TOSOH

TOSOH CORPORATION

NEWS RELEASE

July 1, 2020

Establishment of Next-Generation Zirconia Social Cooperation Program at The University of Tokyo

The following release was issued jointly by Tosoh Corporation, School of Engineering of the University of Tokyo, Japan Fine Ceramics Center, and World-Labo Co., Ltd.

Tokyo, Japan—The Graduate School of Engineering at The University of Tokyo, a renowned national university, Japan Fine Ceramics Center (JFCC), World-Labo Co., Ltd., and Tosoh Corporation established the Next-Generation Zirconia Social Cooperation Program on July 1, 2020. The program aims to revolutionize the concept of traditional ceramic materials by achieving remarkable advancements in zirconia ceramic properties and nurturing talent to drive innovation in this technological field.

Zirconia has found practical applications in various fields. However, there are still many aspects of its functional mechanisms that remain unclear. By uncovering the factors that determine material properties and gaining control over the structure at the atomic level, there is a strong potential to significantly enhance its functionality.

The social cooperation program will employ cutting-edge electron microscopy, computational materials science, and sintering techniques to gain a deep understanding of zirconia's properties. Research will look to maximize its functional potential by applying this knowledge. Specifically, focus will be placed on four key characteristics of zirconia: its exceptional strength and flexibility, versatile processability, solid-state ion conductivity allowing for oxygen ion transport, and high transparency resulting from its refractive index.

By delving into these areas, the program strives to achieve breakthroughs that include achieving metal-like mechanical properties and processability, facilitating ultra-fast ion conductivity for clean energy applications, and developing high-transparency materials for cutting-edge optical applications. The integration of these unique properties will pave the way for exciting advancements in zirconia.

In addition, the program emphasizes the cultivation and development of skilled professionals in the field. By fostering talented individuals who can drive materials research forward, the program aims to accelerate technological progress and contribute to solving societal challenges, ultimately aiming to realize a sustainable society.

3-8-2, Shiba, Minato-ku, Tokyo 105-8623, Japan

Tel: +81 (3) 5427 5118 Fax: +81 (3) 5427 5198

www.tosoh.com

Overview of the social cooperation program

1. Program name

Next-Generation Zirconia Social Cooperation Program

2. Purpose of research

The objectives of the program are to conduct R&D into next-generation zirconia with the goal of addressing societal challenges and to nurture professionals capable of advancing material R&D by leveraging the advanced applications of next-generation zirconia. It also aims to actively promote collaborative research between academia and industry to contribute towards solving diverse challenges in the industrial sector.

3. Faculty members

Specially-appointed professor, Yuichi Ikuhara (Institute of Engineering Innovation)
Specially-appointed professor, Hidehiro Yoshida (Department of Materials Engineering)

4. Period of program

July 1, 2020 to June 30, 2025 (five years)

5. Budget

718 million yen

6. Research structure

The program is structured to foster the development of next-generation zirconia, realize new materials and technologies that can contribute to society, and nurture future material development researchers through collaboration between various key entities: The University of Tokyo, with its cutting-edge nanostructure analysis and novel sintered material development capabilities; Tosoh, which specializes in powder development and manufacturing; JFCC, which possesses exceptional computational materials science and technology capabilities in ceramics; and World-Labo, known for its advanced ceramics structure control technology.

Outline of zirconia ceramics

Zirconia is the oxide of zirconium (Zr) and is chemically represented as ZrO_2. It has an extremely high melting point of 2700°C and is transparent, with a high refractive index resembling that of diamond, making it suitable for use in jewelry.

As shown in Figure 1, zirconia can adopt three different crystal structures. Each structure has its own stable temperature range: monoclinic at room temperature, tetragonal at 1170°C, and cubic at 2370°C. Typically, ceramics are fired at high temperatures and then cooled to room temperature. However, when zirconia is cooled from high temperatures, it undergoes a phase transformation from the tetragonal to monoclinic structure, resulting in approximately 4% volume expansion. This makes it challenging to produce sintered zirconia. Therefore, stabilizers, such as additives, are usually incorporated to stabilize the tetragonal or cubic structure at room temperature. Yttria (Y_2O_3) is one of the most commonly used stabilizers. Adding an appropriate amount of yttria to stabilize the tetragonal structure of zirconia results in excellent mechanical properties in zirconia ceramics.

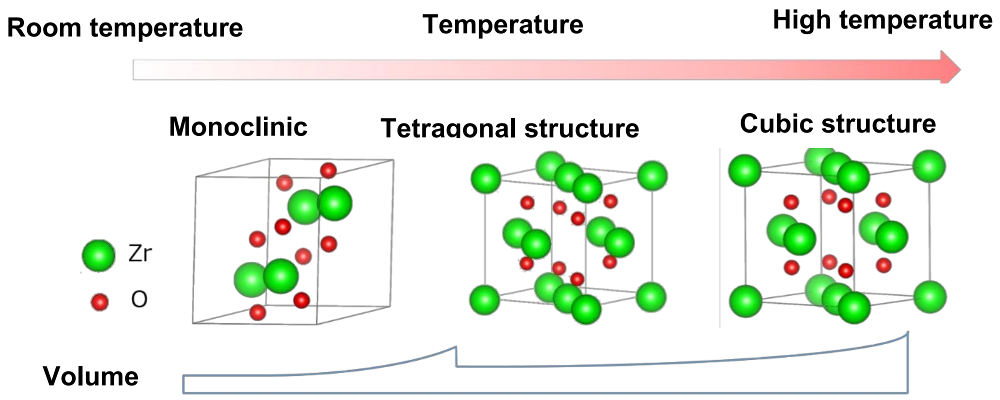

Figure 1. The three crystal structures (polymorphs) of zirconia ceramics

Background

Zirconia, a widely used functional and structural ceramic material, has already made significant contributions in practical applications. Tosoh has played a significant role in the development of the zirconia market by industrializing high-purity zirconia powder, a world first, and promoting its utilization in diverse applications such as structural components and aesthetically superior dental materials. Additionally, The University of Tokyo and Tosoh have conducted joint research for over 20 years, achieving numerous groundbreaking results, including elucidation of the mechanism behind zirconia's crystal phase transformation, and the development of exceptionally durable sintered zirconia. The following are some notable examples of these achievements.

Zirconia ceramics are known for their high strength and toughness. As shown in Figure 1, zirconia has three crystal structures, with the monoclinic phase being the stable structure at room temperature. Yttria is added in an appropriate amount to stabilize the tetragonal phase at room temperature, resulting in superior mechanical characteristics. However, zirconia ceramics can gradually degrade and eventually fracture into small pieces when exposed to high-temperature steam or water for an extended period. This phenomenon, known as hydrothermal degradation, has long been considered an inevitable drawback of zirconia ceramics. However, through collaborative research with The University of Tokyo, Tosoh has made a groundbreaking discovery by conducting atomic-level structural analysis and systematic analysis of phase transformation behavior, identifying the root cause of hydrothermal degradation. The cause lies in the distribution of yttrium ions, which act as stabilizers for the tetragonal phase. As shown in Figure 2, conventional zirconia ceramics had non-uniform distribution of yttrium at the nanoscale level. In such cases, prolonged exposure to hot water would lead to the destabilization of the tetragonal phase, returning it to the stable monoclinic structure that exists at room temperature. The transition from the tetragonal to monoclinic phase results in volume expansion, causing the particles to break into smaller fragments. This is the true nature of hydrothermal degradation. However, by adjusting the distribution of yttrium at the nanoscale level to achieve uniformity, the tetragonal phase remains stable even after prolonged exposure to water, and there is no degradation in strength. In fact, zirconia ceramics with this uniform distribution of yttrium showed no degradation even after being immersed in hot water (140°C) for four years [Reference 1]. The successful development of such highly durable zirconia ceramics can be attributed to the atomic-level structural analysis and fundamental understanding of sintering and phase transformation behavior.

[Reference 1] Koji Matsui, Hidehiro Yoshida and Yuichi Ikuhara, “Nanocrystalline, Ultra-Degradation-Resistant Zirconia: Its Grain Boundary Nanostructure and Nanochemistry”, *Scientific Reports*, **4** (2014) 4758. doi:10.1038/srep04758

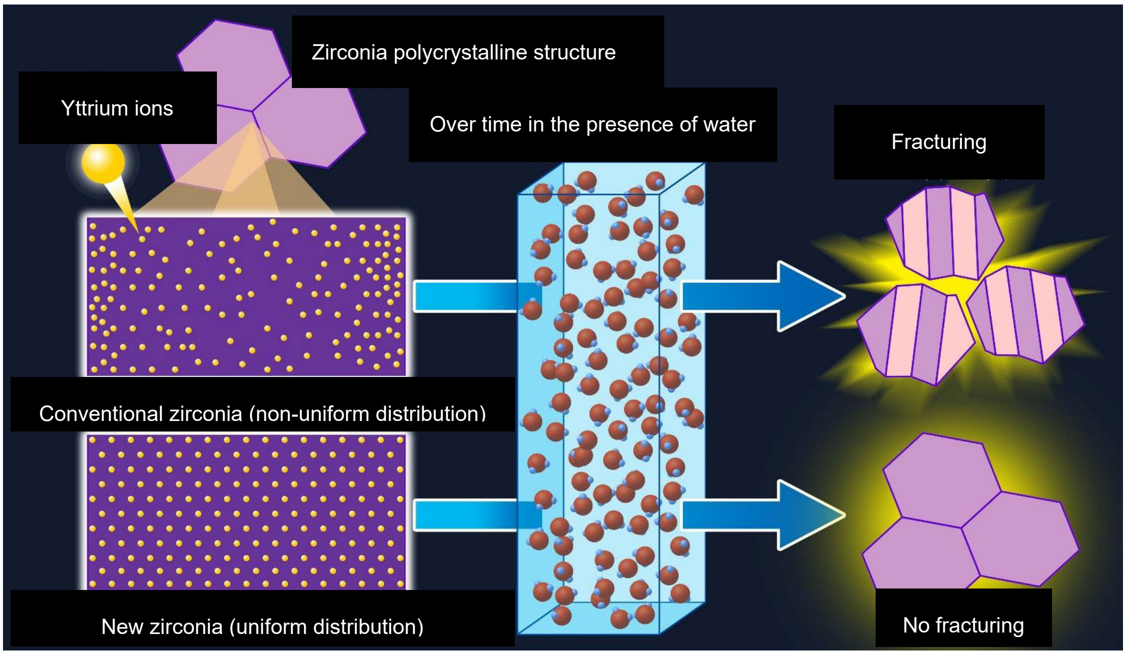

Figure 2. Hydrothermal degradation of zirconia ceramics and development of highly durable zirconia ceramics through collaboration between Tosoh and The University of Tokyo.

TOSOH CORPORATION

TOSOH CORPORATION

Who We Are

Tosoh Corporation is the parent of the Tosoh Group, which comprises over 100 companies worldwide and a multiethnic workforce of over 14,000 people. It generated net sales of ¥1,064.4 billion (US$7.9 billion at the average rate of ¥135.5 to the US dollar) in fiscal 2023, ended March 31, 2023.

What We Do

Tosoh is one of the largest chlor-alkali manufacturers in Asia. The company supplies the plastic resins and an array of the basic chemicals that support modern life. Tosoh's petrochemical operations supply ethylene, polyethylene, and functional polymers, while its advanced materials business serves the global semiconductor, display, and solar industries. Tosoh has also pioneered sophisticated bioscience systems that are used for the monitoring of life-threatening diseases. In addition, Tosoh demonstrates its commitment to a sustainable future in part by manufacturing a variety of eco-products.

Stock Exchange Ticker Symbol: 4042

DISCLAIMER