Human ingenuity is continuously expanding the horizon of engineering. We moved through Paleolithic, Neolithic, Copper, Bronze, Iron, and Silicon ages, when we observed technology being pushed by human capability with materials. Polymers emerged and engineering materials were broadly classified into three non-overlapping categories – metals, ceramics, and polymers. From ancient times, there were sporadic attempts to stitch materials across categories like mud and thatch/husk to attain mechanical properties not attainable in either dried mud or thatch/husk. In our century, we have used conducting metal-metal composites in high tension transmission lines and in superconducting wires in magnets. But systematic study of combined or composite materials across the categories and even within them, started in the early sixties of twentieth century. Two materials could be combined geometrically in a number of ways. If one of them is topologically continuous, it is called matrix in which the second material is dispersed or discontinuously distributed as it happens normally in a composite. But it is also possible to combine two materials when both are topologically continuous and the composite is called interpenetrating composite. The discontinuous material may have a variety of shapes in three dimensions. The simpler shapes like needle, rod, disc etc are often characterized by aspect ratio, the ratio of length to radial dimension. One may combine more than two materials, thus offering an enormous possibility of creating combined or composite materials of different geometrical characteristics but such combination is meaningful if it offers some unique advantage in properties.

When two materials combine they create an interface and in a composite containing discontinuously distributed second material in a matrix, the second material is accessible for transmission of stress or transport of current only through this interface. Thus, status of interface is extremely important and it is broadly indicated by the energy or work of adhesion, which is difference between interface energy and the energies of the surfaces forming the interface. If the energy at the interface remains the same as the sum of surface energies, there is no interaction between the surfaces and the work of adhesion is zero. It may amount to simple stacking of materials. But if there is physical interaction in terms of local rearrangement of atoms or chemical interaction causing significant rearrangement of charged subatomic particles, there will be energy released leading to adhesion between the surfaces. In absence of this interaction, the combination will display properties given by the rules of mixtures without the benefit of synergy between the properties of the materials in combination. Even frictional interaction between the materials may provide considerable synergy in the combination under certain circumstances.

When one combines two materials, the scale of combination is a relevant consideration. In the early sixties of the last century, we started combining materials on a micrometer scale as it happens in multi-phase alloys, which are natural combination of elemental constituents and their discovery started with Bronze Age. The composite being man-made combination is distinct from multi-phase alloy. But human ingenuity could lower the scale of combination even in alloys to nanometer scale by appropriate heat treatment as in those containing GP zones. Increased focus on naomaterials in the nineties, made
materials available in nanosizes for dispersion into a matrix. The resulting nanocomposites often have interesting novel properties distinct from those of the composites where the same materials have been combined in micrometer scale. The step from micro to nanocomposites may be a small step across the scale but it is fraught with challenges. Combining materials of nanosizes is very difficult because of high energy surfaces of nanoparticles giving rise to a tendency of agglomeration of particles. But when nanoparticles could be dispersed successfully, such combination has already resulted in combination of properties like enhanced strength and ductility, which could not be obtained in either microcomposites or precipitation hardened alloys.

A number of composites have been developed to attain unique tribological properties – friction and wear without and in presence of lubricants. The first patent on cast metal matrix composites is of graphite dispersed in aluminium, where graphite could overcome poor gall resistance in aluminium to make it a potential candidate for developing lightweight pistons and cylinders in automobiles replacing graphite bearing cast iron. Thereafter, both hard ceramic particles having relatively low adhesion with metals and soft solid lubricating particles with low shear strength have been dispersed in metal matrix to obtain low friction and low wear composites. Copper-graphite and silver – graphite are employed extensively in electrical contacts like relays and other components. High friction low wear composites are also important for brake pads and discs where large amount of power is to be dissipated quickly. Different kind of composites could be designed for different tribological applications. During sliding of composite surface, the debris generated often get compacted into a transfer layer on the sliding surfaces and it contains the particles of solid lubricants or oxides dispersed in the composite. This transfer layer is very important in determining the observed friction and wear behavior of the composite against a given counterface.

It is really surprising that it took us so long to focus our attention on composites while nature has evolved composite materials extensively in varieties of scales, shapes and distribution. The present book offers glimpses of processing and tribological properties of composites. In this book, the possibility to mimic ventral scales of snake by laser texturing for getting proper frictional response has been examined. Considerable attention has been given in the past to natural fibres but their variation of properties with degree of maturity poses a problem in attaining reproducible properties in a product made of it. Natural date palm fibres have been incorporated in epoxy matrix composites as described in the present book and there is significant improvement in mechanical properties of epoxy based composites. The processing of polymeric composites and manufacturing techniques like machining have also received some attention in this book.

There is significant application of tribomaterials in implants where biocompatibility is of prime concern. Generation of wear debris in joints during movement often creates medical complications necessitating replacement. This book also devotes some attention to development of coatings to reduce generation of debris so that such implants have enhanced life without needing replacement in a lifetime.

Graphite has been dispersed in aluminium/copper matrix since long to produce a low friction and low wear material having mating surfaces covered with solid lubricating layer of graphite during sliding. Some attention has been given in this book to design self lubricating composites based on copper. These composites have now been extended by changing the scale of combination to nano-dimension by incorporating MWCNT and nano-graphite in copper as the book describes one of the efforts. However,
the agglomeration of nanoparticles poses a big challenge in developing satisfactory product. In addition, the book also contains some broad reviews of status of composites as tribomaterials including lightweight nanocomposites. The corrosion and degradation of the tribo-surface has also received some attention in this book.

The composite materials have become a vast subject in the last fifty years and it cannot be expected of a book to justifiably cover its entire span. Even tribo-composites by itself is so extensive that a single book is bound to prove inadequate. The present book may be judged by what it contains rather than what it fails to cover. I am very hopeful that the book will arouse interest of readers in composite tribomaterials inspiring further thought and development in this area.

Subrata Ray
Indian Institute of Technology Mandi, India

Subrata Ray, currently Visiting Distinguished Professor in the School of Engineering at IIT Mandi, India, obtained his Bachelor’s degree from Bengal Engineering College Shibpur, and Gold Medal from Calcutta University for standing first in his discipline. He was awarded M.Tech. and Ph.D. degree by IIT Kanpur. He joined a career in research and worked in National Aeronautical Laboratory, Bangalore, and National Physical Laboratory, Delhi, before joining the erstwhile University of Roorkee in 1978 as a faculty in Metallurgical and Materials Engineering. He has held visiting appointments in the University of Wisconsin – Milwaukee, USA, Institut National Polytechnique de Grenoble, France, and Technical University, Berlin, Germany. He has research interests in Materials development with special emphasis on cast Metal Matrix Composites (MMC). He has many pioneering contribution in cast MMC including introduction of stir-casting and addition of surface active elements for which he held the first patent in the world. Since then, Professor Ray has progressively decreased the size of reinforcement in stir-cast composite from hundreds of microns to nanometers. In the mean time he also developed interest on materials used in Li-ion batteries. He has supervised 29 M.Tech. dissertations and 37 dissertations leading to Ph.D. degree. He has published more than 200 technical papers, mostly in International journals and handbook, including those of ASM and ASLE. He is a fellow of the National Academy of Sciences, India, and Indian National Academy of Engineering.