Abstract—A new head design of a planar configuration for multi track perpendicular magnetic recording is proposed. The new planar multi-track head consists of 4 single-pole-type inductive write heads and 2 ring-yoke-type spin-valve MR read heads. In reproducing process, each MR head can read simultaneously signals from two tracks all together. To realize close-packed track recording, length direction of magnetic yoke of the write heads and head pole are arranged in the track and scan direction, respectively. Though this head consists of even 6 head-elements, the head fabrication process is almost the same as that of a conventional planar head.

II. HEAD DESIGN CONCEPT

A planar multi track (PMT) head consists of 4 single-pole-type (SPT) inductive write heads and 2 ring-yoke-type spin-valve (SV) MR read heads. In reproducing process, each MR head reads signals from two tracks all together. If we use ITOC [5] each data sequence could be discriminated from the mixed signals. Figure 1 shows schematic views of write and read elements for the PMT head. To realize a close-packed track configuration, length direction of a helical coil and magnetic circuits are arranged in track width direction for the SPT inductive write head element as shown in Fig.1(a). In this configuration, it is so difficult to form a merged-type head that a SV-MR read head is separated from the write head. To improve reproducing efficiency, we can realize a very short magnetic circuit for the ring-yoke-type SV-MR read head with a small gap length as shown in Fig.1. Bird's eye views of write and read head elements of PMT head.
Figure 2 shows plane view and cross section of the PMT head with above mentioned head elements. The head elements are arranged alternately in the head moving direction. For a 4.5 turns SPT write head, pitch of the helical coils and the pole-to-pole pitch is 5 µm, 9 µm, respectively. The SV-MR read heads have gap-to-gap pitch of 13 µm. The SV-MR element could be freely designed due to the yoke-type structure. The actually tested element width is 3 µm, and its length is 6 µm, 10 µm and 24 µm relating to the write track width of 1 µm, 3 µm and 10 µm, respectively. The PMT head has a small head pitch compared with the reported array head [3].

The new PMT head design has the following advantages.
1. Feasibility of designing a close packed multi tracks array even for a very narrow track width.
2. A very simple micro fabrication process compared with the conventional merged-MR head.
3. Built-in precision alignment of the head positions without any adjustment.

The PMT head uses 12 bonding pads due to the 2-read/4-write head elements, so a large head slider is necessary for easy bonding. In the present case, a head slider size was designed as 2 mm wide and 3 mm long as shown in Fig.3. The size is almost the same as that of a conventional planar silicon head [6]. The slider thickness is 1 mm determined by the substrate thickness. By improving the pad design, it is possible to reduce the head slider size.

The PMT head has a problem of skew angle by a conventional VCM actuator. To solve this problem, it is necessary to use a piggy-back or linear actuator. It is also necessary to electrical correction of the timing offset between tracks in the operation such as multi-channel ITOC recording.

III. HEAD FABRICATION

The PMT head was prepared on a ceramic-grass substrate, using conventional micro fabrication process. A CoZrNb amorphous film was used as the magnetic yokes of both write and read heads. The coils and leads were made of copper, and SiO₂ layer was used as an insulator. Al₂O₃ was
The SV-MR element was constructed as Ta (5 nm) / FeMn (10 nm) / NiFe (5 nm) / Cu (2.4 nm) / NiFe (10 nm) / Ta (5 nm) / substrate. This element showed 3.5 % MR-ratio in the size of 10 µm x 30 µm.

The PMT head consisted of 8-layers and formed in the following steps as shown in Table I. Each film was deposited by sputtering. Ion beam etching was used to form the CoZrNb magnetic yoke. Reactive ion etching (RIE) was used to form the coil pattern in the SiO$_2$ insulator layer. A focused ion beam (FIB) will be used to make a small gap length such as 0.1 µm for a high reproducing resolution.

In the case of the planar silicon head [4], a through hole connection was adopted to contact bonding pads with coils. Here, we used leads formed on a side edge of the PMT head slider for connection, as shown in Fig.3, because of easier fabrication. Throughout the head fabrication processes, we avoided any lapping processes except the processes of formation of the spin-valve MR films and the head slider installation in a parallel link suspension [8].

<table>
<thead>
<tr>
<th>Layer</th>
<th>Steps</th>
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<tbody>
<tr>
<td>1st and 2nd layer</td>
<td>SiO$_2$ deposition and coil pattern etching, Cu lift-off deposition</td>
</tr>
<tr>
<td>3rd - 5th layer</td>
<td>CoZrNb deposition and forming, SiO$_2$ deposition and coil pattern etching, Cu lift-off deposition</td>
</tr>
<tr>
<td>6th layer</td>
<td>CoZrNb deposition and forming, SiO$_2$ deposition and pillar pattern etching, Cu lift-off deposition</td>
</tr>
<tr>
<td>7th layer</td>
<td>spin-valve deposition and forming, CoZrNb deposition and etching, SiO$_2$ deposition</td>
</tr>
<tr>
<td>8th layer</td>
<td>CoZrNb deposition and forming, Al$_2$O$_3$ deposition</td>
</tr>
</tbody>
</table>
Fig. 5 Magnetoresistance change for a spin-valve MR element with magnetic ring-yoke on PMT head slider.

四方寸元 300
-300 -200 -100 0 100 200 300
H (Oe)

IV. RESULTS

Fabrication process of almost the whole parts of the PMT head except for forming a gap of the read head have been performed as a test. Figure 4 shows the photograph of the PMT head. The first prepared 4.5-turn write head exhibited an impedance of 20 Ω, 800 nH at 1 MHz and a resonance frequency of 30 MHz. The resistance is relatively large, compared with the array heads of reference [3]. Immaturity of our process might be one of the reason. If we could fabricate perfectly the coil of the write head, the coil resistance is expected as 6 Ω.

As shown in Fig. 5, 1.9 % MR-ratio was achieved for the actual size (3 μm x 6 μm) of the SV-MR element with a ring-yoke in the PMT head. The magnetic field was applied to the moving direction of the PMT head. The hysteresis and the lower MR-ratio than expectation are due to roughness of substrate surface, damage of ion milling and magnetic property of the ring-yoke.

Rounded edges of the pole-tips, as shown in Fig.4, will be easily trimmed out by FIB milling.

V. CONCLUSION

A novel head design of a planar configuration for multi track perpendicular magnetic recording and its electrical properties have been described. The PMT head is very promising to realize multi-channel recording for hard disk drives. Although we proposed the read head design for reading signals of only two tracks together, it is easy to change the design for more multiple tracks as to be used a new multi-channel coding scheme design [8].

We will examine read/write characteristics of the PMT head. Furthermore, we will optimize read/write efficiency considering with cross-talk between the head elements by using computer simulation.

VI. ACKNOWLEDGMENT

The authors wish to express their gratitude for guidance and encouragement received from honorary director of AIT S. Iwasaki.

REFERENCE