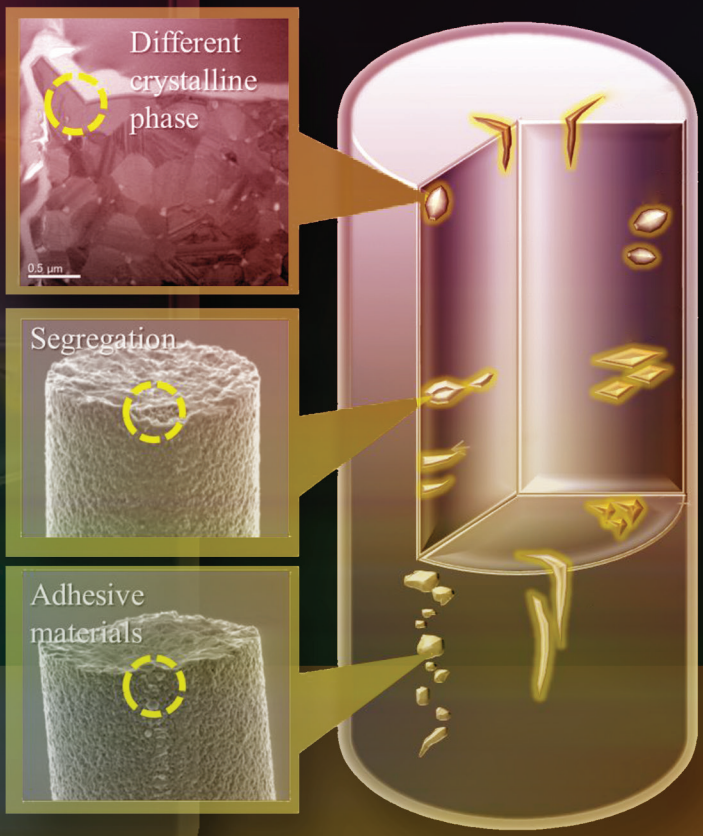
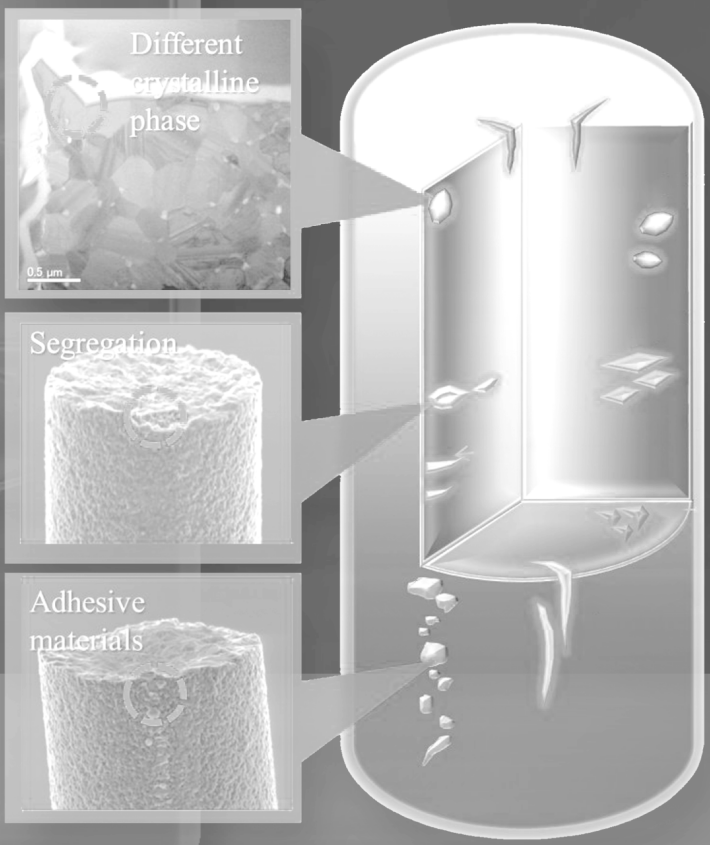
Ceramic Fibers and Their Applications

Toshihiro Ishikawa



Ceramic Fibers and Their Applications



Ceramic Fibers and Their Applications

Toshihiro Ishikawa

JENNY STANFORD
PUBLISHING

Published by

Jenny Stanford Publishing Pte. Ltd.
Level 34, Centennial Tower
3 Temasek Avenue
Singapore 039190

Email: editorial@jennystanford.com
Web: www.jennystanford.com

British Library Cataloguing-in-Publication Data
A catalogue record for this book is available from the British Library.

Ceramic Fibers and Their Applications

ISBN 978-981-4800-78-5 (Hardcover)
ISBN 978-0-429-34188-5 (eBook)

Contents

Preface

Ceramics are produced from clay heated at temperatures above 1000 °C. History of ceramics dates back to the times when humans started making earthenware from clay, which comprised mainly oxide materials. Nowadays, many types of ceramics containing non-oxide materials (carbides, nitrides, borides, and so on) have been developed to achieve better mechanical properties, new physical properties, excellent heat resistance, and so forth. Furthermore, new types of fibrous oxide materials, such as alumina–silica fibers, and fibrous non-oxide materials have also been developed. Alumina–silica fibers have been used as insulating materials in space shuttles, such as fabrics. However, unlike carbon fibers, these oxide fibers have been unable to establish a big market despite continued research on composite materials using oxide interfaces in many research laboratories. Therefore, several types of oxide fibers started steadily being used all over the world. On the other hand, research on non-oxide fibers, such as silicon carbide (SiC) fiber, has also been done for several years. By the way, SiC has attracted keen interest as a high-temperature structural material because of its higher resistance to oxidation, corrosion, and thermal shock. However, since SiC crystals did not have shaping and self-sintering abilities, it was difficult to obtain high-strength products with complicated shapes, especially because the fibrous form could not be realized until the middle of 1970s. The first researcher who solved this difficulty was Prof. Dr. Seishi Yajima. He and his coworkers had synthesized the first SiC fiber from an organosilicon polymer (polycarbosilane) making the best use of the production process of carbon fiber by heating an organic precursor fiber made of a polyacrylonitrile at high temperatures of over 1000 °C under airtight condition. This was the first polymer-derived SiC fiber. After that, several types of researches on non-oxide fibers (Si-B-C-N, Si-N-C, Si-C-O, and so forth) started all over the world. In the meantime, before this epoch-making development, a SiC monofilament (140 μm in diameter) was produced by chemical vapor deposition (CVD) on a carbon filament core. However, as can be seen from this production process, this type of SiC monofilament

had too large a diameter for a wire needed for delicate use. On the other hand, the diameter of the aforementioned polymer-derived SiC fiber could be remarkably reduced, which was similar to that of carbon fiber. In this case, the shaping ability of the precursor polymer resulted in reduced fiber diameter by the use of melt-spinning process. This was a really epoch-making process that made the best use of the characteristics of the polymer. After that, many types of polymer-derived, SiC-based fibers have been developed using polycarbosilane and modified-polycarbosilane containing metal atoms. Furthermore, many types of modifications of SiC-based fibers have been achieved so far. Finally, SiC-polycrystalline fibers (Hi-Nicalon Type S and Tyranno SA) with excellent heat resistance were developed, and then, their many applications have been examined. And also, a tough, thermally conductive SiC-based ceramic (SA-Tyrannohex) composed of a highly ordered, close-packed structure of hexagonal columnar fibers has been developed. Moreover, recently, several types of ceramic fibers with various fine structures and outstanding properties have also been synthesized from other types of organosilicon polymers using new processes. That is to say, up to now, lots of ceramic fibers containing oxide fibers, SiC-based fibers, and other types of Si-containing fibers have been developed. And also, many types of research on composite materials, using the aforementioned ceramic fibers have been performed, aiming for high-temperature applications. Furthermore, some other functional ceramic fibers with gradient-like surface layers have also been developed. By the existence of surface functional layers, these fibers can show excellent functions along with better mechanical strengths.

This book presents the historical viewpoint regarding inorganic fibers and a detailed explanation of ceramic fibers and their applications. It addresses the future prospects of ceramic fibers by focusing on previous fibrous materials and their derivatives. I hope that it offers a vision for future developments and stimulates fresh thinking to develop novel, high-performance ceramic fibers. I also hope that this book meets the educational and research needs of advanced students across multiple academic disciplines.

Toshihiro Ishikawa

Autumn 2019