Highly ordered mesoporous high-k dielectric magnesium niobate with high surface area

THE INVENTION

First successful attempt toward the synthesis of highly ordered mesoporous magnesium niobate (Mg : Nb = 1 : 2 molar ratio) via the Evaporation Induced Self-Assembly (EISA) method. A pure magnesium niobate phase with a well-defined mesoporous structure is achieved in a reproducible manner already after 3 days of gelation time.

Innovative aspects and advantatges

> High specific surface area (169 m^2/g)

> Low temperature fabrication

> High dielectric constant (k ~ 25 at 1 MHz)

> Hexagonal arrays of pores with tunable pore sizes (unimodal distribution arrangement).

> High mechanical stability: hardness value of 340 ± 20 MPa and a Young's modulus of 12.5 ± 1.0 GPa.

> Synthesis is fully up-scalable and cost-effective

IP Rights

PCT/IT2013/000179
Current validation in Europe, China, Japan and the US

Scientific Team

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Summary

Highly ordered mesoporous ternary Mg–Nb oxide powder was successfully synthesized by the Evaporation Induced Self-Assembly (EISA) method. The niobate shows 2D-hexagonal pore periodicity, with unimodal pore size distribution centered at 5.5 nm (see Fig. 1). The material exhibits a large surface area of 169 $m^2 g^{-1}$, which represents the highest value reported so far for the $MgNb_2O_6$ columbite phase. The mechanical properties, determined by means of nanoindentation, are consistent with the presence of ordered domains of honeycomb-like hexagonal pore arrangements, in agreement with electron microscopy observations and N_2 sorption isotherm analyses. The dielectric constant of the mesoporous $MgNb_2O_6$, measured at room temperature in the frequency range 1 kHz to 1 MHz, is rather high (k = 25 at 1 MHz) and correlates well with the k value of the bulk and the porosity level of this material. Moreover, the porosity can be easily tuned in order to modulate the dielectric properties of the material.

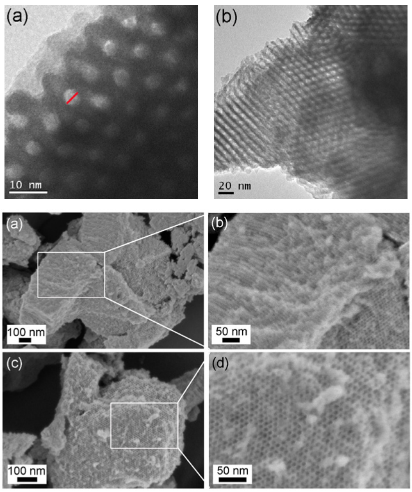

Fig. 1 TEM images at different magnifications of the Mg-Nb oxide after calcification

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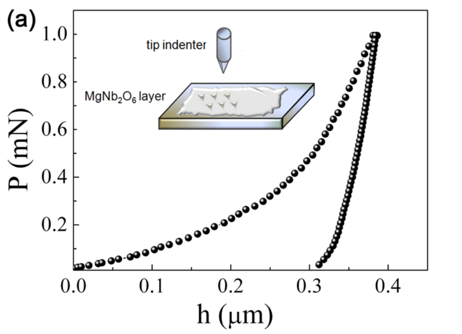

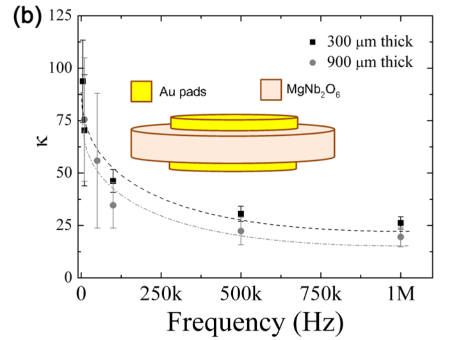

Fig. 2 (a) representative load (P)-displacement (h) nanoindentation curve with a schematic picture of the indentation process.

(b) Variation of the dielectric constact (k) with frequency, at room temperature and a schematic representation of the Metal-Insulator-Metal structure.

Background

The unprecedented growth of advanced mobile and wireless communication technologies has prompted the demand for new types of high-performance, low-cost dielectric ceramic materials. The so-called "high-k dielectrics" have revolutionized the wireless and microwave communication industry by rendering an enhanced gate capacitance while circumventing the detrimental tunneling current leakage arising from the use of increasingly thinner oxide barrier layers in miniaturized electronic devices. Mg and Nb based oxides have attracted much attention due to their high dielectric constants, low cost, high efficiency and ease of availability, as compared to conventional Ta_2O_5, $SrTiO_3$ and related complex perovskites.
Alternative synthetic routes to prepare magnesium niobate with nanoscale morphology control, high surface area and mechanical stability is highly desirable.

Applications

The here-presented highly-ordered magnesium niobate powder can be used in various fields of technological interest. Specifically, it is very well suited as:

(i) A dielectric material for capacitors.

(ii) Host for hydrogen confinement and, in general, energy storage.

(iii) Dopant in PZT ferroelectric system.

Stage of development

The ability to tune on-demand the pore size of $MgNb_2O_6$ powder while keeping the long-range order of the mesopores, makes the material appealing for several applications. In particular, the dielectric properties of the material can be easily tuned by varying the pore size and the pore wall crystallinity. For further details on the synthesis and characterization of material properties, kindly refer to Journal of Materials Chemistry C 1 (2013) 4948- 4955. Currently, $MgNb_2O_6$ role as dopant on piezoelectric PZT ceramics is being tested. Meanwhile, the realization of prototypes is under progress.

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