ANALYSIS OF A PARTIALLY POLE-EMBEDDED HEAT-ASSISTED MAGNETIC RECORDING HEAD

Kwaku EASON[1]

1) Symphonious Technologies, Minneapolis, MN, USA, kwakueason@gmail.com

ABSTRACT

Though significant progress has been made, the continued progression of hard-disk-drive technologies towards 10 Tbpsi remains a challenging endeavor. A panoptic view of the HAMR technology, in particular, indicates several factors that contribute to the challenge, including media as well as recording head design challenges. The HAMR head, specifically, has the broad responsibility of producing a magnetic field, delivering light to the optical transducer, and transforming optical energy into localized thermal energy within the media. Resulting thermal gradients exceeding 10 K/nm can often yield satisfactory recording performance, however, this can be at the expense of elevated temperatures in the system. In this work, we discuss an analysis of a magnetic pole-embedded optical transducer.

A magnetic pole-embedment approach is first motivated and justified by showing that the transverse mode of light propagation is sensitive to *both* conductive as well as magnetic properties. This leads to *surface plasmon polaritons* (SPP) that are, in fact, contrivable utilizing either conductive materials, but also magnetic materials. From the Maxwell equations, it can be shown that with any material, the generalized components of the effective permittivity ε_{eff} is given by

$$\varepsilon_{eff,R} = n^2 - k^2 - \frac{\mu_R \sigma_I + \mu_I \sigma_R - \mu_I \omega \varepsilon_I}{\mu_R \omega} \quad [1]$$

$$\varepsilon_{eff,I} = 2nk + \frac{\mu_R \sigma_R - \mu_I \sigma_I + \mu_I \omega \varepsilon_R}{\mu_R \omega} \quad [2]$$

It is well-known that an SPP forms in the necessary condition of a negative real effective permittivity, which according to Eq. (1), is achievable in a material that is dielectric, conductive, and/or magnetic. But how can this result be exploited? In some HAMR head designs, there is a need to design separation between the magnetic write pole material and the optical transducer, thereby, introducing further complexities because on one hand, this separation is desirable to minimize coupling, however, there is also a need for close proximity between the two to ensure maximal head field at the heated spot in the recording media. Additionally, for the aforementioned reasons, the write pole likely heats up more than anticipated due to potential plasmonic coupling, which amplifies the electric field. Thus, we explore a potential solution to this sort of design dilemma by exploring the feasibility of an optical transducer whose lateral surface area is surrounded by magnetic material acting as a more favorable pseudo-lateral extension of the transducer into the write pole, especially at the air bearing surface near the recording location in the media.

We discuss 2D and 3D single-mesh optical + thermal physics finite element modeling results in the spirit of the proposed design scheme, that allows an analysis of the feasibility of the approach. It is observed that a magnetic material such as nickel, iron, or cobalt effectively screens the electrons at the magnetic-metal interface, and thus serves as a very good pseudo-lateral extension of the transducer into the write pole. It is also shown that *clean* thermal profiles are quite achievable, without any background modes from the wave-guide or write-pole penetrating into the media (see Fig. 1). Overall, the results suggest that this approach cannot only provide improved cooling in the head, but has the potential to achieve competitive thermal gradients in the recording media. The analysis suggests that pole-embedded transducers have the potential to provide a feasible path towards higher linear densities in future HAMR technologies.

KWAKU EASON
E-mail: kwakueason@gmail.com
tel: +1-612-5002960

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e-mail address: **kwakueason@gmail.com**

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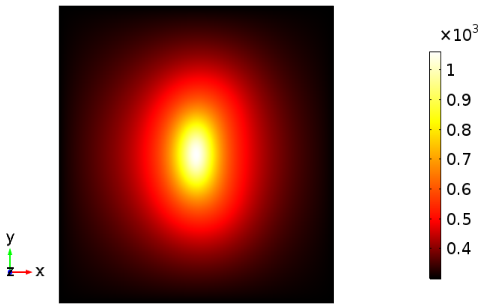

Fig. 1 Example of a simulated thermal profile in the FePt recording layer (temperature in Kelvin), from a pole-embedded transducer design. *x* designates downtrack. The head design also includes a carbon-based overcoat at the ABS, HMS of ~2.5nm, while the media also includes a lube-like layer, a carbon-based overcoat, the recording layer taken to be FePt, an MgO underlayer, a heat-sink, etc.

KWAKU EASON
E-mail: kwakueason@gmail.com
tel: +1-612-5002960