# Initialization-Free Multispeed Blue Laser Optical Disc

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**Brief Communication**

# Initialization-Free Multispeed Blue Laser Optical Disc

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An initialization-free Blu-ray disc was proposed as a candidate for multispeed blue laser recording and successfully fabricated. Experiment results of the initialization-free Blu-ray disc showed that it had a multispeed blue laser recording capability with speeds of 1 to 3×. The crystallization acceleration effect caused by additional layers and the rapid cooling caused by the initialization-free disc structure were suggested as the physical mechanism of multispeed recording in an initialization-free Blu-ray disc. [DOI: 10.1143/JJAP.45.6337]

KEYWORDS: optical data storage, Blu-ray disc, initialization-free, multispeed

The blue laser optical recording disc with a large recording density and a high data transfer rate has been put on the market driven by high-definition television (HDTV) programs and movies. The Blu-ray disc rewritable format was proposed by nine founders[1] and has a recording capacity of 23.3–27 GB and a data transfer rate of 36 Mbps. HD DVD-rewritable specifications was published by the DVD Forum[2] and offers a recording capacity of 20 GB and a data transfer rate of 36 Mbps.

Phase-change recording media are widely applied in rewritable blue laser optical recording discs such as Blu-ray discs and HD DVD rewritable discs. A rapid-phase-transition $GeTe–Sb_2Te_3$ pseudobinary amorphous thin film[3] or a AgInSbTe amorphous thin film[4] is used as the phase-change recording layer of the phase-change media. A phase-change recording layer has two phases, the amorphous and crystalline states. These two states have different optical constants, hence the reflectivities of the phases are different. Recording and erasing are achieved by the reversible changes between the two phases of the phase-change recording layer when the layer is heated by laser irradiation.

The initialization process that changes the phase-change recording layer from the as-deposited amorphous state to the crystalline state must be completed before information is recorded to a disc. However, the time required for the initialization process using a laser beam is significantly longer than that of other manufacturing processes, such as injection molding, sputtering, bonding and inspection. To avoid this bottleneck, shorten the production time and reduce the product cost in the production line, an initialization-free method for phase-change optical discs was proposed and the physical mechanism was discussed.[5] "Initialization-free disc" means that the as-deposited disc is in the crystalline state because the phase-change recording layer has already been crystallized during sputtering. In our previous work,[6,7] we demonstrated an initialization-free DVD rewritable disc (DVD-RAM) and an initialization-free Blu-ray disc. Non-bulk laser erasing (NBLE) phase-change discs, which include a Sb film to partially separate the AgVInSbTe phase-change recording layer, have already been reported.[8]

Rewritable phase-change optical discs have several different applications corresponding to different recording speeds. For example, phase-change rewritable optical discs for video applications are usually used at a low rotation speed that is suitable for real-time operation; phase-change rewritable discs for personal computer applications are usually used at a high rotation speed to achieve a high data transfer rate. Even for the same application, recording speed always increases because of market demand. Therefore, it is necessary to develop rewritable phase-change discs compatible with a broad range of recording speeds. In our previous work,[9,10] we demonstrated an initialization-free multispeed DVD-RAM disc. However, the initialization-free multispeed blue laser optical discs have not been reported yet.

In this study, the initialization-free Blu-ray phase-change optical disc is proposed as a candidate for multispeed blue laser recording. Computer simulation, disc design, disc fabrication and realization of the initialization-free effect are carried out. The dynamic recording properties at different recording speeds of the initialization-free Blu-ray disc are measured and compared with those of the conventional Blu-ray disc.

The disc structure of an initialization-free Blu-ray disc is shown in Fig. 1. Two additional layers are added to the disc. The phase-change recording layer is sandwiched between these two additional layers. The additional layers should be crystallized first during sputtering. This has been suggested to induce the crystallization of the phase-change recording layer in combination with a temperature change during sputtering.[5]

Compared with a conventional Blu-ray disc, an initialization-free Blu-ray disc has two more layers, which significantly changes the optical and thermal properties. The computer simulation and disc design of the initialization-free Blu-ray disc were carried out using our in-house phase-change optical disc design (PCODD) software.[11] The

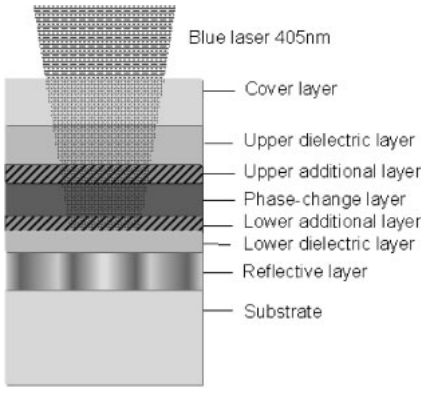


Fig. 1. Disc structure of initialization-free Blu-ray disc.

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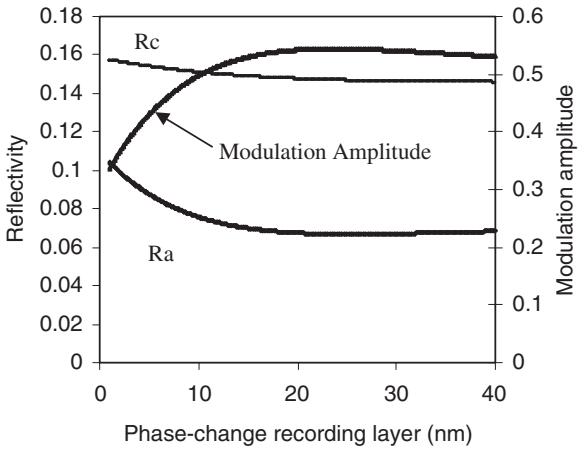


Fig. 2. Simulated reflectivity and modulation amplitude dependences on thickness of phase-change recording layer.

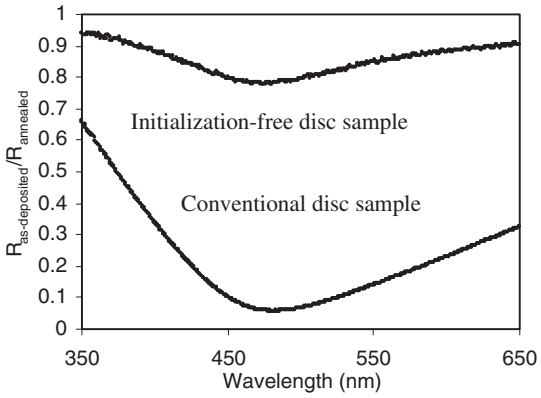


Fig. 3. Normalized reflectivities of initialization-free disc and conventional disc.

reflectance, modulation amplitude, cooling rate, temperature distribution and mark formation were simulated. After the simulations, the initialization-free Blu-ray disc structure was designed. Figure 2 shows the simulated reflectivity and modulation amplitude dependences of the initialization-free Blu-ray disc on the film thickness of the phase-change recording layer. The requirements of a high modulation amplitude and a high reflectivity in the crystalline state ($R_c$) should be balanced. Although the modulation amplitude has a maximum at a phase-change recording layer thickness of 23.6 nm, in this case the reflectivities in the crystalline state ($R_c$) and in the amorphous state ($R_a$) are too low. If the reflectivities are too low, a stable focusing/tracking servo and a high quality readout signal cannot be achieved. Therefore, a phase-change recording layer film thickness of 11 nm is appropriate because of the high modulation amplitude (0.506) as well as the suitable reflectivity (0.1503) in the crystalline state. Moreover, the simulation results of the cooling rate show that the cooling rate of the initialization-free disc is higher than those of the conventional disc at both low and high speeds.

The initialization-free Blu-ray discs were fabricated onto polycarbonate Blu-ray substrates (track pitch: 0.32 μm, supplied by Philips) using a Balzers Cube sputtering system. The AgInSbTe phase-change recording layer, the additional layer (Sb, $Sb_2Te_3$, $Bi_2Te_3$, $Sb_{70}Te_{30}$, or SnTe) for the initialization-free function, and Al alloy reflective layers were sputtered by DC magnetron sputtering. $(ZnS)_{80}(SiO_2)_{20}$ dielectric layers were deposited by RF sputtering. The chamber background vacuum was below $1.0 \times 10^{-7}$ mbar. After the sputtering deposition, the Blu-ray discs were bonded with the cover sheets using a Steag Hamatech bonding machine. The cover sheet had a thickness of approximately 75 μm and the material was polycarbonate. The bonding resin thickness was maintained at approximately 25 μm.

The reflectivities of the discs were measured using a scanning spectrophotometer (Shimadzu UV-3101PC). The dynamic recording properties of the initialization-free Blu-ray discs were characterized using a Pulstec DDU-1000 high-NA tester with a laser diode of 405 nm wavelength and a numerical aperture of 0.85. The eye pattern, jitter, overwrite cycles, erasability and carrier-noise-ratio (CNR) of the Blu-ray discs were measured with a conventional equalizer at different speeds.

After optimizing the thicknesses of the phase-change recording layer, two additional layers and dielectric layers in the Blu-ray disc, an initialization-free Blu-ray disc was fabricated for multispeed blue laser recording. For the reflectivity comparison between the initialization-free Blu-ray disc and the conventional Blu-ray disc, a conventional Blu-ray disc without the additional layer was deposited onto the same substrate as an initialization-free Blu-ray disc. The film thicknesses of all the layers, except the phase-change recording layer, in the conventional disc were the same as those in the initialization-free disc. After bonding, the conventional Blu-ray discs were annealed using a Shibasoku Initializer, the initialization parameters of a 7 m/s track speed and a 600 mW laser diode (LD) power were set. Figure 3 shows the normalized reflectivities of the initialization-free Blu-ray disc and the conventional Blu-ray disc. A normalized reflectivity of over 90% at a 405 nm wavelength, i.e., a ratio of the reflectivity in the as-deposited state to the reflectivity in the annealed state was achieved. The results reveal that the as-deposited Blu-ray disc with the initialization-free disc structure was crystallized during sputtering whereas the conventional Blu-ray disc was in an amorphous state after sputtering deposition. This indicates that the as-deposited Blu-ray disc with the initialization-free disc structure is initialization-free.

To study and demonstrate multispeed blue laser recording, the dynamic recording properties of the initialization-free Blu-ray disc were tested using a conventional equalizer mode after further optimizing the writing strategy. The measured recording speed varied from 5.28 to 15.84 m/s.

Figure 4 shows the jitter dependence on the number of direct overwriting cycles for the initialization-free Blu-ray disc at velocities of 5.28 (1× speed), 10.56 (2× speed), 13.2 (2.5× speed), and 15.84 m/s (3× speed) and for the conventional Blu-ray disc at a velocity of 10.56 m/s (2× speed). The results show that the jitter values of the initialization-free disc are less than 13% after 1000 direct overwriting cycles at the recording speeds of 1 to 3×. However, the jitter of the conventional Blu-ray disc is higher than 20% after only two direct overwriting cycles at double (2×) speed. The experimental results show the initialization-

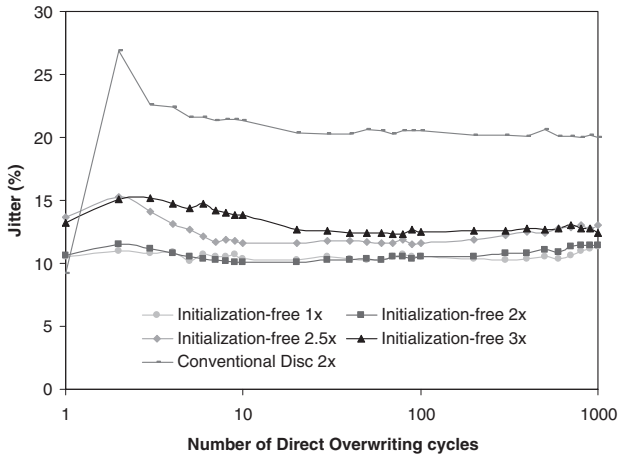


Fig. 4. Jitter dependence of initialization-free Blu-ray disc on number of direct overwriting cycles at different recording speeds.

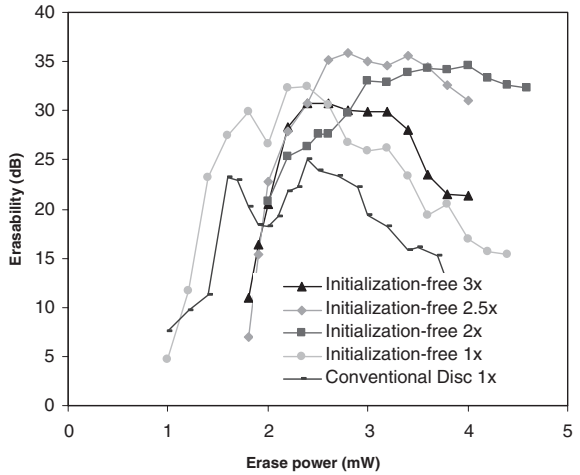


Fig. 5. Erasability dependence of 7 T signal of initialization-free Blu-ray disc on erase power at different recording speeds.

free Blu-ray disc has a broad range of recording speeds of 1 to 3×, which corresponds to the a velocity range of 5.28 to 15.84 m/s, respectively.

The CNR and erasability of the initialization-free Blu-ray disc and the conventional Blu-ray disc were measured at recording speeds from 5.28 to 15.84 m/s by erasing a 7 T signal after 10 direct overwriting cycles. Figure 5 shows the erasability dependence of the initialization-free Blu-ray disc on the erase power at velocities of 5.28 (1× speed), 10.56 (2× speed), 13.2 (2.5× speed), and 15.84 m/s (3× speed) and of the conventional Blu-ray disc at a velocity of 5.28 m/s (1× speed). The results show that the erasability of the initialization-free Blu-ray disc is greater than that of the conventional Blu-ray disc, and indicate that the initialization-free Blu-ray disc shows a higher crystallization speed because the additional layer in the initialization-free disc can accelerate the recrystallization of the phase-change recording layer as a result of surface-induced crystallization during erasing and direct overwriting. The excellent recording performance of the initialization-free Blu-ray disc at high speeds is primarily because of the good erasability. A high crystallization speed and a rapid cooling rate are necessary for high-speed blue laser recording.

The above results reveal that the initialization-free Blu-ray disc has a multispeed recording capability in contrast to the conventional Blu-ray disc. Moreover, the initialization-free Blu-ray disc can support high-speed blue laser recording and high-data-transfer-rate applications.

In summary, an initialization-free Blu-ray disc is proposed as a candidate for multispeed blue laser optical recording, which has many different applications. An initialization-free Blu-ray disc has been simulated and designed using our PCODD software. The initialization-free Blu-ray disc has successfully been fabricated for multispeed recording using a Balzers Cube sputtering system. The dynamic recording properties of the initialization-free Blu-ray disc at different recording speeds have been studied and compared with those of the conventional Blu-ray disc. The experimental results of the initialization-free Blu-ray disc show that the initialization-free Blu-ray disc has a multispeed recording capability with speeds of 1 to 3×. Moreover, the initialization-free Blu-ray disc can support high-speed blue laser recording and high-data-transfer-rate applications because of the crystallization acceleration effect caused by the additional layers and the rapid cooling caused by the initialization-free disc structure. These results are very important for the Blu-ray disc to be used in different applications with a cost-effective fabrication method.

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