

## NANO CELLULOSE REINFORCED ALUMINA AND ZIRCONIA CERAMIC COMPOSITES WITH IMPROVED MECHANICAL AND ELECTRICALLY CONDUCTIVE PROPERTIES

### Fields of use

Nanotechnologies related to electronics & microelectronics, Machining (turning, drilling, moulding, planning, cutting), Machining, fine (grinding, lapping), Ceramic Materials and Powders, Composite materials, Microwave and satellite components, Semiconductors, Chemical and solid material recycling, Engineering services

### Current state of technology

Prototype available for demonstration

### Type of cooperation

License and technical cooperation agreement

### Intellectual property

Patent(s) applied for but not yet granted

### Developed by

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### Summary

A Slovenian and a Spanish research organization have developed a new type of alumina and zirconia ceramics with improved mechanical and electrically conductive properties achieved by nano-particulated cellulose filler. Complex shaped machining as well as electro-discharge machining is possible due to improved properties. Producers of ceramics, especially for automotive and biomedical applications are sought for licensing and technical cooperation.

### Description of the invention

Products of alumina and zirconia ceramics such as moulds, resistors, electrodes, heating elements, resonators etc. are not only designed to operate in harsh environments but also produced in harsh environments undergoing complex shaping or non-conventional shaping techniques (e.g. electro discharge machining or green body machining). Therefore, the capability of these materials to resist high levels of electric and mechanical stress is crucial.

During the course of scientific collaboration on fire retardant foams Slovenian and Spanish research organizations invented new formulation for carbon fibre reinforced and electrically conductive alumina and zirconia ceramics.

The core of invention is insoluble cellulose nanoparticulated material added as a filler to aqueous ceramic suspension followed by optimized steps of drying, green body formation and sintering to form reinforced electrically conductive ceramic article. This filler is - unlike hydrophobic carbon fillers (e.g. carbon nanotubes or carbon black allows) that are already on the market – composed of natural insoluble but hydrophilic nanoparticles (nanofibres and nanorods) of cellulose that are mixed into the aqueous solution of ceramic particles and consolidate their matrix.

The insolubility and nano-size of these hydrophilic nano-cellulose particles enable their homogeneous distribution across the ceramic matrix which is then dried and pressed into the green body preserving the homogeneous distribution of cellulose and ceramic nanoparticles across the material. This homogeneous distribution enables the filler to be added at smaller quantities making the green body stronger and more resistant to machining as compared to green bodies reinforced with more concentrated and/or soluble and/or differently sized and/or less equally distributed fillers available on the market.

High electrical conductivity is established during the sintering of machined green body upon which the cellulose nanofibres convert to carbon fibres. The equal distribution and low concentration of conducting carbon fibres is again preserving the valuable mechanical properties of ceramics made by the procedure described above.

The idea of adding hydrophilic nano-cellulose filler rather than conventional hydrophobic carbon fillers to ceramic matrix was a result of integration of knowledge on ceramics development and nano-cellulose based hybrid and composite materials integrated from Slovenian and Spanish research organizations, respectively.

A patent application with more detailed description of the filler and the procedure of production of these ceramics was filed in November 2016 at UK-IPO. In addition to intellectual property rights described in the patent application the inventors and institutions involved own specific knowledge and practical experiences (secret knowhow) on how to implement the technology with slight modifications of existing industrial production scales.

The method of preparation of nano-cellulose reinforced ceramics was tested in the research pilot production system resembling existing industrial ceramics production lines. The technology needs to be validated, demonstrated and qualified at industrial scale in a course of proposed collaboration between the research organizations and interested industrial partners.

Researchers are looking for producers of alumina and zirconia ceramics, especially electrically conductive and (bio)inert engineering ceramics for automotive and biomedical applications. They wish to license out the technology. Technical cooperation is also offered in the form of facilities and the know-how of involved research institutes and researchers on how to implement the technology with slight modifications to existing industrial production scales of the companies interested in licensing in the presented technology.

### Main Advantages

Improved mechanical properties ( $H_v=20$  GPa) allow complex shaped machining prior to sintering (Figure 1).

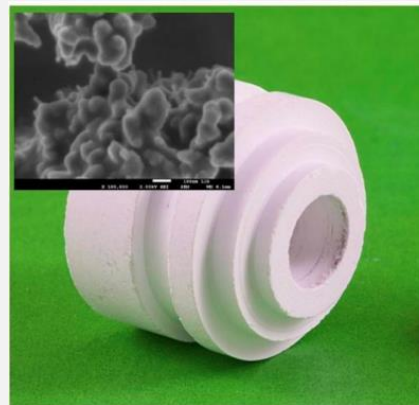


Figure 1. Photograph of a machined greenbody (non-sintered) of nanocellulose-zirconia nanocomposite. High strength ( $H_v=20$  GPa) and improved mechanical properties of the ceramic greenbody allowing to machine complex geometries prior to sintering – due to incorporated nanocellulose inferring high mechanical properties (see the SEM - scanning electron microscope - image in the top left corner).

High electrical conductivity (400 S/m) is achieved at extremely low percolation thresholds due to nanosized filler that is equally distributed across the material. Electrical conductivity is triggered during sintering upon which the nano-cellulose filler is turned to conductive carbon fibres (Figure 2).



Figure 2. Photograph of nanocellulose-zirconia before (left) and after (right) SPS – spark plasma sintering. After sintering it turns black due to graphitization of the nanocellulose. The black sample is highly electroconductive (400 S/m).

Electro-discharge machining (EDM) is also possible due to favourable electrically conductive properties of the material (Figure 3).

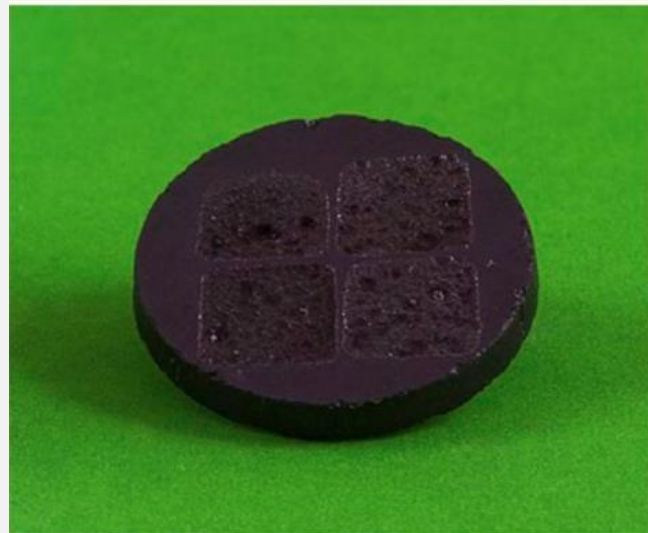


Figure 3. Photograph of nanocellulose-alumina after electro-discharge machining (EDM), which is possible due to the electroconductivity of the sample. EDM is an advanced ceramic machining technique.

### Partner Sought

The technology is ready to be licensed out to interested producers of alumina and zirconia ceramics, especially electrically conductive and (bio)inert engineering ceramics for automotive and biomedical applications. Technical cooperation is also offered, more precisely the facilities and the knowledge of Slovenian and Spanish research institutes and researchers on how to implement the technology with slight modifications to existing industrial production scales of the companies interested in licensing in the presented technology.