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ELECTRICAL EFFECT AND INFLUENCE FACTORS OF TOURMALINE

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Abstract

Tourmaline is a crystalline boron silicate mineral with special electrical and optical behaviors. In this study, electrical performances of crystalline tourmaline samples from various deposit sites in China were evaluated. The results show that the piezoelectric constants of tourmalines, in a fixed crystalline direction, depend on their mineral species and the specialty elements in the crystal. The piezoelectric constant of dravite is higher than that of elbaite. The variety of piezoelectricity is resulted from the element type in crystal structure. Dielectric properties tests show that tourmaline is a low dielectric constant material and the dielectric constant is from 4×10^{-12}pf/cm to 10×10^{-12}pf/cm. The dielectric constant along C axis is higher than that in any other directions. Under room temperature, pyroelectric property of a crystal is proportional to the dielectric properties, and negatively correlated to the ferric oxide ratio.

Introduction

Tourmaline has piezoelectric and pyroelectric property because of its polar structure. The special electrical properties of tourmaline have been found for a long time. According to Schmidt records, Dutch found that tourmaline can attract dusts when it was heated and discharge powder when it was cooled down. A Japanese researcher, Kubo confirmed the tourmaline with spontaneous polarity through an experiment in 1992. It can be used in many areas, such as infrared radiation, release of negative ions, adsorption and activating water [1]. Thus it becomes one of the most important materials in environmental protection. In order to improve its performance, the electrical properties of tourmaline were investigated in this study.

Experimental Procedure

1. Characteristics of Tourmaline Samples

Tourmaline samples used in the experiment were obtained from Nanyang (Henan province, HN), Gaoligong mountain (Yunnan province, YN) and Fuping (Hebei province, HB) in China. Samples of HN-1, YN-1, and HB-1 stand for the pure single crystals from Henan, Yunnan, and Hebei respectively. The chemical composition of samples was analyzed by X-ray fluorescence spectrometry (Instrument Philips PW2404).

The results in Table I show that the main compositions in the samples are SiO_2 and Al_2O_3 while containing a small amount of MnO and Na_2O. In addition, HN-1 contains only trace amounts of Fe and Fe_2O_3 (0.031%). The iron content of YN-1 is less than that in HB-1, which contains the highest MgO content. These characteristics indicated that these samples belong to different categories of tourmalines. According to the classification of tourmaline, HB-1 is dravite, while HN-1 and YN-1 are classified as elbaite [2] [3].

Table I Chemical Components of Samples

Samples	HN-1	YN-1	HB-1
SiO_2	43.64	44.16	38.40
TiO_2	-	0.011	0.99
Fe_2O_3	0.031	1.68	6.31
FeO	-	1.75	-
MnO	0.43	0.14	-
MgO	-	0.029	10.08
CaO	0.72	0.47	0.66
Na_2O	2.17	2.55	2.13
K_2O	0.04	0.15	0.12
P_2O_5	0.05	0.16	-
F	4.09	-	0.01
loss	4.70	5.97	10.02
total	98.601	99.34	99.40

2. Piezoelectric Effect of Tourmalines

2.1 Conditions for the Generation of Piezoelectric Effect

Many crystal minerals such as tourmaline have polar structure. Under the action of pressure, electric charges can be produced due to crystal deformation. This phenomenon is called the piezoelectric effect. Variety of the piezoelectric effect depends on the external pressure and the polarization of the crystal minerals.

Structure of tourmaline belongs to trigonal system, with a symmetry class of $L^3 3P$ and space group of R3m. This is a necessary factor for producing piezoelectric effect. Under room temperature, tourmaline is not conductive. The electric charges of the crystal surface will be distributed unevenly when it is placed under external pressure. Even a small external pressure, it can show piezoelectric effect because of its low crystalline symmetry.
Any stress (tensile stress, compressive stress, or shear stress) applied to this kind of material can produce electric dipole. If the material is placed between two metals, the applied stress T and electric polarization P have a relationship as follows [4]:

$$P = d\,T \qquad (1)$$

Here, d is a constant, which is called piezoelectric modulus (Or piezoelectric strain coefficient), and its unit is $N^{-1}\cdot C$ (Coulomb / Newton). It represents the intensity of the electrodes produced by the unit stress.

2.2 Piezoelectric Properties of Different Species of Tourmalines