CERAMIC PROCESSING

EDITED BY R.A. TERPSTRA
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Foreword

Two years after the foundation of the European Ceramic Society the first ECerS Conference was held in Maastricht, The Netherlands. After this successful conference it was felt that the ECerS should not only stimulate ceramic research but also run projects of an educational character. To this end the Netherlands Ceramic Society decided to sponsor a summerschool on ceramic processing intended for young ceramists from European countries. Several internationally recognized ceramic specialists were prepared to lecture and the course was fully attended. In fact, this course showed that there is a clear need for dedicated courses at a moderate fee. A venue was chosen where the participants would have ample opportunities for personal contacts. In this way the summerschool gave the students more than purely technical training.

After the meeting the ECerS Council established an Educational Committee to take care of educational matters on a permanent basis. Following an initiative of the French Ceramic Society a special Conference of Higher Educational Institutions in Ceramics was organized under the name Euroforum in 1992 in Limoges, France. The second Euroforum was held in 1994 in Höhr-Grenzhausen, Germany. These meetings aim to bring together educators, graduates and industrial managers. Further activities under the auspices of the ECerS are planned.

Having been involved in the preparation of the course, it is a great pleasure to introduce the book of the proceedings of the NKV-summerschool. The contents and the level are such that we trust that many ceramists will benefit from the book.

I congratulate the editors and organizers of the summerschool on their initiative.

R. Metselaar
Past-president, ECerS

Preface

This book has been edited from the lectures given at the NKV-summerschool on ceramic processing which was organized by the Netherlands Ceramic Society (NKV), 5–9 September 1991 in Petten, The Netherlands.

The NKV-summerschool was sponsored by:

- The Netherlands Ceramic Society, NKV
- The European Ceramic Society, ECerS
- Ceramic Manufacturers Association, VKI
- The Netherlands Energy Research Foundation, ECN
- The Netherlands Organisation for Applied Scientific Research, TNO
- The National Ceramic Centre, NKA
- The Centre for Technical Ceramics, CTK
- N.V. Royal Sphinx, Maastricht
- Hoogovens Industrial Ceramics, HIC
- Gimex, Geldermalsen
- NIFA Instruments, Leeuwarden
- CAM Implants, Leiden
- Royal Tichelaar, Makkum
- Ceratec, Haaften

The following people were responsible for organizing the NKV-Summerschool:

- Dr ir R.A. Terpstra, CTK (Chairman)
- Ir P.P.A.C. Pex, ECN (Secretary)
- Mr A.H. de Vries, TNO-Ceramics (Treasurer)
- Prof. dr R. Metselaar, CTK/Eindhoven University of Technology (Scientific Advisor)
- Mrs C.A.L. Ruitenburg, ECN (Local organizer)
- Ing. P.J. van Tilborg, ECN (Local organizer)

The NKV-summerschool was arranged to provide (graduate) students, scientists and engineers an opportunity to attend an advanced course in ceramic processing taught by internationally well-known lecturers.

The lectures were presented by specialists on topics most relevant for ceramic processing, starting from powder synthesis and the behaviour of powder particles in dispersions in relation to colloidal consolidation

processes, various forming routes like dry pressing, tape casting, injection moulding and extrusion. The concluding lecture, which could not be included in this book, treated the theoretical aspects of the sintering process. The opening lecture provided an overview of the trends in ceramic materials and their processing, answering various questions like: why are a limited range of new materials of current interest?, which may become dominant?, what are they?, why develop ultrafine powders?, and what are the prospects for ceramic fibres?

Since the lectures provided an excellent comprehensive overview by specialists in the field of ceramic processing, it was suggested that the organizers publish a book out of the proceedings of this summerschool. The result is this volume on the most important aspects of ceramic processing written by seven specialists in the field.

R.A. Terpstra
P.P.A.C. Pex
A.H. de Vries

Eindhoven/Petten

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CHAPTER 1

Special ceramics for modern applications: which? why? how?

I.J. McColm

1.1 INTRODUCTION

This chapter presents an overview of the trends in ceramic materials and in their processing. Why are a limited range of new materials of current interest? Which may become more dominant? What are they? Why develop ultrafine powders? Do ceramic fibres have worthwhile properties compared to the effort needed to produce them? Can realistic cost targets be achieved? These questions will be approached by examining the concepts of specific strength, specific stiffness, theoretical strength, surface energy, fracture toughness, critical length, pull-out work, limiting particle size and green structure linked to examples of production methods.

In the 1960s ceramic manufacture was centred mainly in Europe and Japan, with Japan producing cheap reproductions of European wares. Now the Japanese ceramic industry is the largest in the world and many countries, such as Korea, Thailand and China, have taken over as cheap production centres. When production becomes uneconomic with respect to certain ware and certain designs in Europe it is becoming common practice to have such items manufactured where it is cheap, whilst still maintaining the brand name.

This situation is one of the factors driving ceramic producers, ceramic scientists, and ceramic technologists towards new technology and new materials. However, within the traditional industry this is represented by changes introduced to lower the costs of existing technology, rather than looking towards completely new products. This is a short-sighted policy: the ceramics industry needs to follow the lead of other technologies.

For example, the manufacture of plates by clay-dust pressing in a steel and nylon mould at high pressure was introduced to make plates faster and more accurately with less labour. This is seen as an advance on the use of soft clay in

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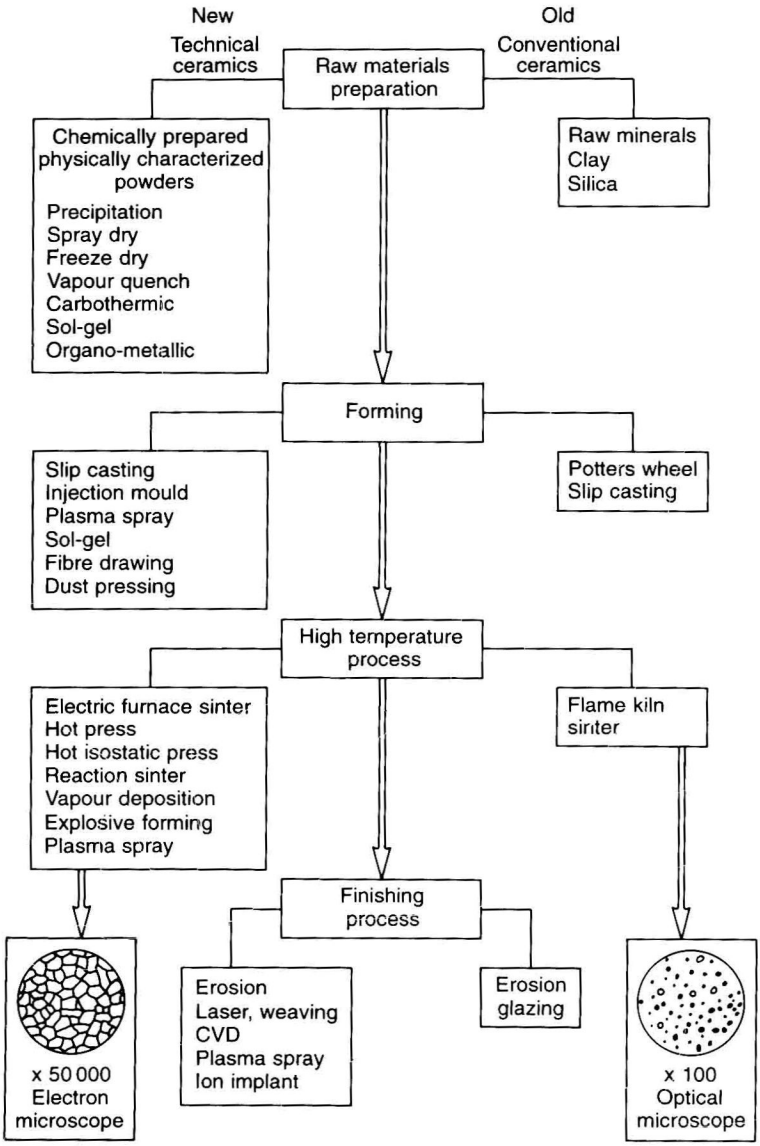

Fig. 1.1 The four steps involved in ceramic processing and the increase in possible ways of achieving them on moving from conventional to special ceramics.

a spinning plaster mould, which was itself seen as a development of the potter's wheel. It would be presented, however, as a use of techniques well established in the powder metallurgical industry, so perhaps a wider look at other industrial technologies would be rewarding for the ceramics industry.

Fig. 1.2 A recent advertisement by the Alcoa company which emphasizes that traditional ceramics can be improved by researching into powder morphology and new forming processes for modern materials applications.

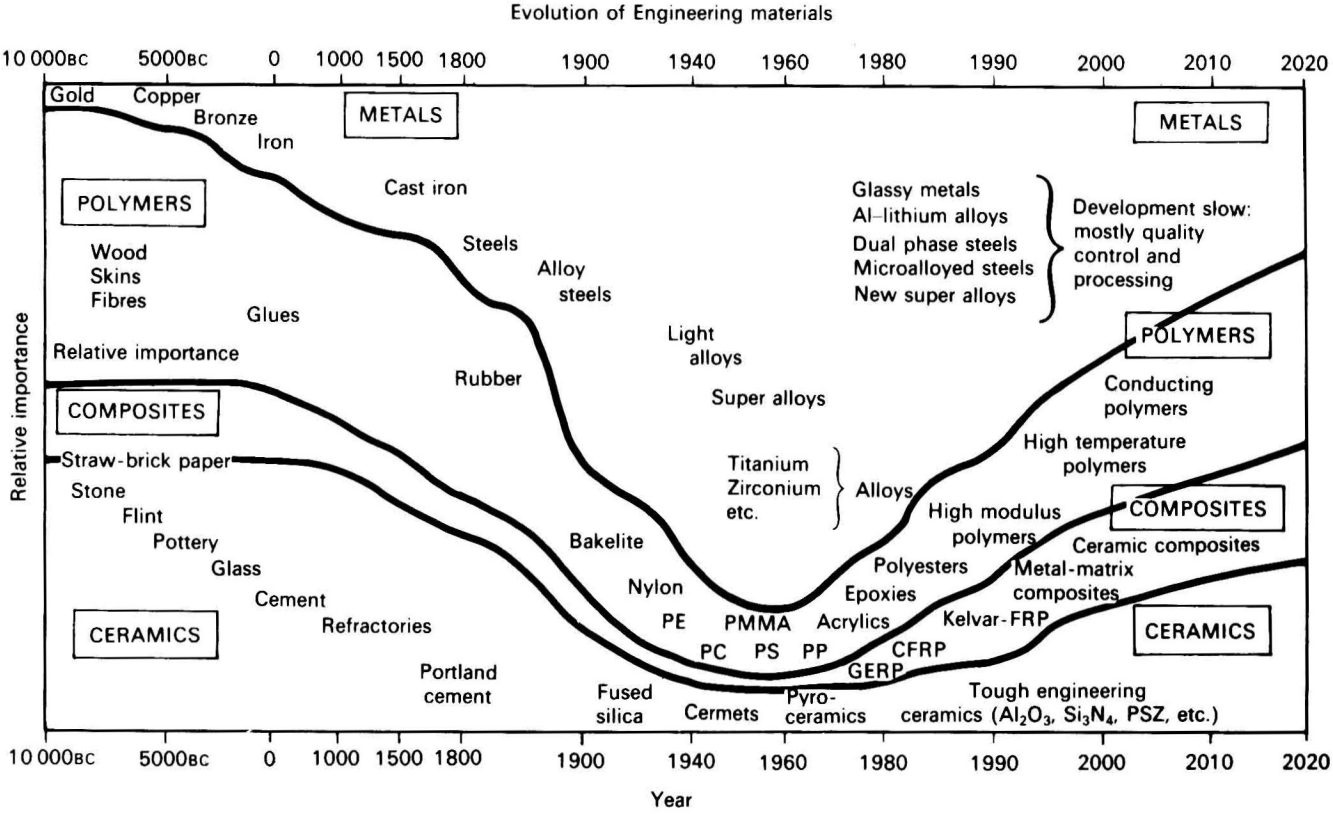

Fig. 1.3 Ashby's diagram [1] showing schematically how after a balanced material usage pattern technology became dominated by the use of metals. Beyond 1990 the figure predicts a return to more balanced usage with ceramics and ceramic-composites becoming more important again.

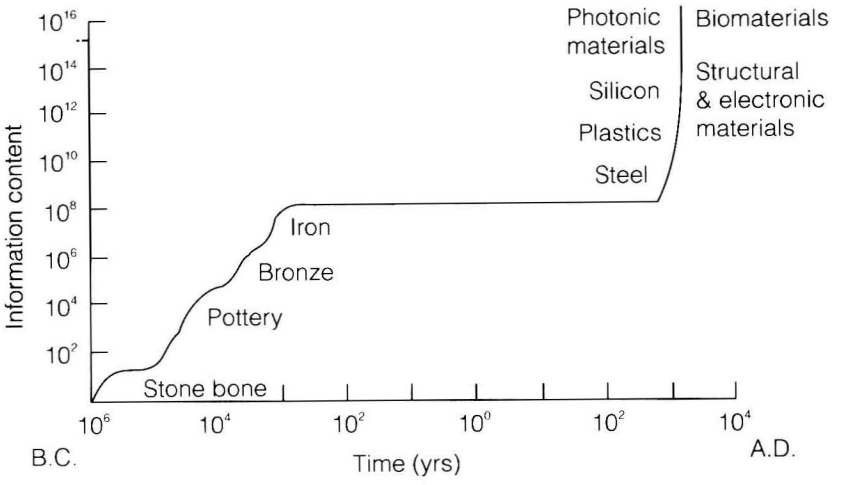

Fig. 1.4 A schematic diagram showing the growth in technology information content inherent in the use of new materials. It emphasizes the present rapidly changing circumstances before reaching another plateau when the second industrial revolution nears maturity.

The way to advanced high technology ceramics lies in the roots of several industries as shown in Fig 1.1. The unbreakable cup, as highlighted in a recent Alcoa advertisement (Fig. 1.2), was achieved by bringing together science and technology from several sectors.

The development and analysis of several simple equations and ideas can show us the way to successful developments in an industry which is now some 7000 years old. The field of ceramics and composites containing ceramics was once 50% or more of the materials experience of humanity and is set to rise to this again when metals diminish in importance, see Fig. 1.3. With such a change we are in the midst of exponentially rising increases in technology information content, following a long period of relative stagnation, and this is indicated in Fig. 1.4.

In a time of such rapid change can we make useful scientific and technological predictions? We will attempt to do this now using a few simple concepts and equations.

1.2 PREDICTIONS ARISING FROM SIMPLE CONSIDERATIONS OF STRENGTH

Clearly, to obtain the unbreakable cup shown in Fig. 1.2 a choice of material of ultimately exceptional strength should be made, and so here we look to the fundamental very early work of Griffith [2] and Orowan [3].