Amorphization and crystallization simulation method

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ABSTRACT

We has taken nucleation, crystal growth and re-crystallization into consideration and constructed a useful simulator. We considered JMA-equation applicability to phase change optical disks, new calculation model, analysis of crystallization speed, and read-out signal simulation obtained by scanning a focused laser beam on calculated amorphous marks

Keywords: Phase change media, simulator, JMA-equation

1. INTRODUCTION

We have established the model for the write process of phase change media and constructed the simulator using the model. Furthermore, we connected it to the simulator for read-out process of read only disk, so that they have constructed the integrate simulator throughout read/write channel for a phase change disk.

2. WRITE PROCESS

Time dependent temperature distribution in three-dimensional optical structure irradiated by laser beam with amplitude modulation was evaluated by solving heat conduction equation by finite differential method of implicit scheme for time domain. Crystallization ratio was calculated with temperature distribution result.

We did not think JMA-equation is applicable to over-write phase change optical disks. This is because temperature in amorphous mark domain changes drastically within crystallization time durance. So, we went back to the fundamental equation of JMA-equation, and added re-crystallization effect at amorphous boundary while cooling process. The modified equation was used as the kinetics in over write phase change media. As the result, the model can explain interaction between nucleation and crystal growth. While cooling process in writing mark, crystallization does not occur because of little nucleation frequency. While the erasing process, crystallization occurs quickly because of many nuclei and large crystal growth rate.

We estimated both nucleation frequency and crystal growth rate as a function of temperature by comparing and fitting the amorphous domain shape obtained from experiment and calculation. Using the estimated crystallization speed, amorphous mark shapes were calculated to compare with actual mark shapes obtained by TEM observation.

3. ANALYSIS

The method to analyze crystallization ratio employed in our work is as follows.

1) Evaluate temperature distribution at a time step with given write strategy
2) Evaluate nucleation. Nucleation frequency is regarded as a function of temperature.
3) Evaluate crystal growth of already existing crystal grains and evaluate re-crystallization at amorphous/crystal boundary. Crystal growth rate is regarded as a function of temperature.
4) Increase time step and go to step 1). If the calculation is over, go to step 5).
5) Calculation over.

Nucleation frequency and crystal growth rate are both functions of temperature, and these values are shown in Figure 1. Figure 2 shows the comparison of actual mark shape observed by TEM. The result is shown in figure 1. The two results were in good agreement. This comparison was made under the condition below.

Tp;0.74 um, Bp; 0.205 um, Minimum Mark Length; 3 T, velocity; 6.0 m/s, Wavelength; 0.65 um, NA; 0.6, Recording layer; GeTeSb, Land and Groove structure.

As figure 2 shows, the both shapes are similar to each other.

As the next step toward the analysis of read out signal characteristics, we chose the play back signal amplitude from periodically written mark and space of the same length, that is pure tone amplitude. Focused laser beam was numerically scanned on calculated amorphous marks to produce read-out signal by the read-out simulator. Simulated read-out signal amplitude was compared between experiment and calculation by using reciprocal pattern of 11T(mark) + 11T(space). The comparison was made with many different sets of write pulse patterns, that is different write strategies.

The result is shown in figure 3. Within all the condition evaluated, read-out signal amplitudes of experiment and calculation were in good agreement. After that, they have proven that their model for read/ write channel of a phase change disk is reasonable.

4. COMPARISON OF PHASE CHANGE MEDIA

We have applied this model to Ag-InSbTe optical disk, which is used by CD-RW optical disk and DVD-RW optical disk, and found that the model can successfully simulate the recording process.

Figure 5 and 4 show layer structure of an Ag-InSbTe optical disk and a GeTeSb optical disk, respectively. They carried out 3-D thermal analysis together with phase change analysis. In phase change analysis, nucleation and crystallization were separately evaluated to estimate the crystallization ratio. To evaluate re-crystallization effect, crystallization form amorphous/crystal boundary into amorphous region was also applied to the calculation.

The nucleation frequency and crystal growth rate were estimated by fitting crystallization speed parameters to have the best match between calculated amorphous mark. Figure 6 and 1 show the nucleation frequency and crystal growth rate wersus temperature for Ag-InSbTe recording material and GeSbTe recording material, respectively. The differences between these two crystallization charachteristics are as follows.

1) Nucleation frequency of Ag-InSbTe recording material was less than 1/3 of that of GeSbTe recording material.
2) Crystal growth rate of Ag-InSbTe recording material was about 1.5 times lager than that of GeSbTe recording material.
3) For Ag-InSbTe material, nucleation frequency and crystal growth rate have similar graphs as a function of temperature.
4) For GeSbTe material, the graphs for nucleation frequency and crystal growth rate hit their peaks at different temperature.

Figure 7 and 2 are the mark shapes obtained by the simulation and the input power to write the mark of Ag-InSbTe and GeSbTe material, respectively. The calculated mark shapes agreed with experimentally obtained mark shapes. We also confirmed the mark shapes similarity between experiment and calculation from 3T mark through 11T mark. Simulated read-out signal amplitude was compared between experiment and calculation by using reciprocal pattern of 11T(mark) + 11T(space). This result is shown in Fig. 8 as the same form as Fig. 3.

5. CONCLUSION

We have established the model for the write process of phase change media and constructed the simulator using the model. Furthermore, we connected it to the simulator for read-out process of read only disk, so that they have constructed the integrate simulator throughout read/write channel for a phase change disk.. Crystallization characteristics of Ag-InSbTe material were analyzed. Nucleation frequency and crystal growth rate were quantitatively compared with that of GeSbTe material. We believe that the proposed analysis method for phase change phenomena is applicable for both Ag-InSbTe materials and GeSbTe materials.

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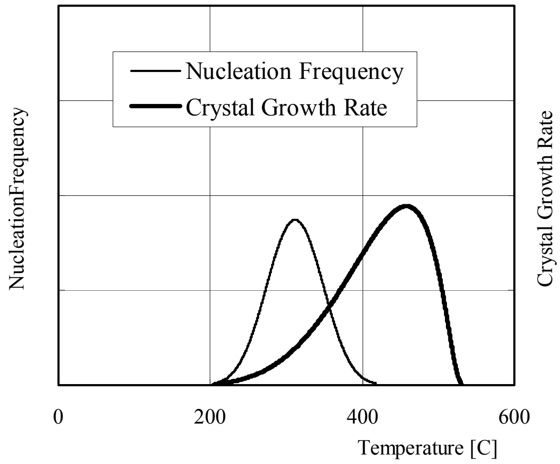

Figure 1. Crystalization Modeling
(GeSbTe)

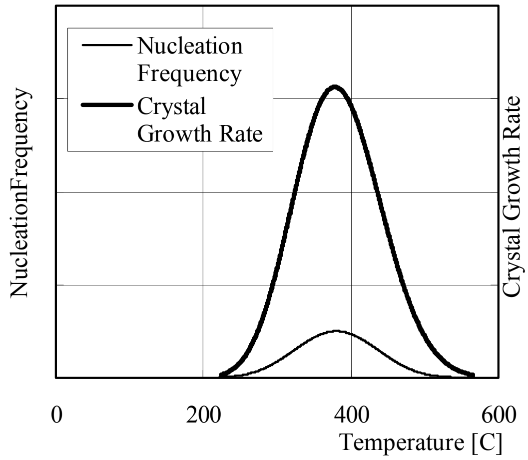

Figure 6. Crystalization Modeling
(Ag-InSbTe)

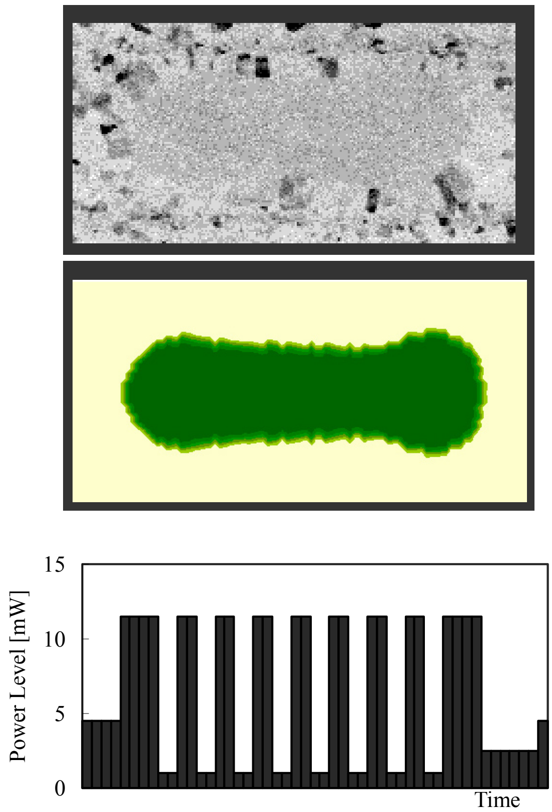

Figure 2. Write Power and 11Tw Mark
(GeSbTe Recording Material)

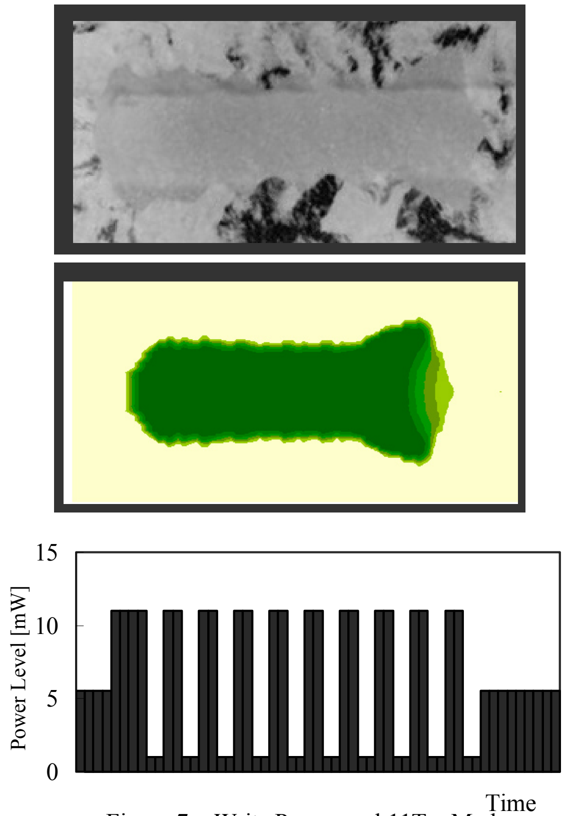

Figure 7. Write Power and 11Tw Mark
(Ag-InSbTe Recording Material)

(Upper; TEM observation, Middle; Calculation,
Lower; Write Waveform)

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Lower; Write Waveform)

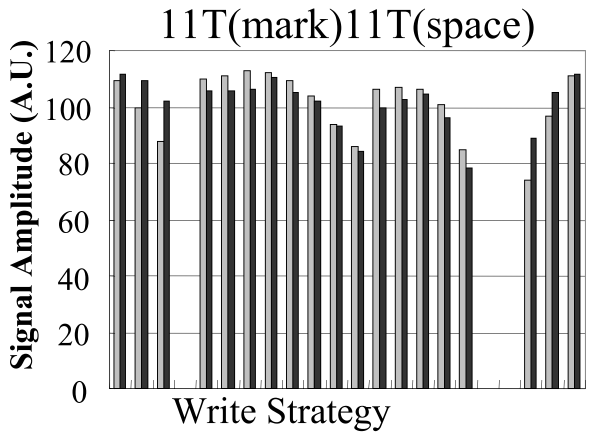

Figure 3. Comparison of Play back Signal with Ge-Sb-Te recording layer (Right bar: Experiment Left bar: Calculation)

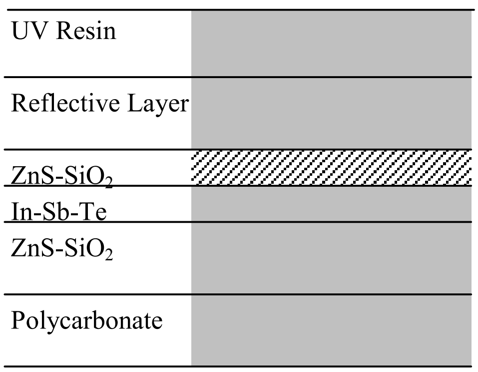

Figure 4. Disk structure with Ge-Sb-Te recording layer

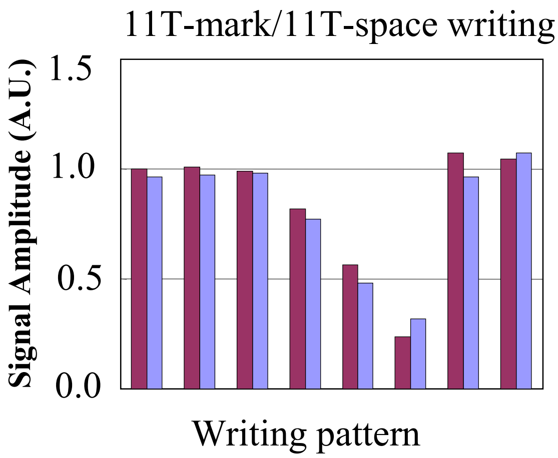

Figure 8. Comparison of Play back Signal with Ag-InSbTe recording layer (Right bar: Experiment Left bar: Calculation)

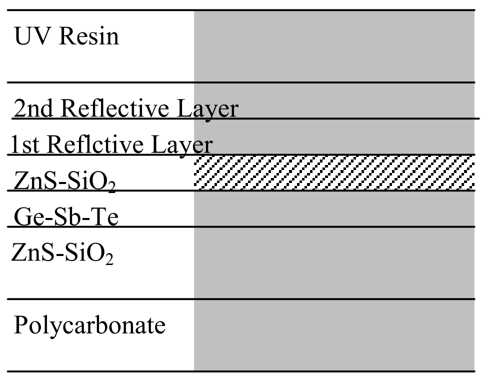

Figure 5. Disk structure with In-Sb-Te recording layer