

Effects of Initialization Conditions on Erasability of Phase Change Optical Disks

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Abstract — Effects of initialization conditions of initialization power and number of initialization cycles on the recording properties of phase change optical disks were studied. It is found that initialization conditions affect erasability but have little effect on carrier-to-noise ratio of phase change optical disks. The initialization conditions also affect bias power margin. Erasability of more than 20 dB and carrier-to-noise ratio of 54 dB with 4 mW bias power margin were obtained by applying 6 mW of initialization power and 5 initialization cycles.

I. INTRODUCTION

Erasable phase change optical disks have many advantages as recording media such as direct overwriting, compatibility with CD and no need of an external magnetic bias field. Writing and erasing on phase change disks are achieved by phase transformation between amorphous and crystalline state. In writing, the recording layer is heated over its melting point and then quenched to amorphous state; in erasing, the amorphous marks are annealed to crystalline state. Usually the written marks can not be completely erased in overwriting [1], which results in residual signal. Hence, erasability is an important parameter to assess the performance of erasable phase change optical disks. In this work, the effects of initialization conditions on erasability, carrier-to-noise ratio, and bias power margin of phase change optical disks were studied.

II. EXPERIMENTS

Typical erasable phase-change disks are composed of magnetron-sputter deposited thin-film layers. Recording layer, $\text{Ge}_{20}\text{Te}_{53}\text{Sb}_{27}$, is sandwiched between upper and lower ZnS-SiO_2 dielectric layers, and Al is employed as a reflective layer. To minimize crystalline grains growing around amorphous marks, a rapid cooling structure [2] using a rather thin upper dielectric layer was applied.

The effect of initialization conditions on erasability was investigated by a dynamic tester with a 780nm wavelength laser diode and a 0.55 NA (numerical aperture) objective lens. Erasability is defined by

$$\text{Erasability} = \text{CNR of } f_1 - \text{CNR of residual of } f_1 \text{ overwritten by } f_2 \quad (1)$$

where f_1 and f_2 represent writing and overwriting signals,

respectively. Because the as-deposited phase change media are in amorphous state, the data tracks must first be initialized to crystalline state by irradiating dc erase power P_e before recording. In initialization process, "dc erase power P_e " was denoted by "initialization power P_i ". Initialization power P_i of 3 to 7 mW and 1 to 100 initialization cycles were used to study the optimal initialization conditions.

After the initialization, the disks were characterized as following: first, an f_1 signal was written on given tracks and the carrier and noise levels were derived. Then, an f_2 signal was applied to overwrite these tracks and the carrier and noise levels were also derived. In addition, the carrier and noise levels of the residual f_1 signal were also measured. Erasability and CNR were thus calculated from these data.

III. RESULTS AND DISCUSSION

A. Requirements of phase change optical disks

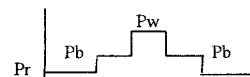
Conferring with the specification of commercial phase change optical disks [3], CNR must be above 46 dB and erasability must be above 18 dB at the read power of 1 mW. Because the read power needs to be raised to 1.5 mW for stable focusing and tracking in this study, hence the required CNR must be higher than 49 dB.

Initialization power P_i of 5 mW were applied to #134 disk with structure of substrate/140nm ZnS-SiO_2 /25nm $\text{Ge}_{20}\text{Te}_{53}\text{Sb}_{27}$ /37nm ZnS-SiO_2 /50nm Al. It was found that recording at P_w of 11 mW and P_b of 5mW allowed CNR to reach 49dB, as shown in Table I. Moreover, erasability of high-frequency signal to be overwritten by low-frequency signal was more than that of low-frequency signal to be overwritten by high-frequency signal, as shown in

TABLE I: DEPENDENCE OF ERASABILITY OF #134 DISK ON f_1 AND f_2

(a) linear speed: 5.5 m/s				
f_1 (MHz)	f_2 (MHz)	CNR of f_1 (dB)	CNR of f_2 (dB)	Erasability (dB)
1.5	4	52	49	20
4	1.5	49	51	25
(b) linear speed: 11 m/s				
f_1 (MHz)	f_2 (MHz)	CNR of f_1 (dB)	CNR of f_2 (dB)	Erasability (dB)
3.4	9	52	49	10
9	3.4	49	54	20

$P_w = 11$ mW, $P_b = 5$ mW, $P_r = 1.5$ mW, and $P_i = 5$ mW



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Table I(a) and (b). Compared overwriting at different linear speed, which corresponds to data tracks at different radius on the disks rotating at a constant angular velocity (CAV), Table I reveals that erasability decreases with increasing linear speed. Therefore, the testing parameters were set as following: low-frequency signal was first written, then high-frequency signal was applied to overwrite at linear speed of 11m/s. As the erasability under these testing parameters reached 18 dB, then erasability under other testing conditions of Table I shall also satisfy the erasability of more than 18 dB.

B. Effect of initialization power on erasability

The initialization results of #134 disk by different P_i were shown in Table II. The measured erasability was only 15 dB at P_i of 3mW, but raised up to 20 dB when P_i was increased to 5mW at linear speed of 5m/s, as shown in Table II(a). However, the erasability was unable to reach 18dB at linear speed of 11m/s, as shown in Table II (b). It was also found that CNR was more than 48 dB and did not change with P_i , as shown in Table II(a) and (b).

Because the erasability of #134 disk was less than 18 dB at linear speed of 11m/s, a series of disks with different structure were made to further investigate their erasability at high linear speed. The #175 disk with structure of substrate/140nm ZnS-SiO₂/25nm Ge₂₀Te₅₃Sb₂₇/25nm ZnS-SiO₂/40nm Al was found to possess adequate overwriting characteristics at linear speed of 11m/s. The dependence of its erasability on P_i , as shown in Fig. 1, revealed that erasability was above 18 dB when P_i was from 5 to 7 mW.

From above measurements, we find that initialization power affects erasability but does not affect CNR. To further examine the dependence of erasability on P_i , equation (1) is redefined by

$$\begin{aligned} \text{Erasability} &= (C_W - N_W) - (C_{OW} - N_{OW}) \\ &= (C_W - C_{OW}) - (N_W - N_{OW}) \end{aligned} \quad (2)$$

where C_W and N_W are carrier and noise levels of f_1 before been overwritten, respectively; C_{OW} and N_{OW} are carrier and noise levels of f_1 after been overwritten by f_2 , respectively. Thus, the term $(C_W - N_W)$ represents CNR of f_1 , while $(C_{OW} - N_{OW})$ represents the residual of f_1 after been overwritten.

TABLE II: DEPENDENCE OF ERASABILITY ON P_i

(a) linear speed: 5.5 m/s, $f_1 = 4$ MHz, $f_2 = 1.5$ MHz

Initialization power P_i (mW)	3	4	5
CNR of f_1 (dB)	50	50	51
CNR of f_2 (dB)	48	48	49
Erasability (dB)	15	17	20

(b) linear speed: 11 m/s, $f_1 = 3$ MHz, $f_2 = 8$ MHz.

Initialization power P_i (mW)	3	4	5
CNR of f_1 (dB)	54	54	55
CNR of f_2 (dB)	48	48	48
Erasability (dB)	12	11	13

$P_W = 11$ mW and $P_b = 5$ mW

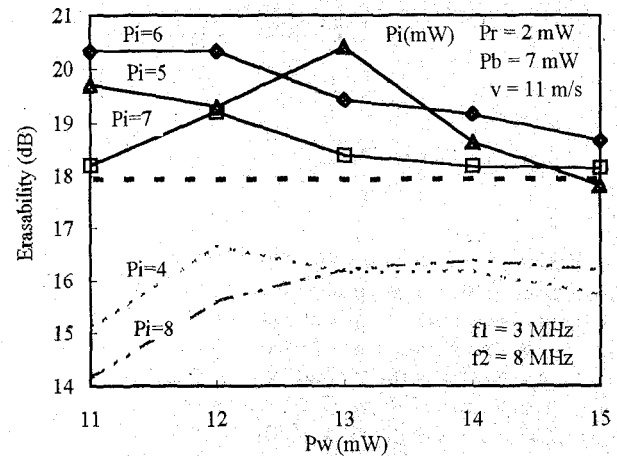
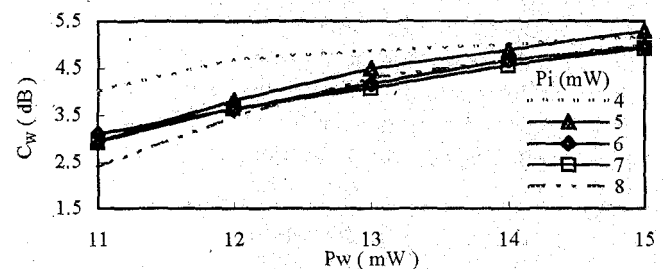
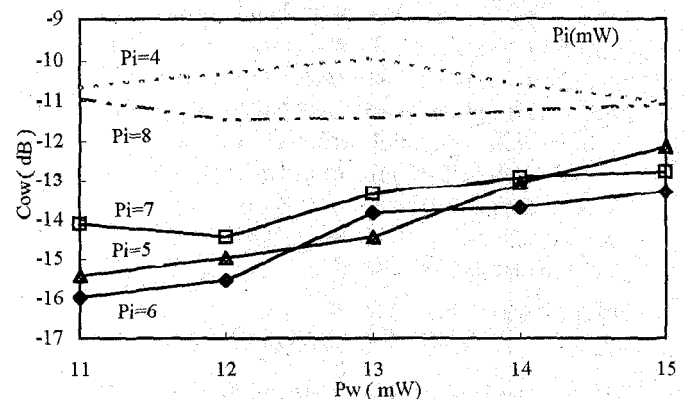


Fig. 1 Dependence of erasability of #175 disk on P_i and P_w . Each data track was initialized 5 cycles by P_i .

Derived from the measured data, we found that erasability was proportional to $(C_W - C_{OW})$ but almost independent of $(N_W - N_{OW})$. After further inspection, the dependence of erasability on C_W or C_{OW} , plotted in Fig. 2(a) and (b), which showed that initialization power affected C_{OW} but had little effect on C_W . Compared Fig. 1 with Fig. 2, erasability is inversely proportional to C_{OW} , but not related to C_W , implying that P_i affects erasability of the phase change disk by its residual signal level. The effects of initialization power on erasability were found not only in #175 disk, but also in other phase change optical disks.



(a)



(b)

Fig. 2 Dependence of carrier levels (a) C_W and (b) C_{OW} on P_i and P_w

The variation of erasability might be caused by disk non-repeated runout, which could result in incomplete initialization. However, the full-width-at-half-maximum (FWHM) of the laser spot is 0.85 μm and the tracking offset of the optical stylus is 0.1 μm , so the optical stylus of 0.85 \pm 0.1 μm FWHM could cover a 0.5 μm groove width of the disks during initialization. Besides, CNR of writing and overwriting signals were both more than 52 dB. Therefore, the disk runout was not the main cause of the variation of erasability. It was suggested that the variant structures of the crystalline states with different P_i might be one of the main reasons. Other factors such as the number of initialization cycles might also affect erasability.

C. Effect of number of initialization cycles on erasability

The number of initialization cycles N_i was varied from 1 to 100 in the initialization process to study whether insufficient erasability was caused by incomplete crystallization. As shown in Fig. 3, when $P_i = 6$ mW, the erasability was found to be almost all above 18 dB except the data tracks initialized by only one time. Moreover, we found that more than 5 initialization cycles could not increase the erasability further. Consequently, the variation of erasability was not caused by incomplete initialization. Under the optimized initialization conditions of P_i of 6 mW and N_i of 5 cycles, CNR was more than 54 dB at 3 and 8 MHz writing frequency, which corresponded to 1.2 μm and 0.63 μm mark length, respectively, and bias power margin was maximized as 4 mW, as shown in Fig. 4.

Hence, the initialization power and the number of initialization cycles should be chosen to make phase change disks with adequate erasability. However, the optical stylus of our dynamic tester is of circular shape in contrast to the elongated shape used in disk initializers[4], as shown in Fig. 5. The energy generated by the elongated beam of 600 mW/100 μm \times 2 μm with overlap ratio of 80% is close to that by the circular beam of 6mW/2 μm^2 with N_i of 5 cycles at the same linear speed in initialization process. Hence, the initialization effects of circular stylus with N_i cycles is comparable to that of disk initializers. The similarity of initialization effect may be caused by generating the similar

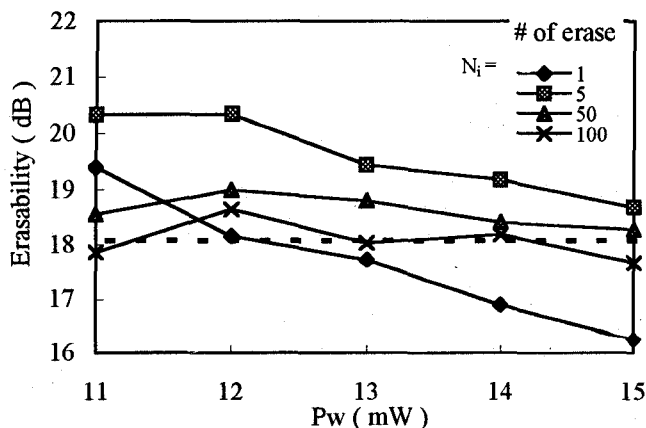


Fig. 3 Effect of the number of initialization cycles N_i on erasability.

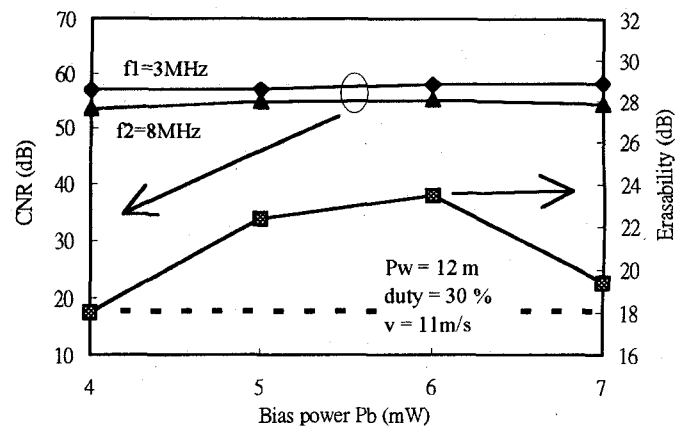


Fig. 4 CNR and erasability of phase change disks. The phase change disk was initialized by $P_i = 6$ mW for 5 cycles.

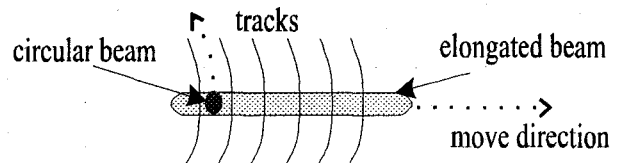


Fig. 5 Elongated beam and circular beam irradiated on optical disks

crystalline size during initialization by the same energy level. To further reveal the erasability on phase transformation and other causes, we shall study crystalline grains resulted by initialization processes, and it is the subject to be reported in near future.

IV. CONCLUSION

The initialization process affected erasability of phase change disks, but had little effect on CNR. The consequence of initialization process of phase change disks was primarily on residual carrier level change but little on other signal levels. The initialization power and the number of initialization cycles should be properly chosen to make phase change disks with adequate erasability. Under the optimized initialization conditions of P_i of 6 mW and N_i of 5 cycles, CNR of 54 dB at data frequency of 3 and 8 MHz, and bias power margin of 4 mW were obtained at linear speed of 11 m/s.

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