PARAMETER EFFECTS ON THERMAL PROTRUSIONS OF MAGNETIC HEAD SLIDERS

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ABSTRACT

The heat transfer in the magnetic head sliders in hard disk drives, the thermal protrusion (TPR) of the head elements, and the flying height change of such sliders were numerically simulated. A simulated temperature distribution of the air-bearing surface correlated well with our experimental results. A parameter study showed that decreasing the thickness of the alumina base coat or increasing the size of the pole and shields of the head elements can reduce the magnitude of write-current-induced protrusion (W-TPR). However, a longer pole and shields increase ambient-temperature-induced protrusion (T-TPR). For W-TPR, the reduced flying height of the slider is partly compensated for by increased air pressure on the air-bearing surface. However, almost the entire magnitude of T-TPR translates into a reduction in flying height.

1. INTRODUCTION

The current flying height of magnetic head sliders in hard disk drives is approximately 10 nm. Under such conditions, both the heat generated by the current in the write coil and the rise in the surrounding temperature cause local protrusion of the head elements [1-5]. Such thermal protrusion (TPR) reduces the flying height below the design value, thus reducing the safety margin for the head-disk interference.

We simulated the effects of important parameters on the TPR magnitude to obtain design guidelines for reducing TPR. In addition, we simulated the actual reduction of flying height due to the TPR using an ultra-thin gas film lubrication simulator.

2. SIMULATION METHOD

The simulation model and parameters are shown in Fig. 1. The heat transfer in the slider and the thermal deformation of the slider were calculated using the finite element method. The heat generation in the write coil was 20 mW, and the rise in the ambient temperature was 30°C. The boundary conditions and material properties of the model are shown in Tables 1 and 2. The change in flying height of the slider due to TPR was calculated by using an ultra-thin gas film lubrication simulator.

3. RESULTS AND DISCUSSION

The simulated temperature rise on the air-bearing surface of the slider due to the write current correlated well with experimental results obtained using an infrared microscope, as shown in Fig. 2.
A parameter study showed that a thinner alumina base coat of the head allows the write element to cool better because the thinner coat transports more heat from the write coil to the substrate. The parameter study also showed that short pole and shields cause less T-TPR but greater W-TPR (Fig. 5).

4. SUMMARY

In this study, head thermal protrusion was simulated in order to obtain design guidelines for a smaller protrusion and keeping the head/disk interface reliability. Simulated temperature distribution on the air-bearing surface agreed well with experimental results obtained with an infrared microscope.

REFERENCES

Table 3 Simulation results.

<table>
<thead>
<tr>
<th>Cause of protrusion</th>
<th>Flying height (nm) w/o TP</th>
<th>Protrusion (nm) w/ TP</th>
<th>Change (nm)</th>
<th>Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Write current (20 mW)</td>
<td>13.2</td>
<td>10.4</td>
<td>2.7</td>
<td>4.0</td>
</tr>
<tr>
<td>Ambient temp. (30 °C rise)</td>
<td>13.2</td>
<td>11.0</td>
<td>2.2</td>
<td>2.3</td>
</tr>
</tbody>
</table>

Table 3 Simulation results.

![Fig 2 Comparison with experimental data.](image2)

Fig 3 Flying height changes of simulated sliders.

The reductions in flying height in the center section of the slider without a TPR, with a write-current-induced TPR (W-TPR), and with an ambient-temperature-induced TPR (T-TPR) are shown in Fig. 3. In the case of the W-TPR, the air pressure on the air-bearing surface increased, lifting the slider upwards. A protrusion of 4.0 nm at the position of the read/write elements thus resulted in a reduction in flying height of only 2.7 nm, as listed in Table 3. The reduction in flying-height was partly (over 30%) compensated in the case of W-TPR. On the other hand, since the T-TPR produces a narrower shape of protrusion, in which only the area closest to the elements protrudes, the air-pressure increase resulting from the protrusion was small. Almost the entire magnitude (94%) of the T-TPR translated into a reduction in flying-height. Therefore, with T-TPR, a compensating effect cannot be expected.

![Fig 4 Effect of alumina base coat thickness on heat transfer in the head.](image4)

![Fig 5 Effect of pole and shields size on thermal protrusions.](image5)