

Electronic and Electro-Optical Packaging at APL: Guest Editor's Introduction

Harry K. Charles Jr.

Imagine a billion transistors on a piece of silicon the size of a thumbnail connected to an electronic system with gold wires several times finer than a human hair—each shaped and precisely placed in fractions of a second. Further imagine that such operations are repeated over 10 billion times daily around the world! In addition, consider that new semiconductor devices can operate at temperatures approaching 1000°C. Also, there are other single devices that can switch, emit light, change carrier type, and oscillate all under external electronic control. Such is the modern world of electronics and electro-optics: a world faced with huge promise and major challenges, especially in the packaging arena.

The world of electronic and electro-optical packaging is a complex, highly interdisciplinary one that continually faces the challenges of new devices and applications. Levels of integration are doubling on an almost annual basis. Integrated circuits dissipate more power, require more inputs and outputs, operate at ever-increasing speeds, and communicate not only by electrons but also by light. Dual- and quad-core desktop computers operate at clock speeds above 3 GHz, with higher speeds in the laboratory. Systems are using combinations of circuit track, integrated light guides, and free-space optics. Electronic and electro-optical systems are getting smaller and smaller but with ever-expanding capability. The commercial electronics and electro-optics market is driven by portability and the wireless interconnect. Packaging technologies are aimed at reducing size, improving connectivity, and

ruggedizing the product for today's active lifestyle. Such attributes also are key for APL's prototype and one-of-a-kind system development efforts. Harnessing the available functionality in a manner compatible with the application and at a reasonable cost is the electronic and electro-optical packaging challenge for APL, a challenge that must be met for APL to continue its leadership in system engineering and integration.

So how does APL fit into the modern electronic and electro-optical packaging world, and is it prepared to meet the challenges of the future? This issue of the *Johns Hopkins APL Technical Digest* attempts to answer these questions by capturing current and developing APL packaging activities and by providing some insight into what the future holds.

In the article by Schaefer et al., the concepts behind the packaging of three recent APL spacecraft (New

Horizons, MESSENGER, and STEREO) are presented. The success of spacecraft packaging is based on the integration of current electronic and electro-optical components, materials, and structures into a low-mass reliable system that satisfies the mission requirements and will survive the rigors of the space environment. The next article, by Maurer et al., describes a particularly important space environmental issue: radiation. Radiation is a key concern for the performance and longevity of electronic and optical components. Maurer et al. focus on space radiation effects and how these effects can be mitigated in silicon-based microcircuits.

The next four articles focus on the building blocks of electronic and electro-optical packaging: devices, substrates, interconnection, and adhesives and encapsulants. Wickenden describes the development of modern integrated circuit and device technology. He takes a look into the future and what changes in device technology will be required to keep Moore's Law going beyond the year 2020. The article by Francomacaro et al. examines APL's substrate technology and how it is evolving to meet the needs of modern electronic technologies, especially electro-optics. Substrates involving integrated light guides and other optical devices as well as signal routing methods are presented.

Clatterbaugh et al. describe miniaturized interconnects for the full range of electronic and electro-optical devices. APL specializes in low-volume, prototype, and one-of-a-kind system builds, yet the interconnections

have to be reliable and performed by using techniques transferable to industry. The final building block article is by Benson et al. In this article, the development of organic-based adhesives and encapsulants for electronic and electro-optical packaging is traced. Adhesives and encapsulants (sealants) are key enablers for modern systems, and their chemistry needs to be well understood to ensure packaging reliability.

The final article in this issue, by Charles, summarizes many of the advances in technology available both at APL and in industry. Recognizing that access to advanced electronic and electro-optical technology is at the heart of all APL systems work, this article raises globalization issues and illustrates how our technology, especially electronic and electro-optical packaging technology, depends on foreign sources and suggests some steps we must take to keep ourselves knowledgeable about overseas research and development.

In summary, I hope that this issue of the *Digest* will demonstrate to the reader that (i) electronic and electro-optical packaging is key to the development of all APL systems both now and into the future; (ii) the rapid pace of evolving technology places many demands on our current packaging technology, ranging from resources to needed research; (iii) APL's system development future depends on access to advanced devices and packaging technology; and (iv) globalization and the loss of domestic research in the device and packaging arena pose challenges for APL's system business.

The Author

Harry K. Charles Jr. is a member of the Principal Professional Staff and Chief Engineer of the Milton S. Eisenhower Research Center. He holds B.S. and Ph.D. degrees in electrical engineering from Drexel University and The Johns Hopkins



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University (JHU), respectively. Dr. Charles has worked for more than 30 years in the microelectronics arena and is a specialist in solid-state physics, electronic devices, packaging, and reliability. His latest interests include multichip-module design, fabrication, and testing; advanced interconnection; biomedical instrumentation; and novel sensors based on meso-, micro-, and nanoscale technologies. He has published more than 200 papers and authored 13 patents and several pending patent applications. Dr. Charles is a Fellow and former President of the International Microelectronics and Packaging Society (IMAPS), a Fellow of the Institute of Electrical and Electronics Engineers (IEEE), and a past member of the Board of Governors of IEEE's Components, Packaging, and Manufacturing Technology (CPMT) Society. He has received international recognition for his research, development, and teaching activities, including the International Society for Hybrid Microelectronics (ISHM) Technical Achievement Award (1987), selection as Maryland's Distinguished Young Engineer (1989), JHU's Outstanding Teaching Award (1992), the CPMT Board of Governors' Outstanding Service Award (1992), ISHM's Distinguished Service Award (1994), the IMAPS Daniel C. Hughes Memorial Award (1998), the R&D 100 Award (2002), the APL Invention of Year Award (2006), the APL Master Inventor Award (2007), the APL "Wave of Contributions" Award for Innovation (2008), and numerous awards for best papers.