

环保型多重掺杂X7R瓷料的多元非线性回归分析

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摘要 通过引入自制复合氧化物掺杂剂, 应用多元非线性回归分析方法, 建立了多元非线性回归数学模型 $y=b_0+\sum b_i x_i+\sum b_{ii} x_i^2+\sum b_{iii} x_i^3$, 确立了环保型多重掺杂X7R 多层陶瓷电容器 (MLCC) 瓷料中各种掺杂剂的用量对介电常数及电容量温度变化率($\Delta C/C_{25^\circ\text{C}}$)的多元非线性回归方程, 并进一步解释了部分掺杂剂的改性机理. 回归方程表明, 介电常数随Nb、Ce掺杂量的增加而降低, 这与当前较为成熟理论“壳-芯”结构模型完全吻合. 最后通过回归方程优化瓷料配方, 研制了环保型X7R MLCC瓷料系统. 在空气中于1140℃下烧成的BaTiO₃陶瓷材料的主要性能指标达到: $\epsilon_{298\text{K}}=2900\pm 50$, $\text{tg}\delta\leq 1.0\%$, $\rho\geq 10^{11}\Omega\cdot\text{cm}$, $\Delta C/C_{25^\circ\text{C}}(-55^\circ\text{C}\sim+125^\circ\text{C})\leq\pm 15\%$.

关键词 [X7R](#) [多层陶瓷电容器](#) [多元非线性回归](#) [钛酸钡](#)

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Multiple Non-linear Regression Analysis for Complex Doping of X7R MLCC Ceramics

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Abstract The multiple non-linear regression analysis method was applied to build up the non-linear regression mathematical model $y=b_0+\sum b_i x_i+\sum b_{ii} x_i^2+\sum b_{iii} x_i^3$, and the complex oxides were used as effective dopants to X7R ceramic powders of multilayer ceramic capacitor (MLCC). The non-linear regression equation regarding the relationship between the dosage of different dopants and the dielectric properties was established based on the testing data. Moreover, the modification mechanism of dopants on the characteristics of the ceramics was explained in this paper. The regression equation suggests that with the increase of Nb and Ce addition to BaTiO₃, the dielectric constant decreases, which is consistent with "core-shell" structure theory. According to the multiple regression equation analysis results, the dosage of different dopants was adjusted to develop the environmental friendly X7R MLCC ceramics. The main features of the BaTiO₃ ceramics sintered in air atmosphere at 1140℃ are $\epsilon_{298\text{K}}=2900\pm 50$, $\text{tg}\delta\leq 1.0\%$, $\rho\geq 10^{11}\Omega\cdot\text{cm}$, $\Delta C/C_{25^\circ\text{C}}(-55^\circ\text{C}\sim+125^\circ\text{C})\leq\pm 15\%$.

Key words [X7R](#) [MLCC](#) [non-linear regression multi-analysis](#) [barium titanate](#)

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