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Application Notes

Data storage

SPM ANALYSIS OF THE CD/DVD DISCS

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Compact Discs (CD) and Digital Versatile Discs (DVD) are popular data storage now. The information unit of CD/DVD is so called pit. CD and DVD are made by stamping of a polycarbonate. Nickel stamper is usually used as a stamp that contains bumps. These bumps form pits. The quality of the group of discs depends on quality of a one stamper, i.e. preliminary control of stamper is necessary.

Magnetic properties of nickel stamper and its large size (140mm) make difficulties for electron microscopy control. There are also devices for surface analysis based on electric principles, but such measurements cannot visualize pit geometry. SPM is ideal tool for pit geometry analysis owing to high resolution, high measurement rapidity and possibility of nondestructive measurements of large samples (Fig.1). The using of the SPM under manufacturing of the stamper for CD/DVD is perspective method of quality monitoring. SPMs help to check the stamper quality and to decrease risk of defect appearances. It is possible to study topography changes of stamper under various external influences, for example observation of the deformation owing to polishing or blow. It is possible also to observe topography changes owing to heating during pressing of a polycarbonate. During manufacturing the several parts of stamper surface are controlled and quality of the stamper is appreciated. Also selective control of discs is executed. The experiments with external magnetic field enable to observe the magnetization reversal processes. The design of the NT-MDT SPMs allows applying the various external magnetic fields during magnetic force microscopy (MFM) measurements. The present results were obtained with SOLVER P47 equipped by electromagnet, which can produce magnetic fields up to 5000e. The studied sample was cobalt polycrystalline patterned film (40nm thick) deposited on high-oriented pyrolytic graphite in the form of the micron size rectangles (Fig.1). Fig.2, 3, 4 corresponds to AC MFM images, obtained by two-pass method. The values of the external field were 1000e, 0Oe, and -1000e for Fig.2, 3, and 4 respectively. The arrow marks the direction of the external field. The opposite direction of magnetization in the cobalt patterns is clearly seen from Fig.2 and Fig.4: the poles traded places. All cobalt patterns are magnetized uniformly in these cases. Fig.3 demonstrate the rest domain structure in cobalt, which formed after switching off of the external field. The domains with different shape are seen on Fig.3. In some cases the external field helps to separate the topography and the MFM image. This is important when the topography correlate strongly with the magnetic structure.

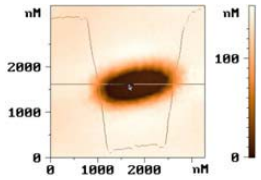


Fig.1. Single pit of CD measured by SPM.

Equipments and methods

As appears from the above possibility of the measurements of the large sample is main demand of CD/DVD industry to SPM. There are three basic configurations of NT-MDT devices that meet this demand and provide effective analyzing of CD/DVD:

1. SPM Solver P7LS (Fig.2). The motorized positioning stage, the vacuum holder for samples with the size up to 300 mm in diameter, optical viewing system and automatic approach make this device most convenient for CD/DVD industry.
2. SPM Stand Alone SMENA in combination with special designed SMENA base for large sample (Fig.3). This device can provide the same noise level as Solver P7LS provide. Such design doesn't include vacuum holder and motorized positioning stage. Automatic approach is available on requirement. Positioning of the sample is carried out by hand.
3. SPM Stand Alone SMENA with special long leg, which allows CD/DVD placing between them. The user haves to provide hard fastening of the sample under tip in this case.

Fig.1. Single pit of CD measured by SPM.

There are two main modes for topography measurements: contact and semi-contact. Semi-contact mode uses cantilever that oscillates at its resonance frequency. As a result tip and sample contact only small part of the oscillation period. This leads to appreciate reducing of destructive action of the friction and capillary forces. Therefore semi-contact mode is more suitable for soft materials such as polycarbonate.

"Whisker type" cantilevers being manufactured by NT-MDT provides more accurate measurements than standard silicon cantilevers. This type of cantilevers is standard silicon cantilever augmented by carbon needle with high aspect ratio. Focused Ion Beam (FEB) grows carbon needle on the end of tip. "Whisker type" cantilever is suitable for more precision measurements of abrupt steps. Moreover, carbon is hydrophobic material therefore adsorption layer of water is absent on the carbon tip. This also increases accuracy of the measurements.

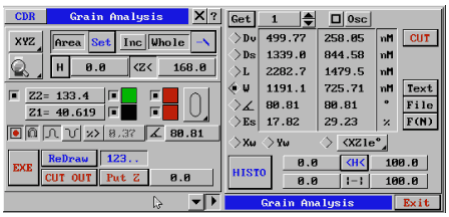


Fig.4. Main view of the menu "Grain analisys".

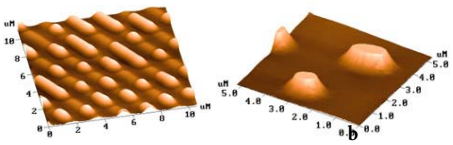
The acquired results need in statistical treatment. NT-MDT software contain menu of tools "Grain analysis" (Fig.4), which was developed to sta-

tistic treating of the particles lying on flat surface (also suitable for pits). With the help of these tools it is possible to determine geometrical size of pits, approximate pits by different figures, such as rectangular, ellipse, and rectangular with rounded sides (imitation of CD/DVD pits). On the basis of such approximation the direction of axes, the angles between them, and other parameters are determined.

CD/DVD parameters for checking

The main test characteristics, which determine either CD/DVD or stamper quality, are:

a) Pit (bump) form and pit (bump) size. For example, pits (bumps) must have flat area (Fig.5a). If such flat surface is not observe (Fig.5b) then error during reading can be made. The depth of the pits is important parameter owing to its influence on the amplitude of signal during reading. SPM Solver P7LS enable to measure the pit height with resolution of a fraction of nanometer.



a

Fig.5. AFM images of the surface of the nickel stampers made by different technologies. Images obtained by semicontact mode, SOLVER P7LS.

b) Slope of the pit (bump) side.
c) Roughness of pit (bump) surface, which influence reflection of the laser beam.
d) Track pitch and track stability.
e) Ratio of pit volume to volume of single pit. This is important technology characteristic of CD/DVD.
f) Number of pits per area unit, i.e. data density.

NT-MDT software can calculate all these parameters for investigated area. Also SPM check quality of the CD/DVD surface by revealing the surface defect. Two scratch and knoll are seen on Fig.6. These defects influence the quality of data reading.

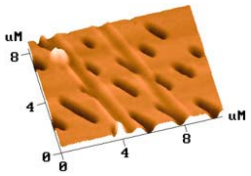


Fig.6. SPM image of defective surface of the CD disc.

Example of application

The knowledge of the either pit or bump parameters measured at different places of the sample allows effective controlling of the CD/DVD manufacture. Fig.7 shows topography of a stamper. After measurements of the topography the menu "grain analysis" was applied to obtained topography data. Black lines on Fig.7 mark contour of bumps at preset level; red lines are approximation of bumps by ellipse. The different parameters were calculated for the bump array. Some of them show in Table1.

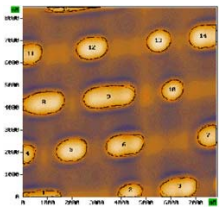


Fig. 7.

Table 1

	Grain 10	Grain 6	Grain 9
Z-Lev	116.70nm	116.70nm	116.70 nm
Dvolume	291.08nm	361.17nm	413.57 nm
Dsquare	756.80nm	1056.55nm	1270.31nm
Length	883.93nm	1581.00nm	2153.94nm
Width	825.00nm	899.00nm	953.89nm
Xpos	6046.41nm	4112.79nm	3468.24nm
Ypos	4404.36nm	2117.78nm	4112.79nm
Orient.	85.28°	85.28°	85.28°
Error	13.20%	19.20%	22.30%

Where: Z-Lev is preset level of section (Fig.8); D_{volume} (D_v) - effective size of bump above level Z-Lev ($\sqrt[3]{V}$); D_{square}(D_s) - effective size of bump at level Z = 116.7nm ($\sqrt{S}$); Length - bump length; Width - bump width; X_{pos}, Y_{pos} - coordinates of the bump center; Orient - angle of bump orientation; Error - error of approximation of real bump by ellipse.

Also information about slope of the bump sides (Fig.8) and other parameters is available.

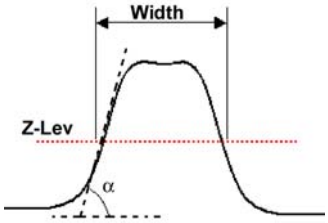


Fig.8. Section of a stamper bump.

Table 2 presents ratios of areas (α^s) and volumes (α^v) for different bumps.

Table 2

$\alpha^v_{10\text{-}6}$	1.24	$\alpha^s_{10\text{-}6}$	1.397
$\alpha^v_{10\text{-}9}$	1.42	$\alpha^s_{10\text{-}9}$	1.68
$\alpha^v_{9\text{-}6}$	1.145	$\alpha^s_{9\text{-}6}$	1.202

The determined parameters can be used for analysis of bump geometry, revealing of the technology defects and other applications.

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