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Materials

Effect of SPM Scanning Range on the Micromorphology Parameters

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Abstract: The surface of a compact disk is analyzed by using SPM and the quantitative micromorphology analysis software SPMIAS developed by the author. Images at the same position but with different scanning ranges are obtained under the same experimental conditions. Micromorphology parameters are calculated and compared, and the relationship between the changing of the scanning range and the changing of micromorphology parameters is summarized.

Key words: Scanning Probe Microscope(SPM); micromorphology; micromorphology parameters

SPM (Scanning Probe Microscopy) plays an important role in quantitative micromophology analysis of materials. Micromophology parameters can be easily calculated from SPM image. But many factors, for example the scanning position, the scanning range and the resolution of the image, will affect the parameters calculated. How these factors affect the micromorphorlogy parameters calculated from SPM image is still a question waiting for answer[1].

1 Experiment

The surface of a compact disk was analyzed by using SPM. And micromophology parameters are calculated by using the quantitative micromophology analysis software SPMIAS developed by the author[2] and by referring to SPM image of a 3μm × 3μm × 100.0 nm standard grating scale obtained under the same experimental conditions. The experimental conditions are showed in Table 1.

Images obtained under the same experimental conditions at the same position but with different scanning ranges (5.7μm × 5.7μm, 13.8μm × 13.8μm, 22.2μm × 22.2μm) are showed in Fig. 1.

Table 1 Experiment condition of the image of the compact disk surface

Image No.	Iref	Delay	Vgain	Scan gain	Step	Memo
FS119	0.70	600	10	10	10	CD
FS120	0.70	600	10	10	22	CD
FS121	0.70	600	10	15	22	CD
FS113	0.70	600	10	15	22	grating
FS114	0.70	600	10	10	22	grating
FS116	0.70	600	10	10	10	grating

Note: Iref—the reference current; Delay—the delay of the feedback; Vgain—the multiplicity of the base-voltage signal from the high voltage calculation multiplier; Step: the stepwise of scan

2 Result

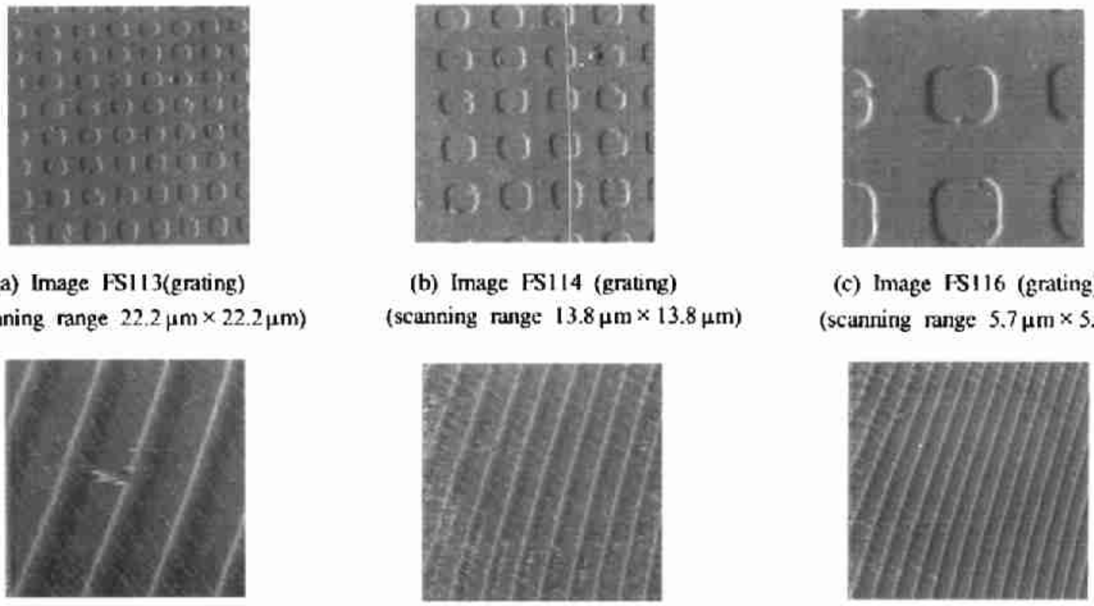
Micromorphology parameters[2] include the arithmetical mean deviation of surface (R_{sa}), the root-mean-square deviation of surface (R_{sq}), maximum height of surface peak (R_{sp}), maximum depth of surface (R_{sm}), maximum height of surface (R_{sy}), amplitude distribution function of surface (SADF), bearing area curve of surface (SBAC), auto-correlation function of profile (ACF), and the power spectral parameters of profile (PSP).

The arithmetical mean deviation of surface R_{sa} is defined as

$$R_{sa} = \frac{1}{n^2} \sum_{i=1}^{n} \sum_{j=1}^{n} H_{ij} \tag{1}$$

where H_{ij}— surface departure of sampling point (i, j); n— number of sampling points.

The root-mean-square value of surface R_{sq} is defined as



(a) Image FS113(grating)
(scanning range 22.2 μm × 22.2 μm)

(b) Image FS114 (grating)
(scanning range 13.8 μm × 13.8 μm)

(c) Image FS116 (grating)
(scanning range 5.7 μm × 5.7 μm)

(d) Image FS119 (compact disk)
(scanning range 5.7μm × 5.7 μm)

(e) Image FS120 (compact disk)
(scanning range 13.8 μm × 13.8 μm)

(f) Image FS121 (compact disk)
(scanning range 22.2 μm × 22.2 μm)

Fig. 1 SPM image of grating and compact disk obtained under the same experimental conditions at the same position but with different scanning ranges

$$R_{sq} = \sqrt{\frac{1}{n^2}\sum_{i=1}^{n}\sum_{j=1}^{n} H_{ij}^2} \tag{2}$$

Amplitude distribution function of surface (SADF) is defined as

$$\text{SADF} \equiv p(y) = \frac{p[y, y + \Delta y]}{\Delta y} \tag{3}$$

$$p[y, y + \Delta y] = \frac{\Sigma_i \Delta s_i}{S} \tag{4}$$

where $p[y, y + \Delta y]$—altitude probability of profile; S—scanning range; Δs_i— the projecting area on the reference plane of the section area of surface peaks obtained by cutting the surface peaks with two planes parallel to the reference plane.

Bearing area ratio of surface SBAC is defined as

$$\text{SBAC}(p) = \frac{\Sigma s_i}{S} \tag{5}$$

where s_i—the projecting area on the reference plane of the section area of surface peaks obtained by cutting the surface peaks with a plane parallel to the reference plane.

Auto-correlation function of profile (ACF) is defined as

$$\text{ACF}(s) = \frac{1}{N - s}\sum_{s=0}^{N-1} H_i H_{i+s} \tag{6}$$

where s—shift spacing; H_i—profile departure of sampling point (i); H_{i+s}— profile departure of sampling point ($i + s$); N— sampling points.

The power spectral parameters of profile (PSP) is defined as

$$\text{PSP}(f_m) \equiv X(f_m) = \frac{1}{N}\sum_{m=0}^{N-1} x(n_\Delta) e^{-n_\Delta m \frac{2\pi}{N}} \tag{7}$$

where Δ—sampling spacing; $x(n_\Delta)$—profile departure of sampling point i; n_Δ—sampling point; f_m—frequency, $f_m = \frac{m}{n_\Delta} = \frac{m}{l}$, $m = 0, 1, 2, \cdots, N - 1$; l— sampling length.

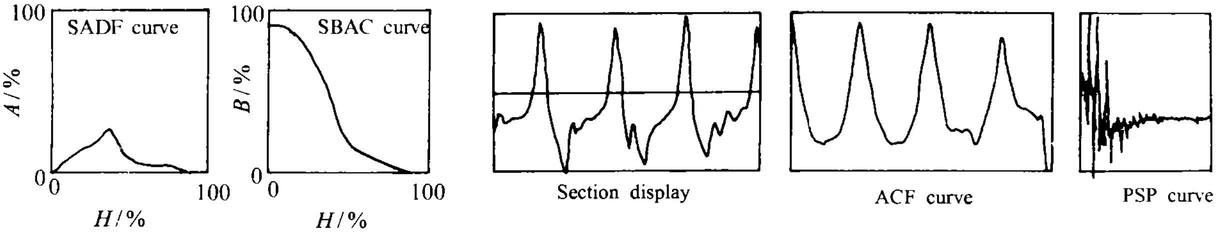
Micromorphology parameters of the compact disk surface obtained at the same position but with different scanning ranges have been calculated by using SPMIAS and listed in Table 2, showed in Fig. 2 respectively.

3 Discussion

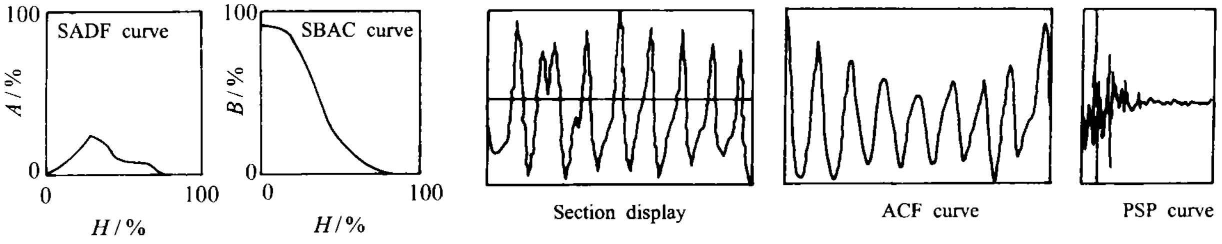
The track width and depth of the disk are firstly calculated by referring to the SPM image of a 3μ m × 3μm × 100.0 nm standard grating obtained under the same experimental conditions. The results (calculated track width = 1.6μm, depth = 52.0 nm) are in good agreement with the known data of the disk[3,4], which showed that the SPM experiments are correctly conducted and the software SPMIAS is working. The experiments and calculations showed that SADF,

Table 2 The calculated 3-D (three dimension) micromorphology parameters of SPM images of compact disk obtained at the same position but with different scanning range

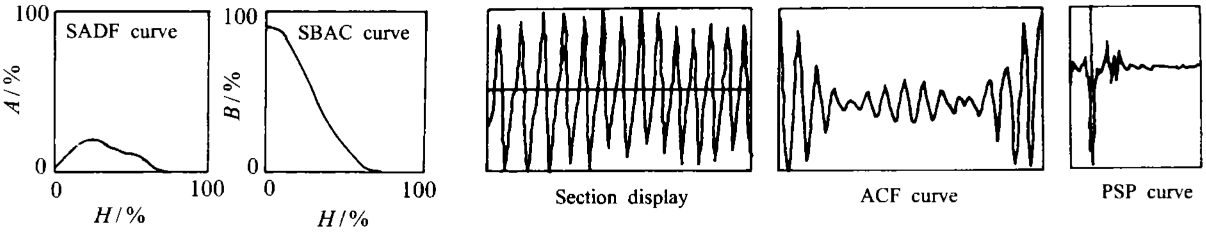
Image No.	R_{sa} / nm	R_{sq} / nm	R_{sp} / nm	R_{sm} / nm	R_{sy} / nm	Scanning range / μm^2
FS119	9.8	12.7	41.6	31.6	73.1	32.5
FS120	11.0	13.8	48.0	35.8	83.8	190.4
FS121	13.9	16.7	63.4	38.4	101.9	492.8



(a) FS119



(b) FS120



(c) FS121

Fig. 2 Micromorphology parameters SADF, SBAC, ACF, PSP of compact disk calculated from SPM images obtained at the same position but with different scanning range (where *H*(%) is the ratio of the surface departure to the maximum height of surface, *A*(%) is the percentage of the current departure sampling points to the total points, *B*(%) is the percentage of the sampling points which departure are larger than or equal to the current departure to the total sampling points)

SBAC, ACF and PSP micromorphology parameters have a commendable stability for different scanning ranges (Fig. 2), but Rsa and Rsq parameters change greatly from different scanning range to scanning range and the bigger the scanning range is, the bigger the two parameters are (Table 2). That means SADF, SBAC, ACF and PSP are more countable when these micromorphology parameters are used to describe a material surface or to compare different surfaces.

References

1 Wenhao Huang, J M Gomez-Rodriguez, A M Baro. 中国科学技术大学学报, 1992, 22(3): 290～294
2 李锁在. 材料表面微形貌SPM定量分析方法、软件研制及应用: [硕士学位论文]. 中国地质大学, 1997.10~17
3 王一知. 光盘技术的发展与应用. 光盘技术, 1995(1): 12～16
4 陈健. CD和CD-ROM系列数据存储格式. 电子技术应用, 1995(1): 4～8