Book Reviews

Toughened Plastics
C. B. Bucknall
Applied Science, Barking, 1977,
359 pp. £18.00

Those who are familiar with the subject will immediately recognize the author of this book as a leading authority in the field of rubbery/glassy polymer blends. A book which brings together the results of extensive research carried out over the last 15–20 years is therefore very welcome.

The book consists of 12 chapters falling approximately in three sections. The first four chapters deal with the chemical and microscopical characterization of multiphase polymer blends. The second section comprises six chapters dealing with viscoelastic properties, yield and fracture aspects. The third section consists of two chapters dealing with processing and electroplating respectively.

The author claims that the book should be of interest not only to specialists involved with the subject in industrial laboratories but also to advanced students of materials and polymer science. In particular, the first section is considered to be of interest to physical chemists engaged in research and development and in characterization and quality control work. The final two sections, on the other hand, should be of interest to all those concerned with the manufacture and applications of rubber toughened plastics.

Although the book bears the general title of 'Toughened Plastics' it considers only rubber/glassy polymer blends, and it excludes, therefore all thermosetting moulding materials and laminated compositions in which the toughness, *inter alia,* is achieved by means of an organic or inorganic fibrous phase. For this reason it might have been better to chose a more specific title, such as 'Rubber Toughened Plastics', which would have then justified the author's rather quick reference to fibre reinforcement (p 265) in dealing with the CTBN-toughened epoxy resins.

In connection with the question of adherence to the theme suggested by the title, one may also find it somewhat surprising to read in the inside front cover that 40% of all polypropylene is rubber toughened, and may not be persuaded by the subsequent arguments about the formation of spherical rubber particles consisting of random ethylene–propylene copolymer chains, embedded in spherulites of homopolymer and block copolymer species.

It is unfortunate, in fact, that the author refers several times to microscopical observations of such spherical rubber particles embedded in polypropylene spherulites but does not provide any micrographic evidence. This is quite unlike the approach taken throughout the rest of the book, where every interpretation is meticulously substantiated by a multitude of pictorial illustrations and references to the original publications.

Apart from a few 'blackboard' style notes (p 295) the book is well written and only occasionally might one find the interpretations given somewhat difficult to follow (e.g. the effects of rubber relaxation in crack propagation in impact tests – p 292).

The book is also remarkably free of typographical or 'minor' errors but the following have been noted: (1) A free-radical electron on the CH group, equation (i), p 25, has been missed out. (2) There should be a + sign (instead of –) between the two terms of the right hand side of equation 6.14 in p 166. (3) The constant π is missing from the numerator of the right hand side of equation 9.14, p 252. (4) The exponent 2 should not appear with respect to σ_y in equation 10.20, p 285. (5) The constant π is missing from the denominator of equation 10.23 p 288, where in the second part it should read +52, instead of ×52. (6) In p 312, $n(0.33)$ should read $n = 0.33$. (7) Several paramaters are not expressed in SI units, e.g. solubility parameters in p 35 and molar concentrations in p 334. (8) In the index, p 359, PRO should read PPO. (9) Some changes in symbols have occurred occasionally, e.g. P_c in equation 9.19, p 256 becomes P_f in equations 9.25, p 258 and 10.1, p 275, δ_c denotes critical *COD* in equations 9.17, p 253 and 9.26, p 261, whereas in equation 10.1, p 275 it is used for the 'critical elastic deflection'.

The layout of the book is very well conceived and each chapter is almost self-contained, and properly divided into subsections to enable those readers only interested in specific aspects to find the desired information without having to make many cross-references to other sections or to the original publications. At the same time the reader will find an enormous list of references (with the exception of chapter 13, perhaps) for a more thorough study of the relevant literature. In this respect, therefore, the book will make a very useful addition to both industrial and academic libraries. Furthermore the highly illuminating interpretations of the deformational mechanisms and kinetics of deformations and fractures of glassy polymers and blends will no doubt go a long way towards increasing standards in the teaching of material (*cum*-polymer) science and technology.

However, some care is necessary in the reading of certain sections of the book in so far as there are statements which are either out of context or erroneous and may therefore create confusion. For instance:

(1) In p 256 the derivation of Irwin's relationship between strain energy release rate, G_I and the rate of change of compliance with crack extension dC/da (an inconsistency in itself in as much as this is practically the only instance, throughout the whole book in which the author shows any preoccupation with the origin of the equations quoted) may confuse those not familiar with fracture mechanics (and there are a great number of these among polymer scientists/technologists). Because the concept of G_I is launched under the section dealing with tests using DCB specimens, where the load remains constant (or approximately so) during crack extension (see Figure 9.6, p 255 for instance), the statement 'at constant P' at the side of the equation proceeding 9.19 may convey the impression that this is the only condition for which the relationship is valid. This is plainly not so. Had the author considered, in fact, the other extreme condition, (i.e. crack extension at constant plate displacement) by differentiating $CP=h=$constant with respect to a and substituting these terms in the first equation, he would have obtained exactly the same relationship, with the only difference of a negative sign (a manifestation of the direction of the energy changes involved).

(2) In connection with the above, one also fears that the concept of J integral in dealing with fractures involving gross yielding throughout the entire width of the specimen (vaguely referred to by the author, as 'fracture surface energy', p 293 and 'plastic work parameter', p 282) will not be easily grasped by many readers and that the important difference between G_C, G_B and J_{IC} may not be appreciated.

(3) Figure 10.5, p 283 has been wrongly reproduced from the original publication, in so far as σ_{11} reaches a maximum value equal to the yield strength, σ_y, only under *plane stress* conditions. Under *plane strain* conditions, the maximum value of σ_{11} is much higher and for the particular case quoted $\sigma_{11} = \sigma_y[1 + (\pi/2) - (\phi/2)]$ where ϕ is the V-notch angle.

(4) The casual comment (p 309) about water exhibiting a swell ratio of 13.5% (without supporting evidence from the literature, theoretical considerations or experimental results) as an argument for suggesting that the swell ratio of polymer melts at zero shear stress should be greater than one, is meaningless. Firstly for a valid comparison one ought to take in consideration the swell ratio of water (as an example of a Newtonian, non-elastic fluid) at zero Reynolds number. Secondly any argument about swelling of polymer melts simply in terms of shear stresses, i.e. without reference to normal stresses, has doubtful validity and thirdly, surface tension at low shear rates may have a predominant effect on the swelling of water whereas it is probably insignificant for polymer melts.

Another criticism about this book is the lack of consistency in some places, with respect to the background knowledge assumed and the possible use to which the book may be put by the reader. For instance, while the author may be justified to assume that a physical chemist is probably familiar with the concept of 'Larmor frequency' of a proton in a strong magnetic field (p 60) but not with the definition of viscosity (p 310), he could not use the same argument when he talks about resolved shear stress (p 137), deformation rate tensor (p 141) and maximum shear stress (p 152). Similarly it is difficult to understand why a treatment of the kinetics of copolymerization for ionic and Ziegler–Natta systems has been omitted when the corresponding free radical process was dealt with in some detail.

In conclusion whereas there are several criticisms about the accuracy of some of the contents of the book (and others could be added to the above list), the reader must not overlook the merits emphasized earlier. The interpretations of yielding phenomena through crazing and shear deformations, and the methodology used to quantify the relative contribution of each of these processes have thrown so much light on the fundamental principles of toughening that they will undoubtedly enable the reader to transfer this knowledge to other situations, such as composites based on particulate and fibrous fillers.

L. Mascia

Proceedings of the Royal Society of London. A. A Discussion on Rubber Elasticity. Volume 351

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This timely discussion meeting, organized by the Royal Society in November, 1975, deals with a branch of physics which has long entered into its second century: rubber elasticity. Indeed, the fundamental contributions made by Joule in 1859, briefly analysed by Price on p 332, may still arouse our admiration. The subject still presents much to challenge both theoreticians and experimentalists.

The introductory remarks by Gee set the scene for the expert and the newcomer, and delineates with precision the interplay between experimental labour and theoretical analysis. The state of play in 1975 is then summarized in one slim volume, from the view-point of mechanics by Treloar, of statistical mechanics by Flory, of thermodynamics by Price, and by Allen from the vantage position of network structure and molecular dynamics. Finally Edwards sets out to dig more deeply to the roots of the physics, where the dynamics of chain molecules and thermodynamic theory meet under the aegis of Boltzmann and Gibbs respectively. The proper treatment of constraints is essential if the Gibbs point of view is not to lead us into paradoxes and controversies, and Edwards sketches how this must be done. The power of the Wiener-integral formalism in compressing an immense amount of algebra is demonstrated by rederiving the Rouse equation and one may hope that more young theoreticians will be led to evaluate the virtues of functional distributions. Edward's point that one needs a really brief mathematical notation in order to proceed, is well taken. Whether this requires the operators to be drawn from the functional calculus, with the implied smoothing of knobbly molecules to continuous and differentiable curves, or whether the discrete world of atoms can furnish the equivalent combinatorial (discrete) operator calculus more directly, will perhaps remain open for some time.

A brief record of exchanges mainly by way of questions and answers, is appended to the lectures. The Discussion is warmly recommended to all who are (or should be!) interested in the rubbery state of matter from the experimental or theoretical angle – including biologists and material scientists, physicists and mathematicians, mechanical engineers and – last not least – chemists.

M. Gordon

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