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Kitchen knife blade made from ceramic

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Abstract. The kitchen knife blades currently on the market are divided into metal blades and ceramic blades, and the performance of ceramic blades is better than that of metal blades. According to the performance of the blade, Yttria-steaded zirconia ceramic material is the most suitable to be made into ceramic blade. Zirconia ceramics have good mechanical properties, anti-corrosion, not easy to leave odor and light weight. The only disadvantage of zirconia ceramics is its high cost, but it can be recycled and reused later to reduce costs.

Keywords: ceramic knife blade, zirconia, yttrium oxide.

1. Background

The kitchen knife is a kitchen essential, the main purpose is to cut the ingredients. The kitchen knife consists of a handle portion and a blade that is fixed to the handle portion which shows in figure 1[1]. The materials for kitchen knife blades in the market are: carbon steel, stainless steel, alloy steel and ceramics. Ceramic knives are more popular than other kitchen knives because of their better mechanical properties. First of all, the ceramic blade is almost as hard as a diamond, so the cutting edge of the ceramic knife is harder than the metal knife and has a long service life, and does not need to be sharpened, but the blade will eventually degenerate or chip. Due to these advantages ceramic knives are ideal for cutting meat, vegetables and fruits and even bread into thin slices. Second, ceramic blades are antifouling. Because the ceramic knife is not porous, the blade will not be soiled or retain the odor of the food. For example, after cutting the onion, simply rinse the blade with water and continue to use without odor being transferred. Third, ceramic knives are lighter than metal knives. Fourth, ceramic knives have better rust resistance, and metals tend to rust in air and water environments, but ceramics are non-reactive[2]. But ceramic knives also have some drawbacks. Ceramic knives cannot be used to cut hard foods such as frozen foods, bones and anything that is not easily cut into thin slices.

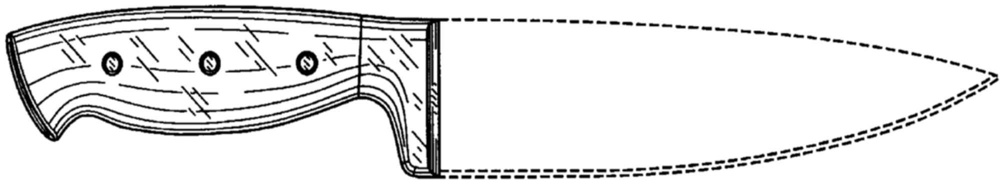

Figure 1 Kitchen knife [3]

2. Material property requirements

First of all, ceramic blades should have good mechanical properties as well as chemical properties. The properties that the material needs to follow [4]:

1. High hardness
2. Chemical stability that prevents reaction with the work material
3. High mechanical strength

Secondly, need to consider whether the blade design is safe and will not cause damage to the human skin. As shown in the figure 2, in the design of conventional blades, a smaller angle is used,

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which can result in a longer blade and a sharper cutting area, which is more susceptible to injury for the user. Because the skin outside the body is hard, and the inner skin is soft. So ,you can change the angle to move the blade's strength to the tough outer layer of the skin, reducing the probability of user injury [5-6].

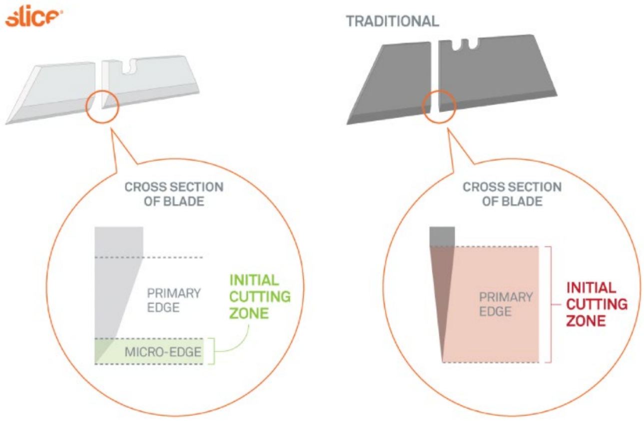

Figure 2 Comparison of previous and current blade designs [5].

3. Composition And Microstructure

Considering the cost of the material, if the cost is low, then the ceramic blade has a long service life, so the mechanical properties of the ceramic blade are good. Since the ceramic material itself has anti-corrosion properties, the mechanical strength of the ceramic blade is mainly considered from three aspects. First of all, the ceramic material needs to be deformed by its Young's modulus of elasticity, because the modulus of elasticity is an index to measure the ease with which the material is elastically deformed. The larger the value, the greater the stress that causes the material to undergo some elastic deformation, that is, the material. The greater the stiffness, that is, the smaller the elastic deformation occurs under a certain stress. The Young's modulus of elasticity is in the range of less than 220 GPa. Second, considering the fracture toughness, since the kitchen knife needs to cut the food, for example, the frozen food is prone to breakage. Fracture toughness characterizes the ability of a material to resist crack propagation and is a quantitative indicator of the toughness of a material. When the crack size is constant, the larger the fracture toughness value of the material, the greater the critical stress required for the crack instability and expansion. When the external force is given, if the fracture toughness value of the material is higher, the crack reaches the instability expansion. The larger the critical size. Therefore, when the critical dimension is known, the loss of material can be avoided. The critical maximum value is set to 9.2 MPa·m^0.5. Finally, considering its hardness. According to the Wikipedia, the Mohs scale of mineral hardness is 8.5.The greater the hardness value, the better the performance. So, the maximum hardness is set to 1.47e3Hv[7].

Therefore, zirconia was chosen as the material for ceramic blades [8]. But, zirconia has a variety of forms. It exists in three phases: monoclinic, tetragonal and cubic. Since the cooling to the monoclinic phase after sintering causes a large change in volume, the stress in the zirconia is broken. Additives are needed to stabilize the high temperature phase to minimize volume changes. By selecting yttrium oxide as an additive, the addition of 3.5-6 wt% yttrium oxide gives zirconia better strength and toughness, resulting in partial stabilization. So, the best chose is Yttria-steaded zirconia with a mixture of tetragonal and cubic phases（fig.3）, not yttria stabilized tetragonal zirconia. Because , zirconia (Y-TZP) is mainly used for bearing surfaces, magnetic tape cutters and reciprocating ic engines-cylinder liners, and its aging temperature is too low to be suitable for high-temperature foods [9-11].

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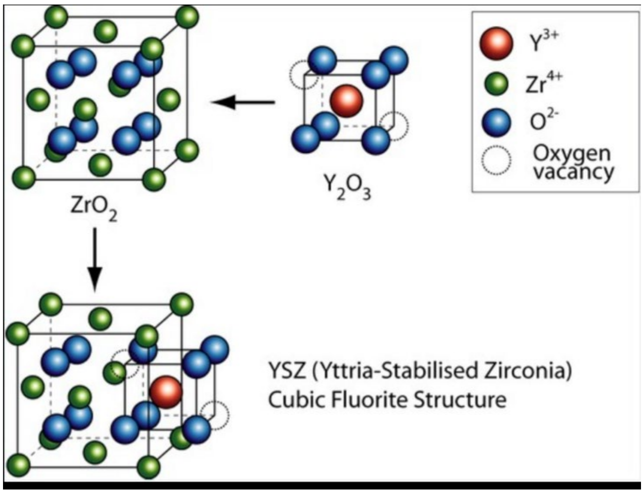

Figure 3 Yttria-stabilized zirconia (YSZ) crystal structure (Wikipedia)

4. Materials Synthesis and processing

There are many ways to synthesize ceramics, but we mainly use the common uniaxial press method to produce ceramic inserts [4]. The method is as follows (fig 4) : First, a cerium oxide additive is added to the zirconia material, and then mixed with a binder to form a slurry. The slurry is then spray dried using a spray dryer through which particles of a specified size are produced. The pellets are then poured into a designated mold and shaped by applying a specified pressure to the top and bottom. Finally, the material is dewaxed and then sintered at 2000 ° C to obtain an yttria-stabilized zirconia ceramic material.

Then, the ceramic material is machined into a previously designed shape using a diamond grinder to make the ceramic part. It is then fixed by insert molding, screwing or bonding to a handle made of resin, metal or wood. This will give you a complete ceramic knife.

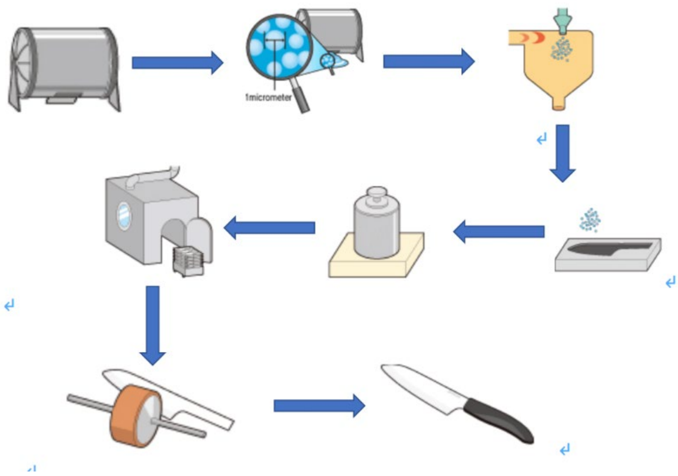

Figure 4 the manufacture process [12]

The microstructure of the material changes during processing. The microstructure is affected by the cooling rate, droplet size, maximum undercooling(before nucleation) and melt cleanliness. Firstly, melt cleanliness can impact on nucleation. Then, cooling rate can define the potential for rapid solidification. When rapidly condensing, as the volume of solids increases, latent heat release becomes remarkable, and re-agglomeration can be observed. So, controlling the cooling rate can control the rate at which the volume increases. The control cooling rate is around 330 ms-1[13].

Thirdly, droplet size allow can influence number of nucleation points or cooling rate.

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5. Final product properties

The final microstructure of the zirconia ceramic is shown in Fig. 5. The zirconia particles are bonded together by a binder，the final microstructure of the zirconia ceramic is shown in Fig. 5. The zirconia particles are bonded together by a binder. Starting with the analysis of the surface of the ceramic knives, the ceramic blades on the market today are colorful, which is obtained by sintering. For example, the most common white ceramic inserts are sintered without pressure. These are called white ceramics and are relatively inexpensive. Another most common black ceramic insert is by adding carbide and then sintering by hot pressing and HIP. Black ceramic inserts are more expensive because of the complexity of the process. Ceramic knives are sharp based on the design of ceramic knives, but the ceramic knives are less harmful to the skin by changing the angle. It is then analyzed from the properties of the material. Adding an additive during processing, and then sintering the zirconia material has good chemical stability, wear resistance and corrosion resistance. The ceramic knives are hand-polished using diamond, and each face is evenly curved inward, which ensures the strength of the ceramic knives to the utmost, while ensuring smoothness during cutting. The use of diamond hand-polished blade and knife surface is uniform, the finish is extremely high, it is easy to clean, and it is not easy to hide dirt, so that the ceramic blade will not leave odor. Because of the low density of the material, ceramic knives are lighter in weight and easier to handle[4,14].

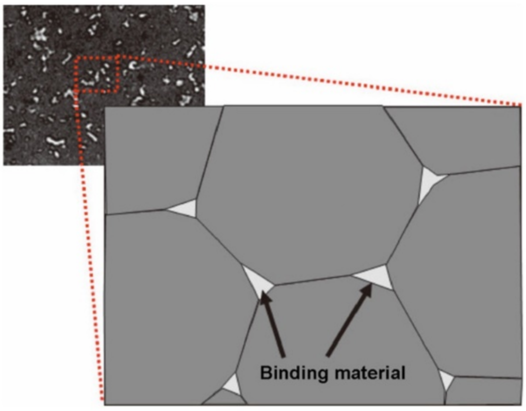

Figure 5 The microstructure of Yttria-stabilized zirconia [4].

6. Processing and quality control

Performance testing of ceramic inserts by instrument. First of all, using the Vickers macrohardness test to measure the material hardness. The standard Vlckers test employs a single crystal diamond cut to a squat square-based pyramid with an angle of 136。 between opposing faces. This is loaded into the surface at a prescribed displacement rate, held for a period of 8 s and removed. For ceramics, the wedging action is far too severe and will fracture small pieces of many materials. It is necessary to limit the load considerably. Most commercial machines have the capability of employing loads of 10, 5, 2.5 and 1 kg. Many experiences of hardness testing have shown that 2.5 kg should be considered the maximum acceptable load to avoid gross fracture of most ceramic materials [15].Secondly, the corrosion resistance of the material can be tested by gravimetric method. By measuring the change of the weight of the material before and after corrosion, the corrosion resistance of the material can be accurately and credibly characterized.

Pay attention to the sintering process during the processing. Pay attention to controlling the cooling rate, droplet size and melt cleanliness. These three factors will affect the microstructure of the material and affect the mechanical properties and chemical stability of the material. So, powder sintering is the most important step in the entire process.

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7. Sustainability

Exhaust gas containing productive powders is produced during processing. Some of the gas is from the process of drying the slurry into powder particles by a spray dryer. Other waste is from the process of sintering at high temperatures. Since these exhaust gases are polluted into the air, the exhaust gas can be recovered, the powder in the exhaust gas can be collected, and then the powder can be cleaned and processed as a raw material, which can reduce production costs and reduce environmental pollution. There is solid waste generated during the polishing process. If the direct disposal increases the amount of garbage accumulation and increases the cost, the waste can be recycled and reused to reduce the cost.

Ceramic knives have a service life 10 times that of metal blades. And the ceramic insert can be recycled again, thanks to its corrosion resistance and chemical stability. The surface of the ceramic insert can be sanded first, then smelted, and cast to produce new parts.

8. Summary

Finally, zirconia is selected as the raw material for the manufacture of ceramic blades, yttrium oxide is added for stabilization, and then the powder sintering method is used to enhance the mechanical properties of the material. The conditions in this article are set in the kitchen knife, and the cost needs to be moderate. Although the unit price of zirconia is high, the overall cost can be reduced by recycling the waste. The ceramic knife is light and slender, and it is easy to use. It will not hurt to use the wrist for a long time. The ceramic blade has no pores and does not easily leave bacteria, grease, etc. like a metal knife, and does not leave odor. The ceramic blade itself is easy to clean. Because ceramic knives are made of ceramics, they will not rust like iron, will not be corroded, and will not pollute food and oxidize fruits and vegetables. The biggest advantage of ceramic inserts is that they do not passivate and need to be polished. Because of the material and process, ceramic knives have superior hardness and wear resistance, which is more than 10 times that of ordinary stainless steel knives. Because of the ultra-high hardness of the ceramic knives, the trouble of repeated honing is eliminated, and the sharpness remains longer. In general, ceramic blades last longer than other metal blades and are easy to operate, so more and more people choose ceramic knife as their kitchen knife.

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