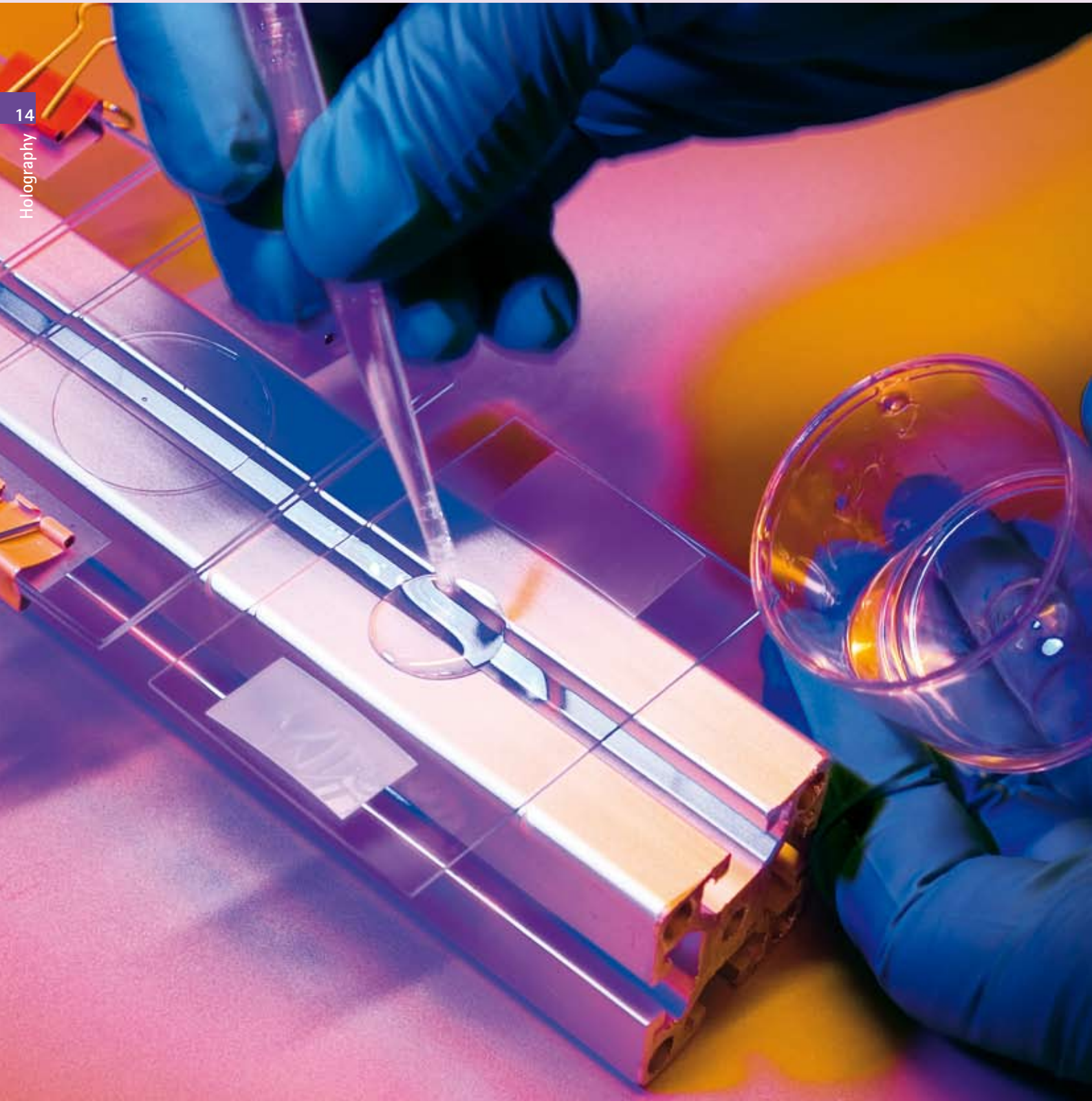
Plastics make holographic storage media a reality

Long life for data



Nothing survives the ages, not even electronic data archives. Magnetic tapes and CDs must be copied repeatedly over the years to rescue the bits and bytes from decay. In cooperation with U.S.-based InPhase Technologies, Bayer MaterialScience is developing holographic data storage media made of plastic which, thanks to a chemical process, preserve data for up to half a century and offer several times more storage capacity than today's DVDs. Bayer MaterialScience is playing a major role as a developer and material supplier in one of the leading data storage consortiums.

Polymer with optical quality: under UV-free light, Norbert Hermanns prepares the glass test slides (above right) on which the liquid Tapestry™ mixture will later dry to form a thin film. Data are stored by laser in the polymer as a hologram.

Be it music, movies or the latest computer applications, today's multimedia users are collecting increasing amounts of digital data in all forms. Similarly, government authorities and institutional archives have to manage exploding volumes of information, from electronic tax returns at the Internal Revenue Service to customer data at banks and insurance companies. Mountains of forms and documents are stored digitally today, and enormous rolls of magnetic tape are deposited for years in archives until the bits and bytes need to be retrieved.

But these data are transient. "Magnetic tapes keep for about five years," explains Dr. Gerhard Langstein of New Technologies at Bayer MaterialScience. Even CDs and DVDs don't have an unlimited archive life. They can become unreadable in less than 20 years. Heat, moisture and mechanical stress take their toll on the sensitive magnetic film or damage a CD's reflective layer. Archives are forced to spend a lot of time and effort regularly replacing the storage media. But innovative memory systems may soon facilitate their work. "New storage media based on holographic technology increase longevity to 50 years," Langstein says.

Holograms already decorate bank notes and ATM cards. They show different sides of a three-dimensional object depending on the observer's angle of view. This characteristic makes it possible to store large volumes of data on holographic materials. Instead of an image visible to the naked eye, they store patterns of light and dark points. Like the punch cards of yesteryear, the points stand for zeros or ones, combining to form binary information. And like a hologram on a credit card, each angle of view can be reserved for a new "punch card" and new data. As a result, holograms offer an immense amount of memory on a very small space.

New data disc holds as much as 50 DVDs

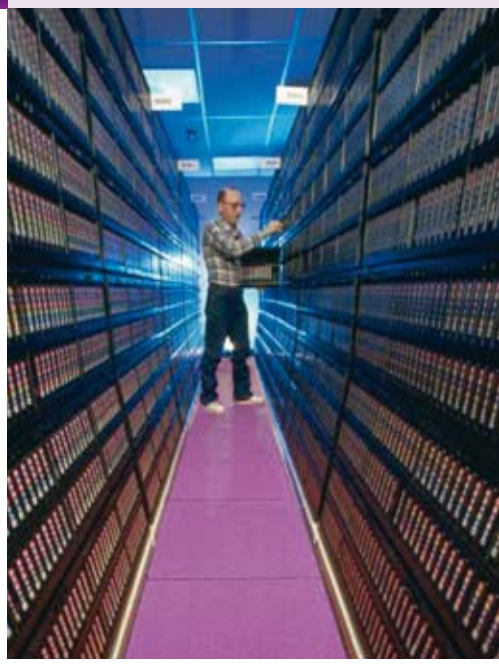
InPhase Technologies, based in Longmont, Colorado, has engineered a prototype read/record drive device for the new holographic discs. Bayer MaterialScience provides the polymers for the storage medium. At a laboratory in the United States, the polymers are used to produce palm-size discs, just millimeters thick, with enough space for over 300 gigabytes of data. To compare, it would take as many as 50 DVDs or 460 CDs to fit that much data! Dubbed Tapestry™, the new storage system is scheduled to go to market in late 2006. InPhase Technologies and Bayer MaterialScience are collaborating to ensure that the jump from an expensive prototype to a durable mass-produced product goes smoothly. The plastics experts in Leverkusen continue to improve and perfect the holographic material for large-scale manufacturing.

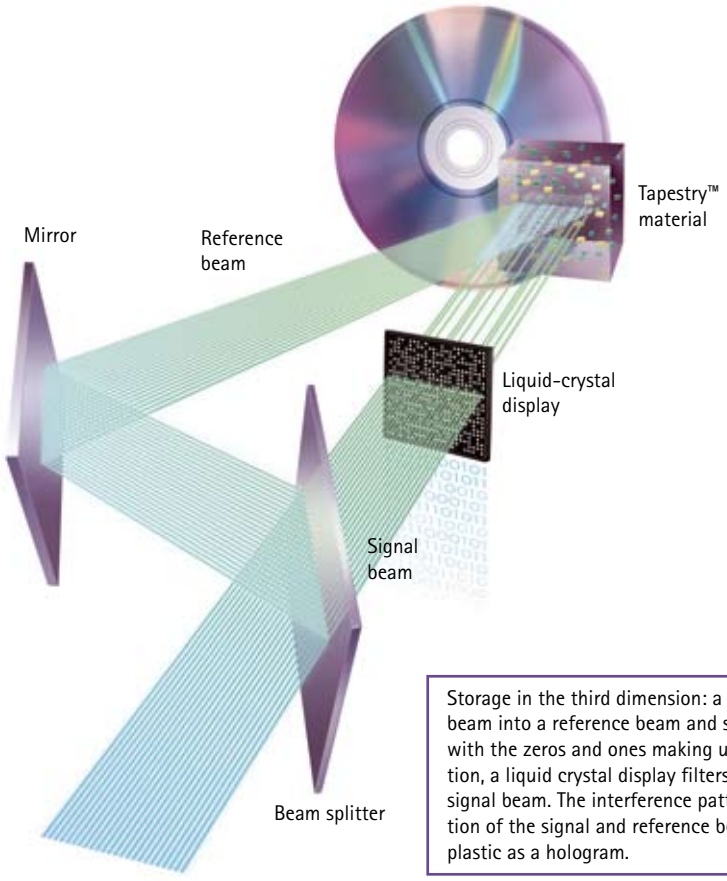
"The Tapestry material comprises two polymers," Langstein explains. Crosslinkable polymer building blocks are dissolved and move about freely in a stable polymer matrix. When the drive writes to the disc, a laser pulse illuminates the regions where data is to be stored. The laser light is akin to a starting gun, set-

Protective lighting: to protect the sensitive Tapestry™ material, Dr. Rafael Oser (left) and Dr. Friedrich-Karl Bruder work in low-energy red light. The hologram in the laser-written film can be visualized as a pattern of illuminated points (right).
Sensitive information: enormous amounts of data from banks, insurance companies and government archives are at risk because magnetic storage tapes last for only a few years (below). Constantly backing up the information with new copies generates exorbitant costs.

ting off a chemical reaction that causes the crosslinkable molecules to first form chains, then polymer clusters, which remain fixed in the tightly meshed polymer matrix. "The more intense the light, the more polymers are deposited," Langstein reports. And where more polymers are deposited, they alter the properties of the material: it becomes optically denser and diffracts light like a lens.

Holograms exploit the wave nature of light. Light waves behave like waves rippling on a pond. When you throw a stone into the water, the waves propagate in concentric circles. If a crest of a wave meets a crest of another wave, they reinforce one another. If a crest of a wave meets a trough, they cancel each other out. The term used to describe this effect is "interference." InPhase uses





Storage in the third dimension: a beam splitter divides a laser beam into a reference beam and signal beam. In accordance with the zeros and ones making up the electronic information, a liquid crystal display filters individual rays from the signal beam. The interference pattern formed by the intersection of the signal and reference beams can be stored in the plastic as a hologram.

laser light to store data because it has distinct wave characteristics, thus enabling compact and contrast-rich interference patterns.

In the recording device, the laser light is first split into a signal beam and a reference beam. While the reference beam remains unchanged and passes directly to the Tapestry™ disc, the signal beam passes through a liquid crystal display, similar to a digital watch, that filters individual rays from the beam, encoding the digital zeros into the laser light. The remaining rays represent the ones. The signal and reference beams then intersect forming an interference pattern that is stored in the plastic as a hologram. "And not only on the surface, but throughout the entire volume," says Langstein, explaining the great advantage of holographic data storage. All you need later on to convert the pat-

Data container: Bigger, faster, longer-lasting

Medium	Capacity	Archive life (in years)	Speed (per second)	Available
AIT magnetic tape	36 GB	5 - 10	4 MB	Since 1989
3.5" diskette	1.44 MB	Approx. 5	62.5 KB	Since 1981
CD	700 MB	5 - 20	150 KB (1x)	Since 1983
DVD	4.7 GB	5 - 20	1.4 MB (1x)	Since 1996
Blu-ray Disc	25 GB	5 - 20	4.5 MB (1x)	Since 2005
Tapestry™	300 GB	50	20 MB	As of 2006

The Tapestry™ disc represents a new generation of durable storage media offering high density and speed (KB = Kilobyte, MB= Megabyte, GB= Gigabyte; 1x = 1-speed - the standard data transfer rate for playback of, for example, a music CD or film on DVD).

tern in the plastic back into electronic data is a single laser beam, which is focused on the disc at the same angle as the reference beam. The polymer pattern deflects the light and generates a copy of the original signal beam, which is interpreted by a high-resolution photo chip: if the beam hits a pixel of the detector, a digital one results; if the pixel is in shadow, the chip registers a zero for that point.

A plastic sandwich protects the data

To make sure the data are readable even after many years, Dr. Nicolas Stoeckel and Dr. Konstantinos Douzinas from Bayer MaterialScience are optimizing the composition of the polymer matrix and the crosslinkable molecules in the Tapestry™ disc. "Both the optical and mechanical properties have to be just right," says Stoeckel, Laboratory Director in the Coatings, Adhesives & Sealants Business Unit. For example, the polymer matrix must not become clouded or yellowed, and the crosslinkable molecules should only react when exposed to laser light. Strict demands are imposed on the mechanical properties of the plastic as well: it has to be resistant to water and oil, can't expand or yellow, and must retain its shape. "Our experience with coating and adhesive raw materials is a big help in this regard," Stoeckel explains. "The medium is also protected by its sandwich structure." The actual storage material is applied between two durable plastic discs. "Bayer has many years of experience in the development and marketing of substrate materials for optical storage media. For example, we have been using Makrolon polycarbonate for years to make CDs and DVDs," Douzinas reports. The robust plastic repels dirt and liquids and protects against oxidation. "Combining new materials with proven ones requires know-how and interdisciplinary teamwork," says Douzinas. His team of physicists at the Bayer MaterialScience laboratory in Krefeld supports Nicolas Stoeckel in his search for a formulation for the holographic disc and tests the material's properties.

In addition to longevity and high storage density, the holographic disc offers yet another advantage: high speed. Instead of reading one bit after another like on a CD or magnetic tape, a single laser flash can read 1,000,000 bits at once. As a result, the holographic disc achieves transfer rates of 100 megabytes per second, twelve times higher than a DVD or a magnetic tape, and 40 times higher than a CD. Systematically searching large databases with millions of entries takes only hours instead of days.

Watching television on the windshield

"Many other highly innovative applications besides computer discs are also conceivable," says Dr. Rainer Hagen of New Business. Holographic polymers open up new possibilities in optics and security technology such as full-color, three-dimensional images. "In a few years it may be possible for graphic artists and designers to print their own holograms, without ink and cartridges. The 'paper' – the polymer film – would come from Bayer," foresees Hagen. It remains to be seen which applications will be suitable for the chemically alterable polymers and when data storage on polymers (see *research* 17) will become a reality, but Bayer is prepared for both technologies. For Gerhard Langstein, the future of holographic media is already here. He knows the market and is convinced that, "the time is right!"

www.inphase-technologies.com
InPhase Technologies presents the new holographic storage media on its webite.