Understanding Viscoelasticity: Basics of Rheology

Nhan Phan-Thien
Springer-Verlag, New York, 2002. $34.95 (145 pp.). ISBN 3-540-43395-3

In *Understanding Viscoelasticity: Basics of Rheology*, Nhan Phan-Thien, who has produced several substantial contributions in rheology over the past three decades, provides a concise account of the behavior of real materials. Most materials, such as the now ubiquitous polymeric composites, display a behavior somewhere between that of ideal (inviscid) fluids and ideal rigid solids. That is to say, they are viscoelastic.

Suitable as a text for a first-year graduate course in viscoelastic materials, the book provides students with some necessary tools to read and better understand technical articles in the field.

Phan-Thien sensibly introduces the reader to a mesoscopic approach to modeling. Although one would prefer to use molecular theories for macromolecular dynamics, their quantitative predictions for a variety of material functions are not yet compatible with reliable predictions derived from theories based in continuum mechanics. Until such compatibility evolves, hybrid continuum–particle theories should help to improve physical understanding of mesoscopic phenomena and to suggest directions for the more fundamental molecular-theory approach.

Among the book's many positive attributes are the clear introductory remarks that begin each chapter. Concepts leading to material functions are well introduced and defined. Nice historical tidbits, sprinkled throughout, convey valuable information on scientists of note and the remarkable scientific advances for which they are famous. Homework problems with ample pedagogical and mnemonic value appear at the end of each chapter. Given its extensive mathematical content, the book is remarkably free of typographical errors.

The conciseness of Phan-Thien's text is reminiscent of other such important works as William Schowalter's *Mechanics of Non-Newtonian Fluids* (Pergamon Press, 1978) and Arthur Lodge's *An Introduction to Elastomer Molecular Network Theory* (Bannatek Press, 1999), both of which deal tersely and at a rather advanced level with viscoelastic materials.

The book's conciseness can sometimes be a liability. For example, group theory and functionals are mentioned in only a few short paragraphs. Also, the book limits its summary of tensor analysis to Cartesian tensors, whereas *Rheology of Polymeric Systems: Principles and Applications*, by Pierre Carreau, Daniel De Kee, and Raj Chhabra (Hanser, 1997), provides a more comprehensive account of generalized curvilinear coordinate systems and higher-order tensors. A longer and more complete account of such topics of interest as stress, strain, and constitutive equations can be found in Cemal Eringen's *Mechanics of Continua* (Krieger, 1980). Finally, a list of modern nomenclature is absent and would have been helpful.

The pedagogically astute homework problems are designed to deepen a student's understanding. However, in some cases, such understanding would require a mathematical maturity that students may lack, given the current content of most undergraduate engineering curricula.

Despite the few limitations imposed by the book's brevity, *Understanding Viscoelasticity* is a joy to read and will be very useful to motivated students.

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Semiconductor Optics and Transport Phenomena

Wilfried Schäfer and Martin Wegener
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In the past three or four decades, the development of semiconductors has led not only to well-known advances in devices, but also to new physics. The root of that development is the ability to make a semiconductor structure whose charge carriers are confined to a nanometer region in one, two, or three dimensions. Electrons interact more strongly with each other under such confinement. In a strong magnetic field normal to a layer of electrons, the electrons' transport reveals the famous integer and fractional quantum Hall effects. These effects have inspired elegant theories that have wider applications in many-body physics. The confinement of electrons in quantum dots has led to mesoscopic physical effects and to a new understanding of electron transport.

Meanwhile, the development of laser optics, especially that of picosecond and, subsequently, femtosecond lasers, has made it possible to optically excite the electron–hole pairs and to measure the phase of the pairs. The resultant motion is known as coherent dynamics. Semiconductor physics has now advanced almost to the point at which specific designs of electrical and optical control of the dynamics of the electron position and spin are possible.

The rapid pace of discovery in semiconductor physics makes it difficult to initiate neophytes to the field. To be sure, excellent monographs exist, but teaching a monograph-based course to cover such a wide range of topics would place great demands on the instructor. With *Semiconductor Optics and Transport Phenomena*, Wilfried Schäfer and Martin Wegener have come to the rescue. Their book, aimed at graduate students who have had an introductory course in solid-state physics, covers most of the developments described above.

The authors are important figures in semiconductor optics. Schäfer has made definitive contributions to the theory of interacting electrons and collaborated with experimentalists to explain exciton dynamics under ultrafast optical excitation. Wegener is prominently known for his experimental exploration of the new world of exciton dynamics in the first few femtoseconds of their creation. The collaboration of a theorist and an experimentalist in this book fulfills the authors' intent to synthesize theory and empiricism. It is delightful to find that, after reading about the Bloch theory, one can understand the four-wave mixing experiment and measurements of the dephasing time. If readers find some parts of the Green's function theory heavy going, they can skip such parts (perhaps temporarily) in favor of the phenomenology.

The text covers basic electron properties, optics, and transport. The optics part provides important paradigms of decoherence and of nonequilibrium physics, both of which are essential to the modern physics of the small. The book also carefully describes such fundamentals as the gauge relation between the $\mathbf{p} \cdot \mathbf{A}$ and $\mathbf{r} \cdot \mathbf{E}$ expressions for light–matter interaction. Had those expositions been omitted, the thoughtful student might have been frustrated.

The authors missed some opportunities to present exact theory in place of approximations. One instance is their treatment of electron dynamics near the band edge. An electron near the band edge can be proved, to all orders of the electron–electron interaction in a static lattice, to be a well-defined quasiparticle with a renormalized mass and a dielectric-screened interaction with other band-edge electrons and holes. Then, in chapters 3 and 6, the Hartree–Fock approximation for the electron is unnecessary; in that approximation, one must, ad hoc, add the dielectric screening to the exciton equation. That difficulty is avoidable, because the standard effective-mass equation for the exciton has been shown to be exact in the Wannier limit.

It would be churlish to dwell on the few flaws (or perhaps merely disagreements between us) in such a large undertaking. I mention them here only for consideration in the next edition. It may lead to errors to assign damping rates (for example, on page 90) without basing them on a microscopic theory. The recombination rate of electrons and holes would give the same decay rate for each species, but some mechanisms that affect the lifetime of only one species contribute to pure dephasing. The statement on page 110 that the semiclassical treatment of the electric field is valid when the field is quantized neglects the correlation between the field and the exciton. The current count in the photodetector, equation 4.79, should be either the electron or the hole contribution.

I believe (with perhaps the excessive fervor of a convert) that interdisciplinary knowledge in coherent optics, in strong-interaction physics, and in mesoscopic physics will play an expanding role in semiconductor and metal physics and thus help physicists to understand nanosystems that are far from equilibrium. The traditional semiconductor physics curriculum—electrons, phonons, transport, and a bit on optical properties (but not coherent dynamics)—is insufficient to prepare a student for the increasingly quantum world. I recommend Schäfer and Wegener's timely and pioneering text for a cohesive presentation of modern semiconductor physics.

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Transport Processes in Bubbles, Drops, and Particles. 2nd edition. D. De Kee, R. P. Chhabra, eds. Taylor & Francis, New York, 2002 [1992]. $130.00