Materials for Optical Data Storage

Hans Coufal and Lisa Dhar, Guest Editors

Abstract

The development of recording materials has been a critical component in the advancement of optical data storage. The continual need for improved performance in both consumer and business applications has pushed forward the capabilities of optical storage. In this issue of *MRS Bulletin*, we review some of the important developments in the materials behind established technologies such as compact discs, digital versatile discs, and magneto-optical recording; the emerging technology of blue recording; and two technologies that seek to extend the performance roadmap for optical storage, multilayer and holographic recording.

Keywords: *magneto-optic, memory, optical.*

Optical storage has become ubiquitous as a method for distributing content, archiving data, and managing information. Given the portability and interchangeability of the recording media, optical technologies have found wide use in consumer and business applications. Propelling the development of optical recording has been the need in consumer electronics for higher data rates and increased storage capacity. For example, the progression of optical storage from capturing high-fidelity stereo audio to high-definition movies has required the evolution from compact discs to digital versatile discs to high-definition DVDs and Blu-ray discs (see Figure 1).[1] In addition, the increasing performance requirements for archiving data have pushed the advancement of magneto-optical recording.[2] Underlying the progress in optical storage has been continual advances in the recording materials to enable the higher storage capacities and faster data recording and readout rates.

The era of commercial optical data storage[3] began with the invention of "video disk" technology, later known as "laserdisc" technology, by David Paul Gregg in 1959. Designed for the distribution of video content, the approach used discs containing surface structures called pits and lands which modulate a readout light beam. The modulated light is captured by a pickup head and translated for playback. Initially configured using transparent discs and followed by more efficient reflective discs, laserdiscs were demonstrated to the public in 1972. The technology, which used 30-cm-diameter discs and stored video in analog format, was made commercially available in 1978. The laserdisc was an early demonstration of the power of optical storage: the absence of physical contact between the readout head and media, random access to content, and the relative simplicity of the media structure.

Building upon laserdisc technology, companies began developing optical discs capable of storing digital audio. In 1983, compact discs were introduced, storing approximately 74 minutes of audio. CD-ROM (read-only memory) discs, targeted for data storage and able to hold 650 Mbytes, entered the market soon after, followed by recordable and rewritable versions. Typically 1.2 mm thick and 120 mm in diameter, a CD-ROM consists of a single disc fabricated from polycarbonate. In the read-only structure, the polycarbonate is molded with pits 500 nm wide and 800 nm to 3.5 μm long on its surface. A thin layer of metal is deposited on the surface of the disc. A semiconductor laser at 780 nm is used to reflect off of the pit and land structure of the disc to reconstruct the recorded data.

The early 1990s saw efforts to increase the storage capacity of these types of optical discs, resulting in the commercial introduction of digital video discs—or, as they have come to be called, digital versatile discs (DVDs)—in 1996. Unlike the single-disc construction of compact discs, DVDs consist of two 0.6-mm-thick polycarbonate discs coated with a thin metallic layer, with each layer containing data that can be read independently. The discs are bonded together to product a 1.2-mm-

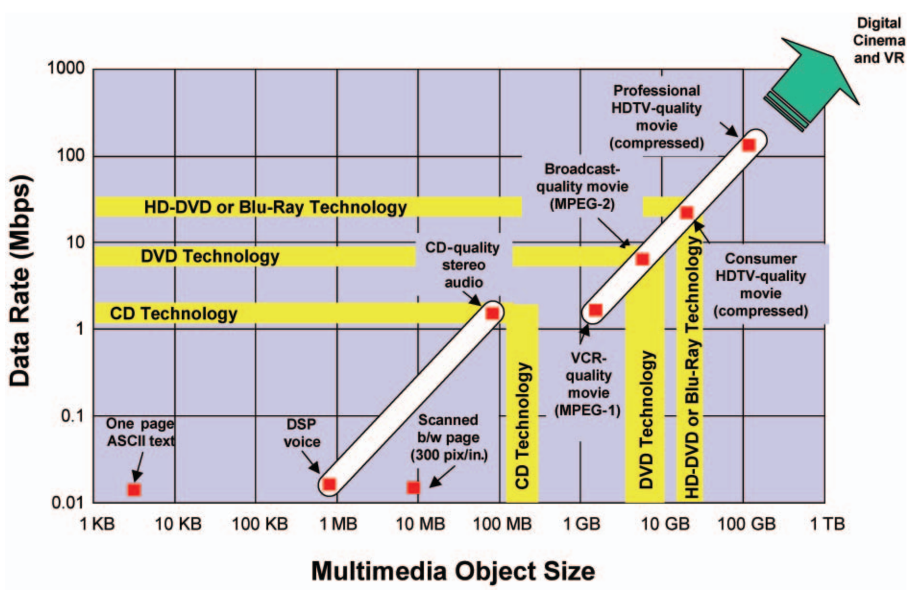

Figure 1. The continuing increase in storage capacity and complexity of multimedia objects has driven improvements in optical storage technologies. CD = compact disc, DSP = digital signal processor, DVD = digital versatile disc, GB = gigabytes, HD-DVD = high-definition DVD, KB = kilobytes, MB = megabytes, pix = pixel, Mbps = megabits per second, MPEG-1 = Moving Pictures Expert Group Standard 1, MPEG-2 = Moving Pictures Expert Group Standard 2, TB = terabytes, VR = virtual reality.

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thick package. The discs can be read from one or both sides, with each side containing one or two layers of data. In addition to taking advantage of the capability of optics to focus on different depths in the media, the increase in storage capacity of DVDs over CDs is achieved by using smaller feature sizes and a shorter-wavelength readout laser (650 nm). A single-sided, single-layer DVD can hold 4.7 Gbytes of information. Efforts to increase the storage capacity have centered on the use of blue lasers with a shorter (405 nm) wavelength, which allows smaller data bits and therefore higher capacity. These efforts are marked by the recent introduction of Bluray and high-definition DVDs that enable capacities of 15–30 Gbytes.

Concurrently with the development of CDs and DVDs, magneto-optical discs were developed, primarily for professional applications and the rewritable data market. Introduced in the late 1980s, this technology relies on the modulation of light by the magnetic state of the material. The performance of these discs has evolved from capacities of 650 Mbytes on a two-sided, 130-mm disc to current capacities of many gigabytes, with future products expected to reach terabytes of storage capacity.

In this issue of *MRS Bulletin*, we have sought to cover areas in materials research and engineering that span the field of optical storage. From the optimization of substrate materials for optical storage, to the growing complexity of materials for magneto-optic recording, to the recent developments of materials for blue laser recording, we hope to highlight the sophisticated design and fabrication methods that underpin the currently available optical storage technologies. In addition, we point to the future by including articles on materials for multilayer optical recording and holographic data storage, two technologies that can extend the optical storage roadmap to even higher performance. We conclude this issue with a contribution that summarizes the process and requirements for media standardization, the key for interchangeability in optical storage.

The importance of optimizing the materials properties of substrates for the various disc formats—CDs, DVDs, and blue laser discs—and issues such as media replication, recording, readout processes, and lifetime characteristics are discussed in the article by Bruder et al. in this issue. In particular, the authors focus on the development of polycarbonate materials that are not only tuned to exhibit the required performance profiles, but also, just as important, able to be cost-effectively manufactured.

The recent development of blue laser recording has extended the performance capabilities of the family of optical storage represented by CDs and DVDs. In their article, Kuiper and Pieterson write of the materials used in both write-once and rewriteable blue laser materials. The authors discuss developments in phase-change materials, spin-coated dye systems, and inorganic alloy materials and their suitability for the smaller optical spot sizes enabled by blue lasers.

We then examine the rare-earth/transition-metal materials and structures central to magneto-optical recording in the article by Kaneko. The author traces the evolution of magneto-optical recording from its commercial introduction in 1988, through the emergence of super-resolution techniques that enabled resolution beyond the optical limit, to current discussions of extensions of super-resolution techniques.

In the article by Milster and Zhang, the authors examine the materials required for multilayer recording, a technique that aims to increase the capacity of optical disc recording by using multiple layers of bitwise-recorded data. The challenges presented by the interplay between materials properties and the optical systems used for recording are summarized.

The last article, on materials for optical storage, focuses on high-performance polymers for holographic data storage. Holographic storage represents a departure for optical technologies from the traditional bitwise approach to recording; data is stored throughout the volume of the recording media in a parallel, rather than serial, fashion. Dhar summarizes the materials requirements of media for holography and focuses on recent progress in the development of polymer recording materials.

Glinka ends the issue with an article on the processes required for optical recording media and the organizations involved in standardizing those processes. For the established optical storage technologies, this standardization has been the key to their broad adoption. As emerging technologies such as multilayer recording and holographic storage reach commercialization and then widespread use, standardization will become a part of their development as well.

We hope that these articles focused on materials for established optical storage technologies will draw attention to the technological challenges involved in optimizing commercially viable materials. The strategies used to optimize materials with respect to issues such as performance, environmental robustness, and manufacturability have been critical in extending the capabilities of established optical technologies. These strategies serve as models for the development of materials for the emerging areas of blue, multilayer, and holographic recording.

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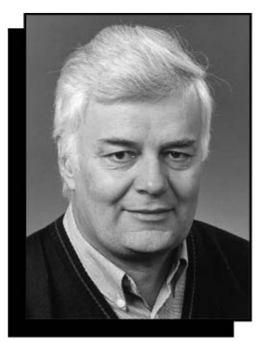

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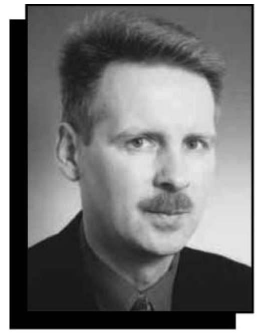

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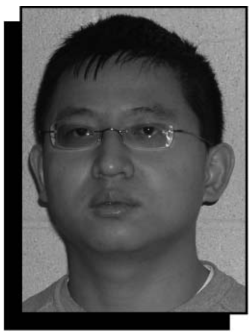

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