures when implemented into lithium-ion batteries used in a variety of applications including electric vehicles. On the other hand, EFCR-44 and EFCR-100 have the feature that the change in resistivity becomes negative at high and low temperatures. For example, by combining with pure copper, Sn, or Ni plating, which tends to have a positive T.C.R., it is expected that it will be easier to design shunt resistors and chip resistors that keep low the absolute value of T.C.R..

Table 3 shows the main mechanical properties of EFCR series, including 0.2% yield strength, tensile strength, elongation, and Vickers hardness. Since each product is classified in temper with strength and hardness, then a suitable material is available to be provided meeting with each manufacturing design or manufacturing process of various resistors.

Table 3 Mechanical properties of EFCR series.

Products	Temper	0.2% yield strength MPa	Tensile strength MPa	Elongation %	Vickers hardness
EFCR-30	O	220	390	40	110
	HS	480	530	10	170
	H	590	600	3	200
EFCR-44	O	280	450	35	120
	HS	550	580	10	170
	H	690	700	3	210
EFCR-100	O	280	590	38	135
	HS	670	740	10	220

(2) Magnetic property

Figure 3 shows the relationship between the magnetic flux density and the magnetic field strength of EFCR-100 and an FeCr based alloy. Since FeCr based alloys are ferromagnetic materials whose magnetic flux density changes in response to changes in magnetic field strength, then this causes a change in resistance value especially in the high frequency range. On the other hand, EFCR-100 is non-magnetic and does not cause changes in magnetic flux density. And EFCR-100 can be applied to resistors for high frequency application, which was difficult to consider using magnetic materials such as FeCr based alloys.

(3) Copper plating adhesion

Figure 4 shows the results of a peeling test (tape test after cross-cutting) held to evaluate the adhesion of copper plating on EFCR-100, FeCr-based alloy, and NiCr based alloy. On EFCR-100, the copper plating on the surface remains even after the adhesive tape is removed, whereas on FeCr based alloy and NiCr based alloy, the plating has been removed. The excellent plating adhesion leads to improvement in the connection reliability of the chip resistors.

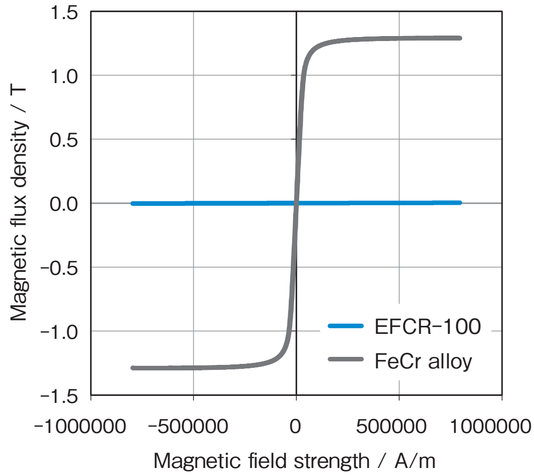

Figure 3 Relationship between the magnetic flux density and the magnetic field strength (EFCR-100 and FeCr alloy).

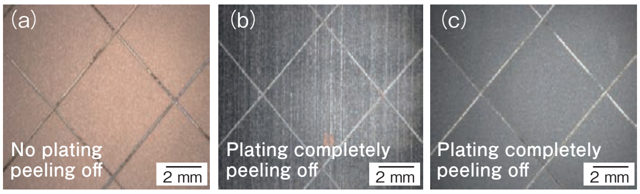

Figure 4 Surface pictures after the peeling test. (a) EFCR-100, (b) FeCr based alloy, (c) NiCr based alloy

3. CONCLUSION

The newly developed EFCR-100 has a high resistivity as a copper based material, moreover, it is non-magnetic and has excellent plating adhesion. None of the other metal based resistance materials have such features. So, new resistor design and productivity improvement are expected with the application of EFCR-100. To meet customer needs by applying these features of EFCR-100, such as non-magnetism and excellent copper plating adhesion, we offer all shapes of strips (coils) and wires (round wires, rectangular wires).

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