NEWS RELEASE

NTT

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New hologram memory "Info-MICA" prototype completed

-- Postage stamp-size plastic media with 1 GB memory capacity --

Nippon Telegraph and Telephone Corporation (NTT; Head Office: Chiyoda-ku, Tokyo; President: Norio Wada) is pleased to announce the results of its work on the research and development of a new high capacity memory storage device, designed with a multi-layered waveguide structure (*1) and based on a thin film holography (*2). NTT has successfully produced a 100-layer postage stamp-sized media prototype with 1 GB memory capacity constructed from plastic material, and a small prototype drive for reading data from the Info-MICA media. Following the progress in creating both the media and drive prototypes, NTT is now planning the future commercialization of these products based on the "Comprehensive Producer Function" and is currently working with technology manufacturers with a view to releasing both products next year using the name "Info-MICA: Information-Multilayered Imprinted CArd) (*3). Note that this work utilizes some outcomes from the project sponsored by METI (Ministry of Economy, Trade and Industry) (*4).

1. Applications for Info-MICA

Compared with existing memory devices, NTT's Info-MICA offers data storage on plastic media with the following characteristics:

1. The media has extremely high memory density;
2. The drive is small and its power consumption is very low;
3. The media can be mass produced at low cost;
4. Copying of the media is very difficult;
5. The media is totally recyclable.

Based on these characteristics, the following three major applications are currently being considered for Info-MICA:

The first application is its use as a replacement of semiconductor ROM (Read Only Memory) because Info-MICA is small in size and considerably cheaper for the equivalent ROM capacity. Widespread adoption of Info-MICA is expected by the electronic dictionary sector where higher data storage capacity is required to accommodate large volumes of dictionaries. Similar applications include the "pachinko" slot machine industry where high data storage capacity is required to support the display of detailed graphics, as well as navigation systems in motor vehicles.

The second application is the introduction of Info-MICA as a replacement of paper products that are used for distributing information. Info-MICA is strongly suited to the mass distribution of information as it is easily disposable and it can be recycled. Info-MICA media can be attached as cover-mounted media to magazines and other

merchandise, or it can be distributed alone as a ticket or coupon.

The third application is for releasing multimedia content such as games, music, movies and electronic publications. This application will benefit from Info-MICA's high storage capacity and the difficulty for reproducing illegal Info-MICA copies. Info-MICA drives will be installed in cellular phones and portable game machines where it will satisfy their demanding requirements for low power consumption and limitations in size. The use of an Info-MICA drive in portable devices will enable users to enjoy rich multimedia content at any time and any place. In particular key organizations in the music industry, which continues to be challenged by the problem of content piracy, is examining Info-MICA as a promising next-generation standard media for minimizing the illegal copying of content.

As part of NTT's recent promotional activity for Info-MICA, information about the device has been communicated to the five major labels and other record companies in the USA and Japan at their annual Technology Summit hosted by the IFPI (International Federation of the Phonographic Industry) and the Techno-Legal Forum hosted by RIAJ (Record Industry Association of Japan) to encourage the exchange of ideas about the use of Info-MICA for distributing pre-recorded music.

2. Principle of the Info-MICA operation

Info-MICA, the newly developed memory device by NTT, involves a technology that stores and retrieves digital information based on the principle of thin film holography (see attachment 1). Information is pre-recorded as follows; first, digital data is encoded into a 2D image, then the 2D image is translated into a hologram by CGH (Computer Generated Hologram) (*5) technology. Finally, the hologram is recorded as a sub-micron concave-convex pattern in each waveguide layer of the media. For data retrieval, a laser beam is focused at the end of a waveguide layer, then the light propagates in the waveguide and is scattered by the concave-convex pattern. The scattered light generates the 2D image on the plane parallel to the waveguide. This 2D image is captured by an image sensor and decoded into the original digital data.

When compared with other hologram memory technologies, the principle of Info-MICA can be characterized as follows.

1. Since Info-MICA is based on the principle of thin film holography, it can tolerate variations in light source wavelength and volume expansion of the media. So, the economical semiconductor laser, whose wavelength inevitably tends to fluctuate due to individual variations and temperature changes, has been used for the first time as a light source for the read drive of a holographic memory, and this has led to the development of a small size, low price read drive. In addition, for the first time it has become possible to use a low price general purpose plastic material that was previously considered to be unsuitable as holographic memory material because of its high heat expansion coefficient. The use of this plastic material enables high-speed and low-cost mass production of media by the master imprinting process (*6) used for CD and DVD production. Furthermore, the media is totally recyclable because it is made of 100% plastic.
2. Since Info-MICA media (similar to optical fiber) has a waveguide structure that confines light, the leakage of light (known as 'cross talk') will not occur even when thin film hologram (concave-convex pattern) layers are stacked. Thus it is possible to increase memory capacity by simply using a multi-layered structure of ultra-thin waveguide layers.
3. Since Info-MICA is a thin film hologram memory, computer generated hologram

(CGH) technology can be used to give greater freedom in optical designing. A newly developed data access method called aperture multiplexing (*7) has been created by the use of this computer generated hologram (CGH) technology. This has led to the development of a system that can be built with low priced components that are capable of efficiently reading accurate, high volume data stored in the hologram media.

3. Development of packaging technology and prototype drive

For the development of Info-MICA, NTT has successfully developed the following packaging technologies:

- When introducing laser light to each of the stacked waveguide layers, the positional error of the injected light is compensated automatically so that an optimum coupling condition can be constantly maintained.
- A unique image reshaping technique and a 2D encoding algorithm that can reduce the amount of processing and improved code rate have been developed. These technologies, while reducing the power used for signal processing, can accurately compensate the positional and angular errors of constructed images and conduct reliable data reproduction. Currently, a LSI specially designed for this signal processing is being developed.
- For creating a master that is used for the imprinting of Info-MICA media copies, a unique drawing algorithm has been developed to make the lines of the concave-convex patterns less likely to overlap. Using this technology, masters of Info-MICA media are easily produced by the DVD mastering machines that are widely used today for DVD master production.

The prototype of NTT's new data read drive, which relies on the above mentioned packaging technologies, measures 88mm (W) x 37mm (D) x 22mm (H), and is small enough to fit into the palm of your hand (see attachment 2). For this prototype drive, a storage medium (size: 25 mm(W) x 25mm(D) x 2mm (T) (see attachment 3) was developed to store digital information after 2D encoding. Then, by using servo control, laser light is introduced to the desired waveguide layer, and the constructed hologram image is captured by the image detector, which is then followed by 2D decoding and digital information reconstruction. The size of the optical system in the drive was made sufficiently small by the use of a semiconductor laser and Fresnel lens. The use of an electromagnetic actuator enables high accuracy access to the 1.5 micron thick waveguide layer. It has also been confirmed that a 100-layer media that can store 1 GB of digital information is capable of being reliably manufactured by the master imprinting process. NTT therefore believes it faces an exciting opportunity for commercializing small data read drives and 1 GB postage stamp size media for a wide range of potential Info-MICA applications.

4. Background to NTT's "Comprehensive Producer Function"

Info-MICA project is in the middle of the process from research and development to its commercialization. In order to evolve through these complex stages, the so-called "valley of death", in a well planned and efficiently managed manner, NTT is applying its "Comprehensive Producer Function" that was started in July 2003. The "Comprehensive Producer Function" is a formalized methodology for promoting business projects based on excellent research and development achievements, directed by their managers (called "producers") who have been assigned responsibility to cooperate with other companies from both inside and outside of the NTT Group. NTT is planning to utilize its Comprehensive Producer Function to widely promote business

projects which emerge from the various achievements that result from its research and development efforts.

5. Future developments

NTT is planning to bring the first commercial Info-MICA products to market in 2005 with a postage stamp-size ROM and a memory capacity of 1 GB. The estimated cost of a mass produced Info-MICA product range will depend on the volumes that are manufactured, but initial estimates suggest it to be several thousand yen for the drive technology, and 100 to 200 yen for the media. In the future, NTT is planning to commercialize an Info-MICA ROM with more than 10 GB capacity (*8) that will be suitable for releases of pre-recorded movies. NTT will also continue its research and development of a writable media and drive configuration so that the Info-MICA storage method can be used in the future for re-writable applications.

Detailed information of NTT's Info-MICA is available at http://www.info-MICA.com/.

Glossary

***1) Multi-layered waveguide structure**

A Multi-layered structure where a layer with a high refractive index (core layer) and a layer with a low refractive index (clad layer) are alternately stacked. When laser light is introduced to this structure, the light is confined to the core layer and then propagated in the same way as optical fiber. With Info-MICA, a concave-convex pattern is created on each core layer, which causes the light to scatter. This concave-convex pattern is a thin film hologram that contains information and the scattered light creates an image that is used for information reconstruction. Information recorded in each layer can be constructed individually because it is made possible to select the layer to which the laser beam is directed.

***2) Thin film hologram and volume hologram**

Thin film hologram is a hologram having a thickness equal to or less than the light wavelength. The required condition to trigger diffraction is not difficult to attain, and so diffraction occurs easily even when the wavelength and direction of injection of the reference light fluctuates. In contrast, "volume" hologram is a hologram thicker than the wavelength of light, and the required condition to trigger diffraction is very difficult to attain. Diffraction occurs only when the wavelength and direction of injection of the reference light is exact. Almost all the high capacity hologram memories that have previously been proposed have been based on the volume hologram concept.

***3) Info-MICA**

This is so named because of the layered structure similar to that of the mica stone.

***4) Project sponsored by METI**

METI's R&D project: "Nanometer Controlled Optical Disk System Project", funded by "R&D Projects on Application of Industrial Technologies", 1998 through 2003.

***5) CGH: Computer Generated Hologram**

A hologram generated by computer processing and used to reconstruct the desired image.

***6) Master imprinting process**
This is the media production process currently used for DVD. First, a master version with a concave-convex pattern is prepared; then this pattern is imprinted onto resin material. This process enables the high-speed mass production of media which allows the media to be manufactured at lower cost.

***7) Aperture multiplexing**
A waveguide hologram constructs an image containing a high volume of information simply by introducing a laser light to one specific layer. However, a density difference exists in the order of two digits between the accurate images constructed by hologram media and the coarse pixel pitch of an inexpensive image detector such as CCD. It can therefore be difficult to capture an image at one time by these detectors. Thus, in order to provide a high-density recording with a reasonably priced, commercially available image detector, Info-MICA uses a filter with multiple apertures between the media and the image detector. The use of this filter makes it possible to select and open any desired aperture one by one, and in this manner it is possible to reconstruct the information stored in each layer by time series.

***8) ROM with more than 10GB capacity**
As for the potential data density of Info-MICA, "1.7Gbit/inch2 per layer" was confirmed through the analysis of the media on an optical bench using a microscope. If media were developed according to the proportions of an SD memory card (24mm(W) x 32mm(D) x 2.1mm(T)) the Info-MICA's capacity would be 25 GB (assuming 100 layers). (Note: The SD memory card is a memory card jointly developed by Toshiba, Matsushita Denki Sangyo and American SanDisk.)

- Attachment 1: Principle of thin film type hologram memory having multi-layered waveguide structure
- Attachment 2: Photo of Info-MICA drive prototype (A) (B)
- Attachment 3: Photo of Info-MICA media prototype (A) (B) (C)

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