

OPTICAL CARRIER FOR LONG-TERM DIGITAL INFORMATION STORAGE

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ABSTRACT:

The task for providing the reliable and long-time storage of digital content is getting more and more actual and important. This is bound up with the transition to a digital form of the information storage in all spheres of the human activity: education, culture, science, banking, medicine etc. The transition to a digital form of the information representation presumes the provision of its long-term and reliable storage. The digital information content, subject to the long-term storage, is growing fast both at the expense of accumulating new data and at the expense of digitizing archival materials. Large potentials on providing long-term and reliable digital information storage have the optical methods of information recording and reading. These potentials are determined by the following reasons: absence of contact with information recording/reading systems, resistance of optical carriers to the influence of electromagnetic fields, possibility of using the information representation in the form of microrelief structures on the surface of homogeneous substrates, high protection of an information layer against mechanical contaminants at the expense of focusing the recording/reproduction radiation through a transparent substrate. Besides the optical recording methods provide high densities of information registration. The main task at developing optical carriers for long-time information storage consists in choosing and synthesizing high-stability materials for optical carriers and methods of applying information on them in the agreed-upon data representation formats. In work the opportunities of using metal carriers for optical information registration systems and methods of information application on them are analysed.

1. INTRODUCTION

Over several centuries the main means for information storage was paper. The service life of high-quality paper is 400-500 years, what allowed in libraries, archives, museums to keep a large volume of knowledge created by mankind. However analog form of the information representation on paper carriers does not provide a timely access of a large number of users to information, to use multimedia information representation, besides paper carriers are gradually broken down. An agreed-upon form of solving a problem of providing a timely access to information resources, introducing into the scientific circulation of archival materials and their preservation is the representation of documents in a digital form (Buchel, 2002; Arndt, 2002). The digitization of archival materials is desirable to make once and for all. The carriers of archival storage should have such basic performances:

- term of storage, corresponding to lifetime of high-quality paper;
- high recording density, as a minimum corresponding to the standard CD recording density;
- to use a form of information representation which allows to read it by different methods.

Currently different types of carriers for long-term storage of digital information: magnetic tapes, microfilms (it is supposed to use them for information storage both in digital and analog forms) and optical disks are analysed and developed. All of them have a term of guaranteed storage of information no more than 50 years (Calmes,1993; Adelshtein,1999). The carriers with such service life can be used as an intermediate link for digital information recording with the subsequent transfer of a part of information on carriers having a longer, as a minimum on the order, term of storage. Large capabilities for essential increase of term of storage have optical carriers, especially with the relief-phase representation of information. One of major factors limiting the term of information storage on carriers, provided for long-term

storage, is the use as substrates of polymer materials subject to time changes of physico-chemical properties and having low mechanical and thermal strength. One of the most steady polymer materials is the polycarbonate which is a base material for CD manufacturing. But its mechanical strength limits reading rate of information from CDs. The reliability of information storage on optical carriers can be essentially increased at replacement of plastic substrates by metal or glass substrates. On such carriers an information layer should be formed in the substrate itself as a relief microstructure.

2. TECHNOLOGY OF MANUFACTURING CARRIERS FOR LONG-TERM STORAGE

The modern optical disks can ensure the term of information storage not more than 50 years. It is bound up with the instability of properties of polycarbonate substrates and the use of multilayer thin-film structures for information recording. Even with such service life the optical disks, primarily CD-R, can be used for creation of electronic libraries, digital archives, databases. The large terms of storage can be ensured at the expense of the periodic transfer of information (such an opportunity of transfer without deterioration of quality is provided with the digital information representation) or at the expense of increasing the stability of information carriers properties. The increase of service life of optical disks is supposed to achieve (HD-Rosetta, 2001; Kryuchyn, 2002) at the expense of making a carrier in the form of a nickel disk with the information representation in the form of submicron-size recesses on its surface. The images on the surface of a nickel carrier can be formed by a method of full bombardment (HD-Rosetta, 2001) or formed by laser photolithographic techniques used in the technology of manufacturing stampers for CD replication. On the glass substrate is applied a positive resist layer on which information is recorded by a focused laser beam at the speed of (300-600) KB/s.

After the chemical etching of a photoresist layer, in the process of which is formed a relief image, and the subsequent metallization in the disk glass substrate is grown a nickel carrier by using electroforming process.

The information on metal carriers can be represented both in an analog form as microtexts (or microimages) (HD-Rosetta, 2001) and in a digital form (Kryuchyn, 2002). The information recorded on a metal carrier as a change of the surface relief can be read by optical methods (projection methods or by using the focussed laser radiation), by a scanning electron beam or tunnel microscopy techniques. We offer to use for recording information on metal carriers the data representation formats used at arrangement of information on CDs. The capacity of carrier is from 650 MB up to 4.7 MB depending on the recording method. The information can be reproduced on CD players after a minor modification of the optical scheme. The modification lies in the introduction into the optical channel of a 1.2-mm thick plane-parallel plate (for CD carriers) or 0.6-mm thick one (for DVD carriers).

The choice of nickel as a carrier material for long-term storage is conditioned by the following reasons:

- nickel has a high melting temperature $T_M=1450\text{ }^\circ\text{C}$ what provides the safety of information at temperature rise up to 400-500 $^\circ\text{C}$;

- the high corrosion resistance of nickel guarantees the safety of information recorded on a metal carrier at storing it at moist conditions and even at falling of moisture on its surface;

- the high mechanical strength and plasticity allow the nickel metal carrier to withstand considerable impact loads.

The manufacture of an information carrier of nickel guarantees its safety in case of fire or inundation.

There are straight corroborations of an opportunity to create long-term storage carriers on the basis of thin (0,3-1,0) mm metal films. The copper-nickel stampers for replication of gramophone records were kept perfectly well. Sound from them can be reproduced on special devices with piezoelectric pickups with sufficiently high quality. The nickel stampers have kept high optical reflection (60%), on their surface there are no traces of corrosion. The ellipsometric investigations of the surface of nickel stampers, manufactured in the 30s of the last century, have shown, that on their information surface there are no continuous oxide films and only in separate areas they are available no more than 10 Å in thickness. The appearance of such oxide films can be bound up with the presence of impurities in a stamper. The further investigations pursued by using techniques of Auger-electron microscopy, micro-X-ray spectral analysis, secondary ion mass-spectrometry, have shown necessary distribution of oxygen in a surface layer of the nickel stamper. The zones with the increased content of oxygen have coincide with the arrangement of impurities such as aluminium, manganese, iron.

During 70 years the electroforming technology was improved significantly, the purity of electrolytes for growing nickel plates has increased by a factor of a few tens, that allowed on the modern equipment to manufacture metal nickel carriers with the content of impurities no more than 0,01 wt. %. In modern stampers for CD replication the impurity content is smaller by a factor of 50-60 than in stampers, that were used in the past century for replication of gramophone records. This allows to make the most optimistic estimations on determining the terms of storage of metal nickel carriers.

On the information reproduction process at the long-term storage the greatest effect can have the changes in the length of bumps, by which the information is coded. The length of bumps can be changed at the expense of oxide layers formation, organic substances contamination. The organic impurities from the nickel carriers surface can be removed by the electrochemical cleaning methods which are widely used in the CD production technology. Some increasing of bumps sizes can occur at the metal oxidation. Such increasing of linear dimensions for nickel makes 15 Å by formation of a 100 Å-thick oxide layer. At this case the change of the signal reproduction duration (at the one-fold reproduction velocity) will not exceed 35 ns what makes 4,2 % of the shortest signal duration. The change of pits geometrical sizes influences most the signals reproduction of the shortest bumps, the length of which is about 1 µm. The allowable length increase of a bump can be 420 Å. The choice of corrosion-resistant metals such as nickel, noble metals permits to forecast, that the allowable extensions of bumps (4-5 %) owing to the formation of oxides or sulphides can occur within 300-400 years. Thus, the metal carriers can provide a reliable long-term storage of digital content recorded with high density. The intrinsic decay of the images on the metal carriers due to aging cannot be stopped totally, but only be slowed down.

As demonstrate the conducted experiments by electroforming techniques one can create the relief microstructures on metal substrates with the size of elements 0,01-0,02 µm, that are smaller by a factor of a few tens of sizes of elements on the surface of DVD carriers (Todorovic, 1999).

One of the main problems at development of long-term storage carriers consists in choosing a method of information representation. As demonstrates experience, the highest long-term reliability of information storage have carriers with a relief form of information presentation. Such a form of representation was used on Edison phonograph cylinders, gramophone records etc. The devices of information reproduction from such carriers created in the time of manufacturing carriers, cannot be used for qualitative sound reproduction any more, however, the carriers have ensured safety of the recorded information. The reproducing devices, constructed on new physical principles of reading, allow to obtain the phonograms with sound quality, which is superior to the sound quality, that existed 80-100 years ago. It is possible to forecast, that more effective methods will be created and the devices, realizing these methods for information reproduction from CDs and carriers, on which a similar form of information representation is used, will be designed.

File formats used for long-term information storage should be widely used, be open and completely documented, have a high flexibility to integrate multimedia information (Buchel, 2002). The formats used for the information representation on CD and DVD carriers meet these requirements.

By using metal carriers it is necessary to take additional care to protect the information surface against contamination by dust particles and mechanical damages. Coating the metal carrier surface by a 0,2-0,3 µm-thick polymer film allows to solve this problem partially. The polymer film can be replaced periodically. A more effective protection of information can be ensured on carriers made in the form of a transparent high-stability substrate with a relief microstructure. Material for such carriers can be shock-proof glass beads, quartz etc.

Cost of information storage on metal carriers is higher than on CDs. It is bound up with the fact, that every carrier is manufactured individually and by its manufacturing are used more expensive materials. But charges about \$15-20 for manufacturing a metal carrier are justified, when it is necessary to preserve information, which is of great cultural, scientific, commercial value. Certain saving in charges can be provided at the expense of excluding the necessity of the periodical information transfer.

The modern technologies of microelectronics and laser lithography allow to manufacture information carriers, the recording of information on which can be carried out with density up to tens of gigabytes per cm², having potentially high service life owing to selected materials and methods of their processing.

3. CONCLUSIONS

The optical methods of information recording/reading thanks to absence of contact, use of physical methods of information protection against dust contaminants allow to provide a reliable and long-term information storage.

Large potentials on ensuring the information storage during hundreds of years have optical carriers manufactured from homogeneous materials with relief-phase information recording.

The long term of information storage on optical carriers can be provided at manufacturing substrates from high-stability materials such as nickel or glass.

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