Aqueous Method to Produce Cubic Hafnia or Hafnia-Zirconia Nanoparticles

Technology #m08-038

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Hafnia in its Cubic Phase of NanoParticle Form Expensive, Selective: Hafnium oxide (hafnia) and zirconium oxide (zirconia) are very similar materials with potential use in catalysis, ceramics and refractory materials. Hafnia especially has ultra high permittivity which makes it useful as gate oxide in field effect transistors. Currently atomic layer deposition (ALD) techniques are being used to deposit hafnia for CMOS electronics. Though ALD delivers ultra high quality hafnia films, the process can not be used for applications that demand low deposition temperatures as well as lower operation costs. Hafnia also has promising use in composite dielectrics if it can sustain the high permittivity in nanoparticles form.

A major roadblock for the use of hafnia in nanoparticle form is its solely monoclinic phase existence at room temperature. This particular phase has less permittivity than the desired cubic phase. Existing solutions to this problem either require near-vacuum conditions or are substrate dependent, making their use costly as well selective. Hence there is a need for a scalable, low cost process which can deliver hafnia or zirconia nanoparticle in a stable cubic phase at room temperature.

Technology Allows Hafnia and Hafnia-Zirconium Nanoparticles to Exist in Cubic Phase: The invention describes a process for preparing hafnia and hafnia-zirconia nanoparticles which are stable in the cubic phase at room temperature. The technique uses control on nanoparticle sizes and annealing conditions to manipulate their phase. The process utilizes the novel use of HMT (Hexamethylenetetramine) in enriching the reducing atmosphere and also helping in slowing down the coarsening of nanoparticles. Structurally cubic hafnia nanoparticles of diameters 5 nm can be achieved with the process.

Applications: • Novel ceramics, catalysts, refractory and super hard materials • Organic thin film transistors, here solution processed cubic phase hafnia nanoparticles can easily be deposited or spun as a dielectric layer at room temperature • Composite high-k materials for ultra capacitors, these nanoparticles can be mixed with polymers to achieve high-k material with high breakdown voltages also. These composites can then also be used as gate dielectrics in organic FET and in super capacitors. • Due to extreme hardness and wear resistance they can be used in chemical mechanical polishing slurry • In die sensitized solar cells as wide band gap semiconductor • Controlled phase hafnia nanoparticles will be extremely useful in applications involving high refractive indexes, like laser powered mirrors

Advantages: • Simple process that achieves cubic phase, high permittivity hafnia/zirconia nanoparticles • Useful for applications requiring room temperature dielectric film depositions • Invention gives a clue in achieving phase control in nanoparticles of other materials by varying the particle size and reducing conditions • Low cost

Related Publications: J. Appl. Phys. 103, 124303 (2008)”
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