Preface

Silicon, the second most abundant element on earth, is a well-established material in microsystems technology. Its properties and technical perfection open up an almost unlimited range of applications. Silicon is the main component of most semiconductor devices, but other materials are also applied step by step in microsystems technology so as to obtain some special properties. Glass is one such material that has some special properties.

Glass-making has a history of almost six millennia. However, the science of glass started only around 1830. But even by the end of the sixteenth century (or the beginning of the seventeenth century), glass articles were decorated with very fine gravured patterns in the form of meanders or garlands, combined with other bas-relieved decors [488]. Many of the patterns were made using copper wheels. Frequently the line width was less than 100 µm. Around 1920, glass-cutting tools positioned in pantographs were used for scratching fine lines into waxed surfaces of glass products. The lines were then transferred into the glass by hydrofluoric acid treatment, resulting in permanent patterns. These final patterns consist of lines that are 200 µm wide and deep. Till date, we find glassware such as drinking glasses and candlesticks being decorated using this technique. This method was also used to produce the scaling of clinical thermometers and laboratory glasses. Powder blasting for decorating glass products and treatment with a diamond tool for producing glass scales have been known for more than 50 years and remain the state of the art even today.

Between 1940 and 1950, Dalton, Armistead and Stookey, while working for Corning (USA), discovered that specially composed, UV-sensitive glasses can be micro 'sculptured'. Partial UV exposure through a mask, followed by thermal and chemical treatments, allow for a defined microstructuring of glasses in a 10-µm range. Unnoticed by the world, the age of glass microstructuring had started, possibly 30 years too early. Only with the rise of silicon technology did microstructuring of glasses become important.

Glass is an amorphous material with a unique property profile. Glasses offer different transparency 'windows' for electromagnetic radiation, have

superior chemical stability, are biocompatible, have excellent abrasion resistance and allow for adapting their thermal expansion coefficients to those of other materials. Glasses can be electrically insulating, but they can also be good ion conductors or even semiconductors. The properties of glasses depend strongly on the chemical composition of the glass itself, which can vary widely. The property profile opens a wide range of applications of different glasses in microtechnology. The amorphous character of glasses implies that all its properties are isotropic and that the ability of microstructuring is therefore independent on predefined directions of crystal lattices. Sometimes glasses are the only material that fulfil the specifications for special applications.

As a consequence, and in contrast to silicon, quite different glasses can be used for microstructuring. The producer of microdevices has to select a glass that is suitable for his application and also has a composition that offers the desired property profile. Mostly, the amount of glass ordered is relatively small. Of course, the glass industry is able to produce special glasses, but it is costly to produce very small quantities of glasses with specific composition. It is therefore a disadvantage for the glass producer if a customer demands very small quantities of a glass having a specific composition. For this reason, it would be good to have a theoretical idea of the feasibility of producing a desired glass in a certain small quantity.

Silica coatings, light wave guides, silicon sensor encapsulations and membranes in piezo-driven ink jet printers were the first applications of glass elements in microcomponents. The ability to fabricate extremely thin glass components without additional, geometrical structuring was the only requirement for these early applications. The need for small holes allowing for electrical connections through thin glass coatings to the silicon element soon required additional machining. Initially, these were manufactured by drilling. As of date, almost every geometrical feature that is needed at or near the surface and even in the bulk of the glass element can be made.

However, because of limited communication and knowledge transfer between the glass manufacturer and the microsystems industry, it is hard for the glass manufacturers to estimate the issues and the real demand for microstructured glasses in the microsystems area. Vice versa, the specialist in the microdevices industry cannot assess the full range of possibilities and problems of this amorphous, brittle material. The aim of this book is to link the thinking and understanding of specialists in terms of glass production as well as the fabrication of microdevices. The book attempts to explain the most important fundamentals, methods, features and highlights in the production of glass half products used for microstructuring as well as the microstructuring itself. It does not cover the entire subject matter, because of the growing nature of this field. Rather, the purpose of this book is to provide the newcomer to glasses with enough background to be able to access the specialist literature. Therefore, we start with the basics of glass materials and frequently refer to existing publications so that readers across cognate disciplines can easily understand what happens, for instance, between the ions in the glass

and the ways in which glass processing affects the final properties of glass microdevices. The book's aim is to present an additional source of information on the three aspects, namely, the fundamentals of glass composition and glass processing and the many different methods of its microstructuring. It provides a comprehensive discussion of the various microstructuring methods, with appropriate references to literature, so that the book can be used as a source of information for glass manufacturers, producers of microdevices, engineering professionals with a background in designing (of microdevices) and structuring processes, as well as scientists in general, and students in particular.

The book is divided into two main parts:

Part I deals with the fundamentals of inorganic-nonmetallic glasses and their processing.

Part II explores and explains the principles of geometrical microstructuring of glasses, joining processes and applications.

First (Part I), an introduction to the amorphous state of glasses provides the background to the study of glasses, which is necessary for understanding the unique role of glass in microsystems. This is followed by a description of the characteristics and properties of specific glasses that are important for microsystems. The reader is then provided with information about glass processing, keeping in mind the requirements and specifications of microglass elements.

Part II provides the reader with a general overview of geometrical microstructuring and the special methods used for mechanical, thermal and chemical structuring of glasses. It focuses on methods of glass structuring, using various types of lasers, as well as on structuring of photosensitive glasses. The book also describes in some detail the methods of joining glasses with themselves as well as with other materials, such as silicon. The discussion of the methods is supplemented with relevant applications.

The book focuses mainly on subtractive methods, i.e. the removal of material, and on thermal reshaping methods as well as techniques that allow for the manipulation of locally confined properties. We do not discuss ion or electron beam structuring, because of their limited application in industry; nor do we discuss additive methods such as the deposition of powders or coatings. Silicate glasses form the centre of discussion of the book. We also exclude special microoptics and photonics made from glasses because excellent specialist books are already available, and the reader is referred to them; the processing associated with their manufacture is, however, described in different sections of the book.

We hope that the reader will find sufficient interesting facts and be motivated to use glasses for microdevices. We welcome comments to this work.

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