THE EFFECT OF FILM STRESS ON SURFACE MORPHOLOGY AND CN RATIO OF A GARNET FILM

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Introduction

A magnetic garnet film which consists of rare-earth elements, iron, bismuth (Bi), and gallium (Ga) is one of the most attractive magneto-optical recording materials used at the wavelength region shorter than 550 nm. But, because the film texture of a garnet is crystalline, a film deposited on a glass substrate must be exposed to a high annealing temperature more than 500°C. Authors minutely investigated and compared the crystallization process of Bi and Ga substituted dysprosium (Dy)-iron (Fe) garnet film on two types of glass substrates of which thermal expansion ratio show one order of difference to study the effect of film stress on a crystallization process of garnet film. The potentiality about improvement in a CN ratio of garnet disk by tuning film stress with a difference of thermal expansion ratio between a garnet and a glass substrate and/or an annealing temperature will be finally reported.

Experimental

A film was deposited on a glass substrate by RF sputtering method and then annealed for 1 hour to crystallize a garnet film in an infrared image furnace. Quartz and non-alkaline (NA) glass were used as a substrate. A thermal expansion ratio of the former is $5 \times 10^{-7} / ^\circ C$ and that of the latter is $48 \times 10^{-7} / ^\circ C$. Three sintered targets which consist of Dy, Bi, Fe, Ga, and oxygen (O) were used. Compositional ratio of constituents except for O are listed in Tab.1. Annealed samples were characterized with XRD and surface morphology was observed with a polarizing optical microscope. An infrared image furnace attached to an optical microscope was also used for a real-time observation of crystallization process. From this result, the number of crystal nuclei, an incubation time, and a growth rate were decided.

Results and discussion

An optimum annealing temperature depends on a thermal expansion ratio of a substrate. Fig.1 shows the dependence of upper and lower limits of an annealing temperature on a Bi compositional ratio to make a single phase and perfectly crystallized garnet film on a quartz and on an NA glass substrate. The lower limits on both substrates are almost in a same level and decrease monotonically with a Bi density. The upper limit is larger on an NA glass than on a quartz.

Another notable feature of the upper limits on both substrates is that the upper limits have the maximum at a Bi density of 33 at.%. Rough textured and muddy films were sintered or a film had been partially peeled off in the extreme case at a temperature above the upper limit in the region.
of Bi density below 33at.%. Curiously, non-crystallized region remained even after annealing of 1 hour at a temperature higher than upper limit in the region of Bi density higher than 33at.%. From a real-time observation of crystallization process, it was confirmed that grain growth could stop at 1 minute after a start of annealing as shown in Fig.2.

It was also found out from this experiment that higher the annealing temperature was and/or smaller the thermal expansion ratio of a substrate was, more crystals nucleated. When an annealing temperature was 620°C, the number of crystal grains on a quartz is larger than on a non-alkaline glass with an ratio of 50%. Both high annealing temperature and small thermal expansion ratio result in a high film stress state. So, it is speculated that a nucleation probability and activation energy of crystal growth depend on a film stress. Since the averaged diameter of crystal grains after impingement of all grain boundaries becomes small, the reduction of noise level is surely expected from this result.

<table>
<thead>
<tr>
<th>Bi (at.%)</th>
<th>Dy (at.%)</th>
<th>Ga (at.%)</th>
<th>Fe (at.%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>25.5</td>
<td>20.0</td>
<td>12.7</td>
<td>41.3</td>
</tr>
<tr>
<td>33.0</td>
<td>12.5</td>
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</tr>
<tr>
<td>36.5</td>
<td>9.0</td>
<td></td>
<td></td>
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</tbody>
</table>

Tab.1 Compositional ratio of targets.

Fig.1 Temperature region for a garnet single phase on NA and quartz. ● indicate single phase films on NA. △ and × indicate partially non-crystallized or peeled films on NA.

Fig.2 Stopping of crystal growth above the upper limit. The degree of crystallization is smaller at 680°C ((a)) than at 650°C ((b)).