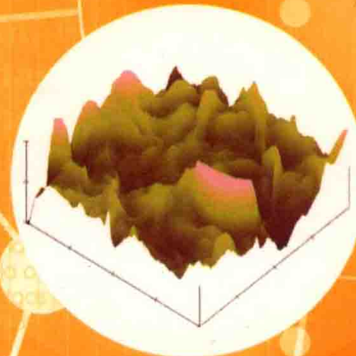

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Sujeet K Sinha ◆ Brian J Briscoe

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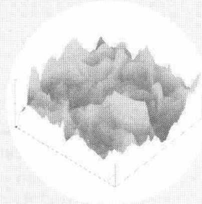

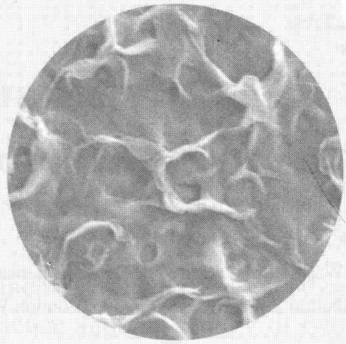

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EDITORIAL

POLYMER TRIBOLOGY — A PREFACE

Tribology is defined as the branch of study of interacting solids. In more technical terms, it is the science and technology of two contacting solid surfaces in relative motion that produces effects such as friction, wear, adhesion, stiction, surface fatigue and so on. These simple terms obviously entail a host of complex surface mechanical and materials issues. Tribology is a very materials-related discipline where each material may produce entirely different phenomenon during contact sliding and a "trail of events" that will decide its performance in terms of the measured quantities such as the coefficient of friction, wear rate and the durability. The fact that tribology is an interfacial phenomenon, it also greatly depends upon the surrounding (environmental) factors such as the presence of contamination, oxide layer on the solid surfaces, thermal heat and lubricants, in addition to the intrinsic chemical, physical and mechanical properties of the two interacting bodies and operational conditions of contact pressure and relative speed. There is another factor that may change the tribological performance of two bodies and that is the presence of loose debris materials that is ejected from either of the interacting bodies and this is known as the "third-body".

The above serves as a broad definition of tribology and presents the complexity that is faced while dealing with the design of any contacting mechanical system where relative motion, intentional or unintentional, is experienced. With this background, tribology of polymers and their different modifications presents further complexity as polymers are easily influenced by the operating conditions and the prevailing environment. However, tribology of polymers is also a fascinating area because polymers can be modified by various chemical and physical means to suit a particular application. In addition, they are available in liquid, solid or semi-solid forms at room temperature and thus provide opportunities of their use as solid or liquid lubricants, low friction and wear resistant bulk solid or as films.

Although research activities on polymer tribology started almost at the same time when tribology was gaining importance as recognized mechanical and materials field in engineering, important works really started with the works on rubbers and elastomers. This was because of the importance of rubbers and elastomers in the development of modern automotive industry. These materials served as tyres and brake pads which were all subjected to severe sliding and loading conditions coupled with the onslaught of external factors such as the adverse road conditions, dirt and water. Earliest reference that can be found on the friction studies on rubber is by Roth, Driscoll and Holt [1]. The concern for the tribological (mainly friction and wear) performance of rubbers led to the classical work by Schallamach by needles and spherical balls under scratching or sliding conditions [2]. His works have remained the hallmark of many subsequent works on rubbers and elastomers. Further adaptations of these works can be found in later researches.

Tribological work on non-elastomeric polymers can be traced back at least to the publication by Shooter and Thomas [3] in 1949 in which they investigated friction coefficients for polymer sliding on polymer and on steel for Teflon (PTFE), poly(ethylene), poly(styrene) and Perspex (PMMA). They found that the area of contact was proportional to the normal load, thus verifying Bowden and Tabor's proposal for metals. This work established that the value of friction coefficient of PTFE and PE were very low (low interfacial shear strength), a result that led to many tribological applications of these two linear thermoplastics. By late 1950s, many other polymers were also recognized for their value as tribological materials and work had begun on understanding the fundamental mechanisms of friction and wear of many polymers of the day. Research on polymer tribology intensified in 1960s and 1970s and many of the current understandings in these subjects can be traced back to the classical works by Tabor's group [4-6] at Cavendish Laboratory, University of Cambridge, UK. Works by Tanaka [7, 8], Lancaster [9], Steijn [10], Grosch [11] and by the Russian group are also notable [12, 13] on PTFE and many other thermoplastics. These early works found many new tribological applications of thermoplastics in areas such as biology and space technology. One notable example is the application of ultra-high molecular weight poly(ethylene) (UHMWPE) as load bearing acetabular cup in hip prostheses [14, 15] that was used almost accidently after a failed attempt with PTFE by John Charnley in 1962. UHMWPE is still the most popular material for hip/knee prosthetic joints. Similar tribological applications of polymers in engineering are abound.

The successful applications of bulk polymers in engineering led to the work of using polymers as composites where modifications to properties could be achieved by adding fillers such as strong fibres, lubricating solid particles and even metallic particle and fibres. Polymer composites have been very successful in finding many engineering applications as tribological materials for gears, bearing cage, shoe soles, automotive brakes and so on. Important early works on polymer composites were conducted by groups led by Briscoe [16, 17], Bahadur [18] and Rhee [19]. The popularity of the field of tribology of polymer composites led to the compilations of many edited works and a notable early work among them was the edited book by Friedrich [20] in 1986. Polymer composites have been so successful in tribology that in today's time, probably it would be hard to find a polymer for tribological application which is not in composite or even hybrid form. This work has further extended to the application of nano-sized fillers such as nano-clay, carbon nanotubes, nano-sized ceramic particles (Si_3N_4) and so on, with further improvements in the friction and/or wear performances [21, 22]. Presently, composites are used as bulk or as films for various applications where surface friction and wear are important design requirements.

In line with the developments in the area of polymer tribology, as briefly outlined above, this book was commissioned to present the achievements in a manner that incorporates all facets of the tribology of polymers, their modifications and most importantly, their applications. Each selected topic has been written by experts in the field. Though not initially intended, this book has naturally followed its division into three major parts: bulk polymers, reinforced polymers and polymer films. These are the three important forms of polymeric solids that a user may find during the course of engineering design and materials selection or in tribological research involving polymers. Part I of this book deals with polymers that have not been modified with any strengthening agent for bulk mechanical properties. Chapters in this part are on the fundamental studies of adhesion, friction, hardness and wear of some important thermoplastics. This part also includes chapters on the application of pristine thermoplastics for biomedical and Microsystems, and, a chapter on the tribology of rubbers, all in un-reinforced form. Part II deals with the popular subject of tribology of reinforced polymers, also called polymer composites. As many of the polymers are inferior in load carrying capacity when compared to other engineering materials such as metals, it is useful to add fillers to increase the strength and thus reduce wear. This trend started with the use of fillers such as glass fibre, carbon fibre, aramid fibre and a host of particulate fillers in polymer matrices such as epoxy, phenolics and many thermoplastics. Fillers are also added to polymers to modify their friction property and thus wear performance; addition of PTFE particle comes under this class of materials. These trends in the area of tribology of polymer composites have been captured by several chapters in this book. There are many applications of polymer composites and hence we have included chapters on the tribological applications in gears, brake and other automotive components. Currently, there is a new trend on the tribological application of polymer films and coatings. Polymer coatings, in pure or blended (composite) form, can be applied to almost all materials by chemical, physical or even mechanical bonding or interlocking. There are many advantages of having polymer coatings on substrates such as metals, Si or even some polymers which are very poor tribological materials. Use of solid or partly-lubricated polymer films would avoid the need for liquid lubrication if the conditions are well-controlled. Therefore, Part III of this book is dedicated to some works on polymer films. This includes chapters on the mechanical property characterizations and several applications such as in Microsystems for achieving low friction and low wear performance. A very novel approach in this field is the use of polymer brushes that have shown excellent tribological properties and hence we have included one chapter on polymer brushes as well.

Overall, we are very hopeful that this book provides an excellent spectrum of results and analysis on the tribology of polymeric solids in their various forms and manifestations. It has been a privilege to collaborate with leading researchers from around the world for this book and we are very grateful to them for providing us their chapters as presented in this book. The meticulous hard work by the authors of the chapters made our editing job relatively easier and any error still found in this book is entirely due to our incapability.

The Editors
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