DUAL WAVELENGTH STATIC TESTER FOR DIRECT ANALYSIS OF HIGH-DENSITY PHASE CHANGE DATA STORAGE MEDIA

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1. Introduction

Rewritable high-density optical data storage moves into the blue (405 nm) laser wavelength to achieve a smaller spot size and higher capacity than standard DVD technology in the red (650 nm). To adapt existing DVD experience and optimize new materials and systems for the development of high-density blue recording systems a direct comparison of blue and red phase change dynamics is essential. We realized a dual wavelength static tester for detailed and intercomparable analysis of the relevant processes at both wavelengths. First static investigations of phase change dynamics with blue laser and a direct comparison of the dynamics of blue and red laser induced phase transitions in $Ge_1Sb_2Te_4$ films are presented in this work.

2. Experimental

The scheme of the dual wavelength static tester for the investigation of phase change optical recording films is shown in fig. 1. The tester includes both an existing red [1] and a newly added blue (*Nichia*) laser system with correspondingly optimized focusing optics. The laser beams are coupled into the respective focusing optics, which can easily be exchanged by rotating the revolver of the optical microscope setup, and are focused through a 0.6 mm glass substrate onto the phase change layer. With rise and fall times of 1 ns (blue) and 3 ns (red) the temporal intensity profiles of write and erase pulses have nearly rectangular shapes with respect to the timescale at which phase change occurs. The pulse width can be adjusted from 10 to 500 ns, up to power levels of 13 mW (blue) and 22 mW (red). In order to measure the reflectivity change induced by write and erase pulses, a bias power of < 0.1 mW is constantly applied (read laser level) and the reflected laser beam is detected.

The samples are designed for investigation with blue and red wavelengths on the same sample: Thus the thickness of the protective layers is not optimal for any of the individual wavelengths. A compromise design was implemented to yield a similarly high optical contrast at red and blue wavelengths. Various sample designs were adopted and analyzed. Here, we focus on a multi-layer structure consisting of a bottom protective layer (120 nm $ZnS\text{-}SiO_2$), a single active $Ge_1Sb_2Te_4$ layer (17.5 nm), an upper protective layer (15 nm $ZnS\text{-}SiO_2$) and a reflective aluminum alloy layer (100 nm). The layers were consecutively deposited on 0.6 mm glass substrate.

3. Measurement of phase change dynamics

A precise evaluation of phase change dynamics can be performed in PTT (power-time-transition) diagrams as shown in fig. 2. Here, the relative reflectivity change ΔR_{ij} is analyzed as a function of pulse width (τ_i) and laser power (p_i). The measurement is done in three steps: In a first step an amorphous mark is written in a crystalline matrix. The intensity of reflected laser beam is measured as R_W. In a second step the amorphous mark is partially erased by a laser pulse $P(p_i, \tau_j)$. The influence of $P(p_i, \tau_j)$ is detected as the reflectivity R_{ij}. In a last step an erase pulse irradiates the sample and the reflectivity R_E is recorded. The relative change of reflectivity ΔR_{ij} is calculated as:

$$\Delta R_{ij}(p_i, \tau_j) = \frac{R_{ij} - R_W}{R_E - R_W}$$

The change of reflectivity reflects directly the change of crystallinity. A quantitative analysis of phase change dynamics can be derived from these plots. Optimal conditions for fast phase transition can immediately be determined. In fig. 2 examples of PTT analysis at blue (left) and red (right) laser wavelengths are compared. For this structure, a blue laser pulse power of 4.5 mW and a width of 75 ns are sufficient to complete phase change. The red laser requires a longer pulse of 90 ns and 8.5 mW. The shape of the PTT diagrams is strikingly distinct. While in the blue the dependence is rounded towards low pulse energies ($\tau_j \times p_i$), at red wavelengths the dependence is more rectangular. This divergence is certainly in part due to the dispersion of the thermo-optic coefficients in this material system [2]. Additionally, the different focal waist diameter influence the spatio-temporal temperature profile. A detailed thermo-dynamical modeling [3] of the phase change dynamics is applied to confirm this picture, although an additional unknown retardation component for phase change at blue wavelengths persists even after detailed calculations.

Altogether, a static tester set up for the direct analysis of phase change dynamics at both red and blue wavelengths is presented. Examples of first investigations are demonstrated. The divergence of the observed behavior and of the optimal writing/erasing conditions illustrates the relevance of detailed static tester analysis for the systematic optimization of future blue optical data storage systems, storage media and writing strategies.

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[2] F. Gan, et al. Material Science and Engineering B **76**, 63 (2000).

[3] B. Hyot, et al. Journal of the Magnetics Society of Japan **25**, 414 (2001).

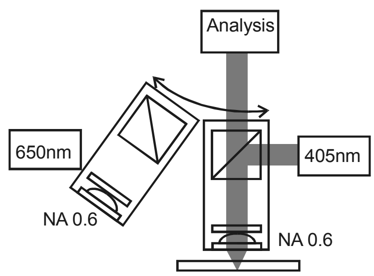

Fig. 1: Schematic of the combined red and blue static tester set up

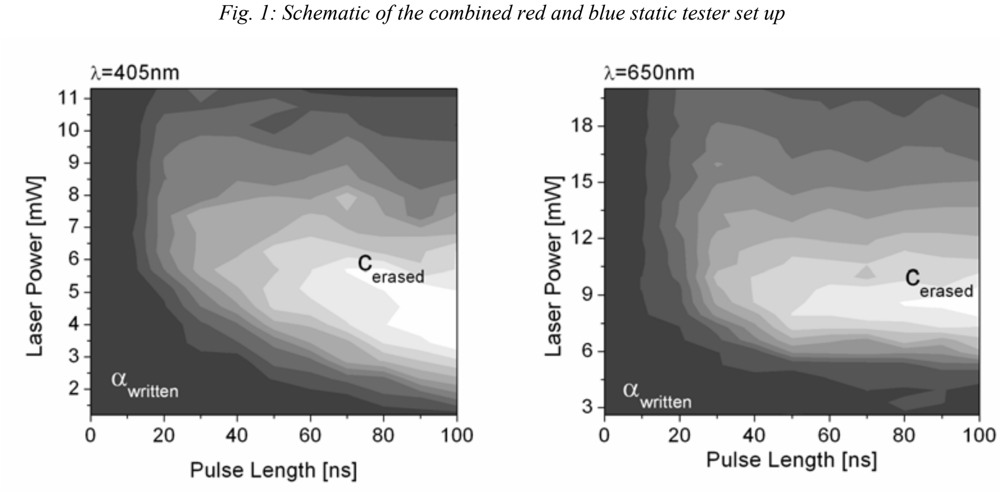

Fig. 2: PTT diagrams of the $a_{written}$-c_{erased} phase transition of a sample without a nitride interlayer at red (left) and blue (right) laser wavelengths.