SUMMARY

**[0004a]** In an aspect of the present disclosure, there is provided a method for preparing high-density magnesia-alumina spinel ceramic by low-temperature pressureless sintering, comprising:

using $MgAl_2O_4$ powder as a raw material powder, adding calcium phosphate as a sintering aid and controlling the calcium element of the calcium phosphate to not exceed 500 ppm of the total mass of the raw material powder; and then

performing pressureless sintering, thereby preparing a high-density magnesia-alumina spinel ceramic; the pressureless sintering includes normal pressure sintering or vacuum sintering, wherein

the composition of the calcium phosphate comprises at least one of $Ca_{10}(PO_4)_6(OH)_2$, $Ca_3(PO_4)_2$, $Ca_4O(PO_4)_2$, $Ca_{10-X}H_{2X}(PO_4)_6(OH)_2$, $Ca_8H_2(PO_4)_{6.5}H_2O$, $CaHPO_4{\cdot}2H_2O$, $CaHPO_4$, $Ca_2P_2O_7$, $CaP_2O_7{\cdot}2H_2O$, $Ca_7(P_5O_{16})_2$, $Ca_4H_2P_6O_{20}$, $Ca(H_2PO_4)_2{\cdot}H_2O$, and $Ca(PO_3)_2$,

a pressureless sintering temperature is 1,360 °C to 1,460 °C, and

a pressureless sintering time is not longer than 20 hours.

**[0004b]** In another aspect of the present disclosure, there is provided a method for preparing high density magnesia-alumina spinel ceramic by low-temperature pressureless sintering, comprising:

using MgO powder and $Al_2O_3$ powder as a raw material powder, adding calcium phosphate as a sintering aid and controlling the calcium element of the calcium phosphate to not exceed 500 ppm of the total mass of the raw material powder; and then

performing pressureless sintering, thereby preparing a high-density magnesia-alumina spinel ceramic; the pressureless sintering includes normal pressure sintering or vacuum sintering, wherein

the composition of the calcium phosphate comprises at least one of $Ca_{10}(PO_4)_6(OH)_2$, $Ca_3(PO_4)_2$, $Ca_4O(PO_4)_2$, $Ca_{10-X}H_{2X}(PO_4)_6(OH)_2$, $Ca_8H_2(PO_4)_{6.5}H_2O$, $CaHPO_4{\cdot}2H_2O$, $CaHPO_4$, $Ca_2P_2O_7$, $CaP_2O_7{\cdot}2H_2O$, $Ca_7(P_5O_{16})_2$, $Ca_4H_2P_6O_{20}$, $Ca(H_2PO_4)_2{\cdot}H_2O$, and $Ca(PO_3)_2$, and

a pressureless sintering temperature is 1,360 °C to 1,460 °C, and a pressureless sintering time is not longer than 20 hours.

TECHNICAL PROBLEM

**[0005]** Adding sintering aids to a magnesia-alumina spinel ceramic raw material is a common means to promote sintering, reduce a sintering temperature, inhibit grain growth, and achieve

better mechanical, optical, and high temperature properties. Over the years, a variety of sintering aids such as CaO, $CaCO_3$, LiF, $B_3O_2$, $MgF_2/AlF_3$, $TiO_2$, $V_5O_2$, $Cr_2O_3$, $Y_2O_3$, $MnO_2$, $ZrO_2$, $CoCO_3$, and so on have been developed and used to reduce the sintering temperature of the magnesia-alumina spinel ceramic, which have shown a certain effect. At the same time, there are also some sintering aids that can provide an effective assistance for improving the transmittance of the transparent ceramic. However, in general, these sintering aids also have some shortcomings to a greater or lesser extent. Some sintering aids have no significant effect in reducing the sintering temperature. Some sintering aids may react with the raw material to generate impurities (for example, CaO or $CaCO_3$ reacts with magnesia-alumina spinel to form $CaAl_4O_7$ phase). Some sintering aids require a higher content to be added, affecting the intrinsic properties of the ceramic material.

**[0006]** Therefore, developing a novel sintering aid that can be used to reduce the sintering temperature of the magnesia-alumina spinel ceramic, slow down its grain growth, and obtain a magnesia-alumina spinel ceramic with an excellent mechanical and a high temperature property, is of great value for obtaining a transparent magnesia-alumina spinel ceramic with excellent mechanical, high temperature, and optical properties.

TECHNICAL SOLUTION

**[0007]** Regarding the above issues, a first aspect of the present invention provides a method for preparing a high-density magnesia-alumina spinel ceramic by low-temperature pressureless sintering, comprising using $MgAl_2O_4$ powder as a raw material powder, adding calcium phosphate as a sintering aid and controlling calcium element of the calcium phosphate to be not higher than 500 ppm of the total mass of the raw material powder, and then performing pressureless sintering to achieve the preparation of the high-density magnesia-alumina spinel ceramic. Preferably, the composition of the calcium phosphate includes at least one of $Ca_{10}(PO_4)_6(OH)_2$, $Ca_3(PO_4)_2$, $Ca_4O(PO_4)_2$, $Ca_{10-X}H_{2X}(PO_4)_6(OH)_2$, $Ca_8H_2(PO_4)_{6.5}H_2O$, $CaHPO_4 \cdot 2H_2O$, $CaHPO_4$, $Ca_2P_2O_7$, $CaP_2O_7 \cdot 2H_2O$, $Ca_7(P_5O_{16})_2$, $Ca_4H_2P_6O_{20}$, $Ca(H_2PO_4)_2 \cdot H_2O$, and $Ca(PO_3)_2$. The pressureless sintering is atmospheric pressure sintering or vacuum sintering.

WHAT IS CLAIMED IS:

1. A method for preparing high-density magnesia-alumina spinel ceramic by low-temperature pressureless sintering, comprising:

using $MgAl_2O_4$ powder as a raw material powder, adding calcium phosphate as a sintering aid and controlling the calcium element of the calcium phosphate to not exceed 500 ppm of the total mass of the raw material powder; and then

performing pressureless sintering, thereby preparing a high-density magnesia-alumina spinel ceramic; the pressureless sintering includes normal pressure sintering or vacuum sintering, wherein

the composition of the calcium phosphate comprises at least one of $Ca_{10}(PO_4)_6(OH)_2$, $Ca_3(PO_4)_2$, $Ca_4O(PO_4)_2$, $Ca_{10-X}H_{2X}(PO_4)_6(OH)_2$, $Ca_8H_2(PO_4)_{6.5}H_2O$, $CaHPO_4 \cdot 2H_2O$, $CaHPO_4$, $Ca_2P_2O_7$, $CaP_2O_7 \cdot 2H_2O$, $Ca_7(P_5O_{16})_2$, $Ca_4H_2P_6O_{20}$, $Ca(H_2PO_4)_2 \cdot H_2O$, and $Ca(PO_3)_2$,

a pressureless sintering temperature is 1,360 °C to 1,460 °C, and

a pressureless sintering time is not longer than 20 hours.

2. The method according to claim 1, wherein

the method further comprises subjecting the raw material powder to forming to a green body before the pressureless sintering, and

the forming method is dry molding or wet molding.

3. The method according to claim 1, further comprising subjecting the obtained high-density magnesia-alumina spinel ceramic to hot isostatic pressing sintering to obtain a transparent magnesia-alumina spinel ceramic.

4. The method according to claim 3, wherein a hot isostatic pressing sintering temperature is 1,350 °C to 1,800 °C, a hot isostatic pressing sintering pressure is 50 MPa to 200 MPa, and a hot isostatic pressing sintering time is not longer than 20 hours.

5. A method for preparing high density magnesia-alumina spinel ceramic by low-temperature pressureless sintering, comprising:

using MgO powder and $Al_2O_3$ powder as a raw material powder, adding calcium phosphate as a sintering aid and controlling the calcium element of the calcium phosphate to not exceed 500 ppm of the total mass of the raw material powder; and then

performing pressureless sintering, thereby preparing a high-density magnesia-alumina spinel ceramic; the pressureless sintering includes normal pressure sintering or vacuum sintering, wherein

the composition of the calcium phosphate comprises at least one of $Ca_{10}(PO_4)_6(OH)_2$, $Ca_3(PO_4)_2$, $Ca_4O(PO_4)_2$, $Ca_{10-X}H_{2X}(PO_4)_6(OH)_2$, $Ca_8H_2(PO_4)_{6.5}H_2O$, $CaHPO_4 \cdot 2H_2O$, $CaHPO_4$, $Ca_2P_2O_7$, $CaP_2O_7 \cdot 2H_2O$, $Ca_7(P_5O_{16})_2$, $Ca_4H_2P_6O_{20}$, $Ca(H_2PO_4)_2 \cdot H_2O$, and $Ca(PO_3)_2$, and

a pressureless sintering temperature is 1,360 °C to 1,460 °C, and a pressureless sintering time is not longer than 20 hours.

6. The method according to claim 5, wherein the molar ratio of the MgO powder to $Al_2O_3$ powder is 1: (0.98 to 2.2).

7. The method according to 5, wherein the method comprising: subjecting the raw material powder to forming a green body before pressureless sintering; wherein, the forming method is dry molding or wet molding.

8. The method according to claim 5, wherein the method further comprises: subjecting the obtained high-density magnesia-alumina spinel ceramic to hot isostatic pressing sintering to obtain a transparent magnesia-alumina spinel ceramic.

9. The method according to claim 8, wherein a hot isostatic pressing sintering temperature is 1,350 °C to 1,800 °C, a hot isostatic pressing sintering pressure is 50 MPa to 200 MPa, and a hot isostatic pressing sintering time is not longer than 20 hours.