This is the most comprehensive book to date on the production, structure, properties and applications of metal matrix composites, an important new class of materials that is making a major impact in many diverse areas of industry.

The emergence of metal matrix composites is partly a consequence of an improved understanding of their potential and limitations, based on principles of physical metallurgy, interfacial chemistry, stress analysis and processing science. This book is intended as an introduction to the microstructure, behaviour and usage of these materials. In each chapter, a simple outline is given of the underlying principles, followed by an assessment of the current state of research knowledge in the area. At a more detailed level, the mathematical background to the analytical treatments involved, including the Eshelby method, has been incorporated into the book, although emphasis is placed throughout on the concepts and mechanisms involved.

The book encompasses particulate, short fibre and long fibre reinforcement. The accent is on mechanical performance, describing how the presence of reinforcement in a metallic matrix influences the stiffening, strengthening and failure characteristics. This involves a critical examination of both load transfer and microstructural modification effects brought about by the presence of the fibres or particles. Comprehensive coverage is also given of other properties, including thermal/electrical conductivity and resistance to thermal shock, wear and corrosive environments. Fabrication and processing are also treated in some detail. The final two chapters provide a source of useful practical information, covering a range of specialist techniques for the study of these materials and detailed examples of commercial applications.

This book is aimed primarily at scientists, engineers, production managers and all those involved in research on new materials in general and metal matrix composites in particular, but it is also suitable for use as a text in graduate and undergraduate courses.

AN INTRODUCTION TO METAL MATRIX COMPOSITES

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Preface

Over the last 30 years or so, metal matrix composites have emerged as an important class of materials. During this period, a very substantial research effort has been directed towards an improved understanding of their potential and limitations, invoking principles of physical metallurgy, stress analysis and processing science. This book is intended as an introduction to the field, covering various aspects of the structure, behaviour and usage of these materials. It is designed primarily for scientists and technologists, but the content is also suitable for final year degree course students of materials science or engineering and for postgraduate students in these disciplines.

The structure of the book is designed to allow several different modes of usage. Chapters 2 and 3 provide a background to stress analysis techniques used to describe the mechanical behaviour of MMCs. In these chapters we have aimed to introduce the concepts pictorially, while the details are discussed in the main text. The finer points of these treatments are relevant to those with a keen interest in composite mechanics, but they are not essential for use of the rest of the book. The following four chapters then form a core description of the load-bearing behaviour. Chapters 4 and 5 cover the basic deformation mechanisms and characteristics, over a range of temperature. A chapter is then devoted to various aspects of the interface between matrix and reinforcement. This is relevant to several areas, particularly the fracture behaviour outlined in Chapter 7. A chapter follows dealing with various transport properties (such as thermal conductivity) and environmental performance (such as the resistance to wear and corrosion). The final four chapters then deal with a variety of special topics. Chapter 9 covers fabrication and processing in some detail, followed by a short chapter on the evolution of matrix microstructure during fabrication and in service. The last two chapters are largely independent of the rest of the book. The first introduces a number of experimental techniques and examines their potential for the study of composite materials, while the second highlights,

through a series of illustrative applications, how useful property combinations offered by MMCs can be exploited in practice. To aid in the use of the book, a compendium of materials properties and a nomenclature can be found in the Appendices.

There is a strong research effort in metal matrix composites at Cambridge University and we have both been involved in this over the past several years. We decided to cooperate on this book late in 1989 and the writing was done during 1990 and 1991. Each chapter is very much a joint effort. We hope that this is reflected in a homogeneity of style and nomenclature throughout.

We are grateful for numerous discussions and contacts with colleagues and visitors here in Cambridge. In particular, we would like to thank M. F. Ashby, C. Y. Barlow, W. J. Clegg, I. M. Hutchings, D. Juul Jensen, J. E. King, O. B. Pedersen and W. M. Stobbs. We would also like to acknowledge the substantial contributions from past and present research students in the Materials Science and Metallurgy Department, especially those within our own groups. In addition, we are indebted to all those who have furnished us with micrographs and unpublished information, notably A. Ardekani, A. Begg, A. W. Bowen, G. S. Daehn, D. Double, J. F. Dolowy, T. J. Downes, D. C. Dunand, F. H. Gordon, E. A. Feest, J. A. G. Furness, W. R. Hoover, S. J. Howard, F. J. Humphreys, A. R. Kennedy, R. R. Kieschke, J. J. Lewandowski, J. Lindbo, Y. L. Liu, D. J. Lloyd, J. F. Mason, V. Massardier, A. Mortensen, A. J. Phillips, P. B. Prangnell, D. A. J. Ramm, A. J. Reeves, K. A. Roberts, C. A. Stanford-Beale, R. A. Shahani, R. A. Ricks, A. Tarrant, T. J. Warner, C. M. Ward-Close, C. M. Warwick, M. C. Watson, W. Wei, J. White, A. F. Whitehouse and F. Zok. We would also like to acknowledge the financial and moral support we have received over recent years for our own research work on metal matrix composites, in particular from the Science and Engineering Research Council, Alcan International, British Petroleum, Imperial Chemical Industries, National Physical Laboratory, Pechiney, RAE Farnborough, Risø National Laboratory and Rolls Royce. We have had extensive scientific contact with various people from these and other organisations, which has been of considerable benefit to us.

Finally, we would like to thank our wives, Gail and Lindsey, for a degree of forbearance well beyond any reasonable call of marital duty. Without their support, this book would never have been finished.

T. W. Clyne
P. J. Withers
Cambridge, January 1992