Oct 27th 2016

It has come to our attention that there have been concerns and discussions on the safety of ceramic coils recently. As the first company to apply porous ceramic for use with electronic cigarettes, here at Shenzhen Smoore Technology Limited, we have faith that the innovative ceramic heating element is a tremendous help in advancing the vaping industry forward.

As a leading designer and manufacturer of electronic cigarettes, we have been working closely with universities, research institutes on vaping base technology for years, actively implementing our findings into our line. .

The CCELL Ceramic Coils have been verified by rigorous tastings and optimized to assure its performance, safety and consistency. Our research started to take place as early as 4 years before applying into Vaporesso products.

We are delighted to share a scientific report on ceramic coil in the appendix which will explain in length the application of porous ceramic in different fields and focus on its application to electronic cigarettes.

We will continue to develop industry-leading products aimed at satisfying our customers. And we will never stop to taking vaping further!

**The Safety of Porous Ceramic Application to E-cigarette**

As a new-type of heating element material, ceramic is being widely applied in E-cigarette industry due to its advantages in terms of uniform heating, lifecycle, and taste improvement. With its application as a new material, people may be inevitably concerned about its safety. Its safety and reliability are discussed in this Paper through the production stages and operating status.

Porous ceramic is one kind of ceramic-like material, its microstructure is characterized by multiple pores, from nano scale to micron scale. With the development of new technologies in the recent years, porous ceramics and related products have become increasingly popular in people’s lives, due to its unique functions, superior absorptive property, higher resistance, and sustainable source: from bio-medical ceramics (such as skeletal and dental prosthetic materials)[1-4], to daily products such as facial masks and toothpaste, or water dispenser filtration purifiers, etc.[5-7] With its excellent performance and environmentally friendly appetency, porous ceramics has been gradually adopted by food industries, pharmaceuticals, biomedicine, space engineering, emissions control, and many other scientific areas[1-7].

Porous ceramics have accumulated a certain reputation by its long-term use in food and medical science, which have laid a solid foundation for its popularization and application in e-cigarette industry. As a new-generation ceramic coil of e-cigarettes, the advantages of porous ceramics mainly refer to the following aspects. Firstly, both the micron-level duct in porous ceramics and the minor contrast between ceramic material and e-liquid can provide effective for the absorption and conduction of e-liquid; Secondly, with higher specific heat capacity and heat conductivity, porous ceramic can retain certain heat and at the same time disperse the rest in an effective and uniform way, which can reduce the production of detrimental aldehydes materials; Porous ceramics also bear certain filtering capacity to effectively eliminate impurities and guarantee a pure taste. Ceramic coils have a high structural strength and heat stability: while the operating temperature of e-cigarettes rarely goes beyond 250℃, this material is made to withstand above 1,000℃ and can ensure that neither the chemical components nor the mechanical structure shall change while in use, making it more reliable and durable.

Though there is a wide variety of porous ceramics that are in use, the production and preparation process for them is quite similar, it generally consists of several critical processes[5], including mixing, molding, pore-forming and foaming, sinter molding and ultrasonic cleaning in later stages. Mixing some inorganic salt and raw materials with environmentally friendly adhesives in an sufficient way; molding refers to injection molding at certain temperature and pressure; sintering shall be performed at temperatures above 1,000°C to gain a steady microstructure and satisfy dimension control accuracy; sintering is followed by ultrasonic cleaning, which shall remove the tiny dust generated in the fabrication process. The safety of the raw materials and products can be guaranteed in each step of the processing and molding of porous ceramics.

The following images are respectively the microstructure of the biomedical ceramics and the ceramic coil of e-cigarettes after sintering

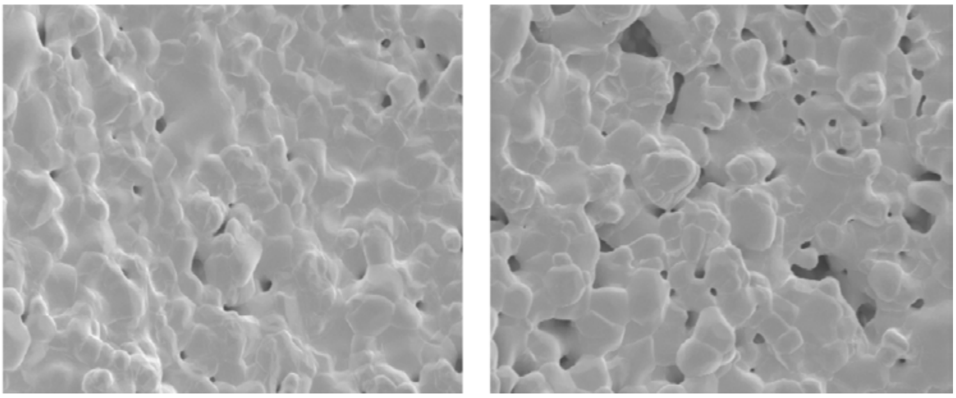

Image 1: SEM image of biomedical skeletal ceramic[8]

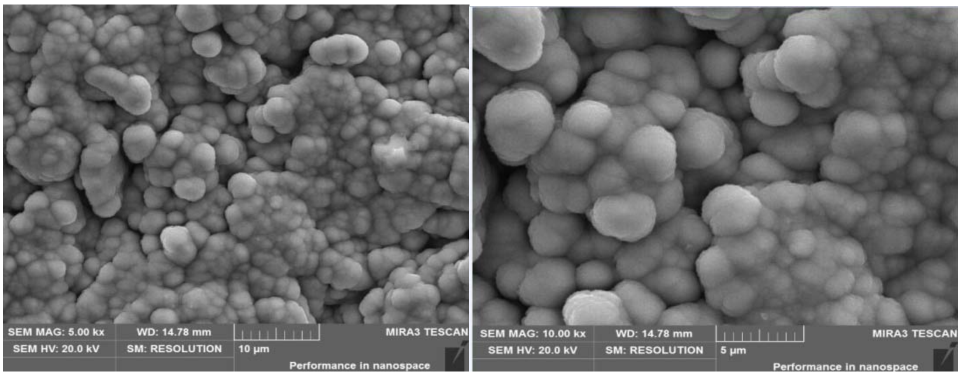


Image 2: SEM image of the ceramic coil as used in e-cigarettes

By comparison of the above images, we can see that they are quite similar in microstructure: featured by porous structure and tight grain boundary; the ceramic body of e-cigarettes has relatively larger porosity, but there's no obvious and essential difference in microstructure between the two.

The sintering raw material of the ceramic coil of e-cigarettes is food-grade inorganic salt powder which is mainly composed of the most abundant elements on earth, such as O, Si, Al and Fe, etc., without transition metal or heavy metal elements. It is still secure though in terms of the constituent of raw materials, and it is graded at the edible level. It is also proven that there are no heavy metal elements by RoHS security inspection (SCL01I037009) performed by a third party on the ceramic specimen after sintering, see Table 1 for the inspection method and results. Control of the particles size and distribution of raw material powder is enforced in a strict way to eliminate the source of micro dusts from raw materials; We raise the temperature during sintering in order to guarantee safety during use by increasing the inter-granular bounding force of the ceramic; Though the ceramic coil may inevitably absorb some particles and dust after sintering and molding, ultrasonic cleaning is introduced in later process, during which sonic vibration with certain frequency is adopted to generate bubbles in the tiny interspace of the object being cleaned, and cleaning of the interspace can be realized by the shock wave generated by the swelling, bursting and closing of the bubbles. The micro powder particles in the interspace of the ceramic coil can be eliminated in a quite effective way by repeated exploration of the parameters, such as ultrasonic frequency and vibration time.

Table 1 ROHS Inspection Method and Results of Ceramic Coil

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**Test Method**

| Tested Item(s) | Test Method | Measured Equipment(s) |
|---|---|---|
| Lead(Pb) | IEC 62321-5:2013 Ed.1.0 | ICP-OES |
| Cadmium(Cd) | IEC 62321-5:2013 Ed.1.0 | ICP-OES |
| Mercury(Hg) | IEC 62321-4:2013 Ed.1.0 | ICP-OES |
| Hexavalent Chromium(Cr(VI)) | IEC 62321:2008 Ed.1 Annex C | UV-Vis |
| | IEC 62321-7-1:2015 | |
| Polybrominated Biphenyls(PBBs) | IEC 62321-6:2015 | GC-MS |
| Polybrominated Diphenyl Ethers (PBDEs) | IEC 62321-6:2015 | GC-MS |

**Test Result(s)**

| Tested Item(s) | Result | | | MDL | Limit of Directive 2011/65/EU |
|---|---|---|---|---|---|
| | (1) | (2) | (3) | | |
| Lead(Pb) | N.D. | N.D. | N.D. | 2 mg/kg | 1000 mg/kg |
| Cadmium(Cd) | N.D. | N.D. | N.D. | 2 mg/kg | 100 mg/kg |
| Mercury(Hg) | N.D. | N.D. | N.D. | 2 mg/kg | 1000 mg/kg |
| Hexavalent Chromium(Cr(VI)) | --- | N.D. | N.D. | 2 mg/kg | 1000 mg/kg |
| | N.D.▼ | --- | --- | 0.10μg/cm²(LOQ) | |

In order to explore whether the ceramic coil of e-cigarettes can produce and extract micro power particles during working, simulation analysis and experimental data collection can be performed on the working condition when e-cigarettes are atomizing. During the inhaling phase, the ceramic coil is heated through battery power supplied to atomize the e-liquid.

The influences caused on the ceramic coil during the process of heating and atomization when the e-cigarette is in working condition mainly refer to:

1) Influence on the mechanical strength by repeated heat shock:

The temperature of heater coil is within 320℃ when the e-cigarette is in working condition, which is far lower than the sintering temperature (above 1000℃) of the ceramic, and the normal inhalation time is under 10s, which won't be enough to cause any modifications on the structure and mechanical property. For long-term structural reliability demonstration, experiment evaluations can be performed on the reduction status in flexure strength of ceramics before and after heat shock according to Hasselman theory[9]. The flexure strength of our ceramic coil only dropped by 1% after 10 quenching at the temperature of 320℃, which is still higher than 45 barometric pressure shocks. The actual temperature in use is below 320℃, and the heat stress during heating and atomization is far insufficient to destroy the mechanical structure and further cause broken and detached components. The micron-level duct in the ceramic coil structure make it easy to diffuse the heat all around to release heat and stress in case there's any overheating.

2) Structure stability with long-term immersion in e-liquid

The oxide of ceramic coil shall not produce chemical action with e-liquid due to its chemical inertness, which has ensured the chemical and structural stability of the ceramic coil by long-term immersion in e-liquid in theory. In addition, it is found by immersion test that the strength of ceramic coil has only dropped by 3% or so after immersing for 3 months at the temperature of 200℃. Therefore, the immersion of e-liquid shall not have obvious influence on the stability of ceramic.

3) As for influence on ceramic particles by air pumping and inhaling flow rate

According to the standards of tobacco industry ISO 3308:2000, the average of smoking flow rate is 17.5 ml/s, and it can be calculated that the steam flow rate when smoking is 2 to 5 m/s based on the universal airflow tube sectional area of e-cigarettes, and this wind speed equals gentle breeze of 2 to 3 grade. Suppose that a ceramic particle whose diameter is 40um is to be tested during smoking, the necessary wind speed can be calculated by simple physical model (Figure 3). Suppose that there no constraint with the particles, and the wind power is only to overcome the gravity of ceramic particles.

By force balance equation and momentum conservation:

1): $F_{wind} = m_{ceramic} \times g$；

2): $F_{wind} \times t = m_{wind} \times V_{wind}$

$m_{wind} = V_{wind} \times \rho_{wind}$

$V_{wind} = S \times L$；

S is the action area and L is the movement distance of wind

$V_{wind} = L/t$;t is action time

Bring it to formula 2), we can get: $V_{wind}^2 = m_{ceramic} \times g/(S \times \rho) = 2/3\ D \times (\rho_{ceramic}/\rho\ air) \times g$

$V_{wind} > 22.4$m/s.

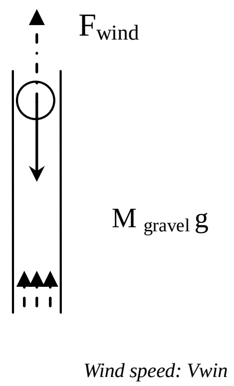


Figure 3: force analysis of particles

This wind speed equals the speed of 7 to 8 grade wind, which is far greater than the smoke flow rate during the inhaling of e-cigarettes. From this perspective, suppose that there are ceramic particles on the bottom of e-cigarettes, the airflow rate generated during suction cannot bring the particles out of the chamber. Moreover, there's strong chemical bond resultant force between the internal crystal of the ceramic body after high sintering, and the strength of ceramic body is typically above Mpa level. The airflow brought by the suction on e-cigarettes needs to destroy the ceramic microstructure with the action of the force that is far greater than the gravity of the particle itself. The acting force on the ceramic coil by the airflow generated by inhalation is quite weak and cannot destroy the microstructure of ceramic body.

In order to further prove whether ceramic particles can be inhaled when vaping the ceramic coil, we have added cellulose ester filter on the outlet (driptip) of the product and calculate the weight change of the filter and observe the particles by vaping for 25 puffs in the velocity of 55mL/3s. The test results (MVA11333) from the authorized third party in America are as following:

| Pre Weight Filter (g) | Post Weight Filter (g) | Filter Mass Gain (g) | Puff Count |
|---|---|---|---|
| 27.0650 | 27.2584 | 0.1934 | 1-25 |

The weight of the filter has increased by 0.1934g after vaping for 25 puffs, and no particles have been found by the observation with 40 times amplifying optical microscope whose resolution ratio is up to 5um, and the increased weight is the result of the liquid drops coagulated after the atomization of e-liquid.

In conclusion, the particles and dust of the ceramic coil are under control and there's no doubt that the safety of ceramic coils can be guaranteed by the strict control of the production process of ceramic body, powder removing of the ceramic coil by ultrasonic cleaning with different frequency ranges after molding, and structure reliability and stability of the ceramic coil of e-cigarettes in working condition and under airflow environment.

Of course, we are willing to face and receive the discussion of the problems brought by the updating of e-cigarettes technology, since discussion itself is a kind of inspection and supervision, which shall facilitate us to continuously boost the technology research and development and focus more on the safety and reliability of our products. We shall step forward practically and steadily and be responsible for the consumer with emphasis on their health.

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