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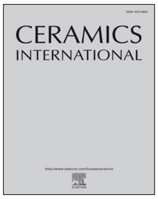

Preparation and properties of anti-static coating on the 3Y-TZP ceramics

Xianfeng Yang[a,*], Zhentao Ni[a], Xiaole Yang[a], Qinglong He[a], Hehan Xie[a], Xiewen Xu[a], Zhipeng Xie[b]

[a] *College of Materials Science and Engineering, Changsha University of Science & Technology, Changsha 410014, China*
[b] *China State Key Laboratory of New Ceramics and Fine Processing, Tsinghua University, Beijing 100084, China*

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ABSTRACT

Anti-static coating on the 3Y-TZP ceramics was prepared through adding ZnO and SnO_2 to the glaze. Wettability and surface resistivity of the coating was studied. Dissolving, crystallization and distribution of ZnO and SnO_2 in the coating were analyzed. Static dissipative mechanism of the coating was explored. The results showed that the interface bonding and wetting between the coating and 3Y-TZP were perfect. The surface resistivity of the coating could be reduced to $10^7\ \Omega/\square$. ZnO was helpful to improve the wettability of the coating and inhibit the crystallization of the SiO_2. ZnO and SnO_2 dissolved in the glaze and the semi-conductive composition rich melt layer around SnO_2 was formed. The melt layer contacted each other and the static dissipative network was established, which attributed to the anti-static properties of the coating.

1. Introduction

The electrostatic phenomenon is quite common in the fields of electronic information, aerospace, textile, oil paint, petrochemical, etc. Aggregation of electrostatic charge may lead to great damages, the discharge of accumulated electrostatic charge can easily disturb the operation of precision instruments and even burn microelectronic components. According to U.S. statistics, in the electronics industry, the annual loss due to electrostatic hazards amounts to $10–20 billion. Anti-static materials must be applied to the surface of artificial satellite run in space, or electrostatic aggregation will interfere with satellite operation, for the satellite surface collides with charged particles. Electrostatic discharge may also lead to satellite failure. Electrostatic aggregation can lead to dust or bacteria in medical or clean space, and can easily lead to fire explosion in mining, petrochemical enterprises and fireworks enterprises. In powder industry, electrostatic aggregation can lead to powder gathering on the grinding medium, seriously impact the grinding efficiency. It can also cause fiber gathering in the textile industry. The anti-static materials play an important role in eliminating electrostatic hazards. According to the related anti-static materials standard in China, a material with a surface resistivity in the range of $10^5\ \Omega/\square$ to $10^{12}\ \Omega/\square$ and a volume resistivity in the range of $10^4\ \Omega{\cdot}cm$ to$10^{11}\ \Omega{\cdot}cm$ is defined as an anti-static material.

At present, anti-static materials applied in engineering can mainly be divided into two categories:

(1) Polymer-based composites
Such polymer-based anti-static materials or coatings are prepared by the adding of carbon black, graphite, chopped fiber or conductive mica powder. Unfortunately, it is difficult to manipulate the dispersion and homogeneity of the electrically conductive phase in such materials, and they also exhibit poor durability and high-temperature resistance, and also low wear resistance [1].

(2) Anti-static glazes
Anti-static glaze is mainly applied in the fields of building materials, the anti-static function is realized by adding conducting (or semi-conducting) oxide powders or conducting fiber to form networks in the conventional anti-static glaze. The manufacture of anti-static glaze is combined with the technology from conventional ceramic preparation, the products have high porosity and low mechanical properties, mainly used as anti-static platen, wall and floor tiles [2].

Materials that combined great mechanical properties with anti-static properties are needed in the field of harsh environment such as aerospace, high-temperature and high-frequency friction applications.

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[*] Corresponding author.
E-mail address: yangxf05@mails.thu.edu.cn (X. Yang).

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Compared with metals, traditional structural ceramics such as Al_2O_3, ZrO_2, and Si_3N_4 have more excellent wear resistance, corrosion resistance and high temperature stability, but these are insulating materials at room temperature. Other structural ceramics such as SiC, ZrC, TiN, and ZrN are expensive and require complicated synthesis techniques [3–5].

In the preceding studies, much attention has been putting on the mechanical properties of structural ceramic materials, rather than its electrical performance, not to mention anti-static advanced ceramic materials. Nakayama et al. reduced the surface resistivity of a structural ceramic to 10^4 Ω/□ and the volume resistivity to 10^2 Ω·cm by doping it with 40 wt% ZnO, but the bending strength was only 60 MPa [6]. Fan et al. reduced the volume resistivity of zirconia to 2.14 Ω·cm via an iron implanting method, but the microstructure was easily damaged, and the manufacturing cost was high [7]. TiO_2 ceramic is a semi-conducting material with the volume resistivity about 1000 Ω·cm and an electrostatic dissipative function that is widely applied in the textile industry, yet the abrasion resistance and compactness are poor [8]. Yang et al. prepared an anti-static ZrO_2 ceramic through a high-temperature Fe infiltrating method, but the mechanical properties of ZrO_2 ceramics have dropped to a certain degree [9,10]. Yang et al. have also developed a solution infiltration method by introducing element Fe to the porous ceramic body, but the solution infiltration method was just suitable for the pre-sintered or green body [11].

In this study, the anti-static coating was prepared on the surface of 3Y-TZP ceramic, aim to prepare materials that combine prominent mechanical properties with anti-static properties.

2. Experiment

2.1. Materials and experimental procedure

The mixture of SiO_2, Al_2O_3, CaO, K_2O, Na_2O with B_2O_3 was put into a ball-milling jar and trundled for 24 h, then the dried powder was put into alumina crucible to melt, with a heating rate at 10 °C /min and holding time at 1100 °C for 30 min, the base glaze was got through water quench. CaO, K_2O and Na_2O were introduced by the form of carbonate as $CaCO_3$, K_2CO_3 and Na_2CO_3. Then the base glaze mixed with ZnO, SnO_2 and deionized water and put into a ball-milling jar trundled for another 24 h to get the slurry. The disk-shaped 3Y-TZP ceramic part (diameter 15 mm, thickness 8 mm) was dipped into the slurry once and about 0.8–1.0 mm slurry was adhered on the ceramic part's surface. Then the sample was dried and heated at 1150 °C for 30 min, with a heating rate at 5 °C /min and cool down to room temperature naturally inside the furnace. Then the 3Y-TZP ceramic with surface coating with thickness of about 0.5–0.8 mm was prepared.

2.2. Characterization

The surface resistance was tested via megger (AR907A, Heng Gao electronics, Hong Kong) and converted to surface resistivity. The image sintering point tester (SJY, Xiang Yi Instrument Co., Ltd., China) was adopted to test the wetting angle between the coating material and the matrix at 950 °C. The phase composition was analyzed by an X-Ray diffractometer (XRD, Rigaku D/max 2200 ×, Rigaku, Japan). The microstructure of the coating was observed by scanning electron microscopy (SEM, JSM-6700F, JEOL, Japan).

3. Results and discussion

3.1. The wettability and interface between the anti-static coating and the matrix

Fig. 1a depicts the influences of ZnO/SnO_2 ratio on the wetting angle, the total adding amount of ZnO and SnO_2 was 30%. The wetting angle of the base glaze was 38.9°. When the ratio was 5%ZnO/25% SnO_2, the wetting angle increased drastically to 48.3°.

As the relative content shows an increase in ZnO and a decrease in SnO_2, the wetting angle decreased, when the ratio was 15%ZnO/15% SnO_2, the wetting angle decreased to 35.7°, which was below the base glaze wetting angle. The Young's Equation shows that the wetting angle increases with the increase in glaze melt's surface free energy and decreases with the surface free energy's decrease. There is a fluxing action with a small amount of ZnO, lower viscosity and higher mobility was realized by reducing the melting temperature and surface free energy of the glaze, thus reduce the wetting angle gradually and improve the wettability of glaze melt to the ceramic. As a high-valent metal oxide and a surface-inert material, SnO_2 will increase the surface tension of

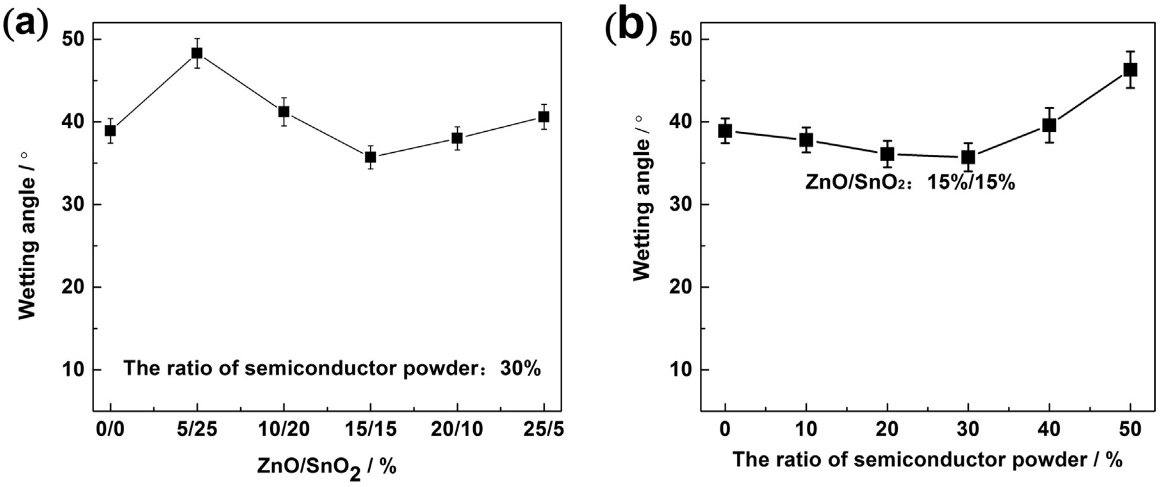

Fig. 1. Influence of the ratio of ZnO/SnO_2 (a) and the addition (b) on the wetting angle.