OPTICAL ABSORPTION IN HEAT ASSISTED MAGNETIC RECORDING MEDIA

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According to a recent International Data Corporation (IDC) white paper [1], worldwide creation of data will grow to 160 zettabytes (ZB) by 2025, ten times the amount of data produced in 2017. 70% of this enormous amount of information was predicted to be stored on HDD based cloud data centers. According to the ASTC technology roadmap, this massive capacity is going to be delivered by the next generation of HDDs. Heat Assisted Magnetic Recording (HAMR) has been shown to be a viable technology for the future of magnetic data storage by, for example, the recent Seagate demonstration of $2\,Tb/in^2$ HAMR drives [2]. Furthermore, pilot volume manufacturing is expected to be launched by the end of 2018 [3]. In principle, the areal density of HAMR can be increased far beyond the current demonstration by identifying and mitigating different sources of recording noise that restrict scalability of the system. For instance, by adding a superparamagnetic layer to the storage layer (Thermal Exchange Coupled Composite media), the impact of T_c variation can be significantly reduced and user areal density can be increased to approximately $4\,Tb/in^2$ ($4.7\,Tb/in^2$ with shingling) [4].

In addition to magnetic parameters, structural randomness is one of the main criteria that can restrict scalability of HAMR. We show that variation in the optical power absorption of recording grains can be considered to be one of the most immediate consequences of this structural randomness. Specifically, variation in the optical absorption can directly affect the recording owing to the large thermal boundary resistance of grain boundaries. Despite its crucial role, random absorption has been generally neglected by the averaging technique used to describe the response of media. This effective medium theory (EMT) can be traced to the earlier work of Maxwell and Garnett that describes the response of composite structures to electromagnetic excitations by effective electric permittivity approximations [5]. Generally, the fundamental assumption for validity of EMT is that spatial features of the geometry of interest are much smaller than the profile of the electromagnetic field. However, as discussed in [6], this assumption is not valid at the operating length scale of HAMR; as a consequence, a novel model is required to describe the optical response of the recording media.

Contrary to the effective media approximation, a realistic recording media contains plasmonic particles (FePt) with random shape, size, or position that can interact with each other through the dipole-dipole interaction. The role of randomness in HAMR media can be quantified by studying the effects of shape and permittivity on the depolarization field of an isolated particle. For a linear isotropic particle located in vacuum, the electric field inside the particle can be written as:

$$|E|^2 = |E_0|^2 \sum_{i=x,y,z} \left|\frac{1}{1+N_{ii}(\epsilon_r-1)}\right|^2 \tag{1}$$

where E_0 is the projection of applied field on x, y & z axis, ϵ_r is the permittivity of the particle, and N_{ii} is the depolarization factor along different directions ($i = x, y, z$). Therefore, from the perspective of local field variation, any sort of randomness in the shape of the particle, i.e. depolarization factor, can drastically affect the optical response of particles. For example, our analysis indicates that oblong grains absorb much more optical power than circular ones. As a consequence, a combination of random aspect ratio and lightning rod effect at sharp corners can lead to a significant variation in the absorption of recording grains.

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This local field variation can be analyzed in more detail by investigating the collective response of grains. As discussed in [7], the weighted local density of states of the depolarization field inside the recording media can be described in the following form:

$$\rho(\vec{r}) = \sum_n \left|\frac{\nabla\psi_n}{\lambda_n}\right|^2 \tag{2}$$

where ψ_n and λ_n are the *n*th depolarization mode, respectively. As depicted in Fig. 1b, the behavior of the local field enhancement inside the recording media can be accurately understood in terms of ρ(r) and the spatial fluctuation in ρ(r) can be considered to be a source of local field variation in recording media. According to our Finite Difference Time Domain (FDTD) and heat transfer simulations, local field variation can have a significant impact on writing temperature, leading, in extreme cases, to temperature variation of 10%.

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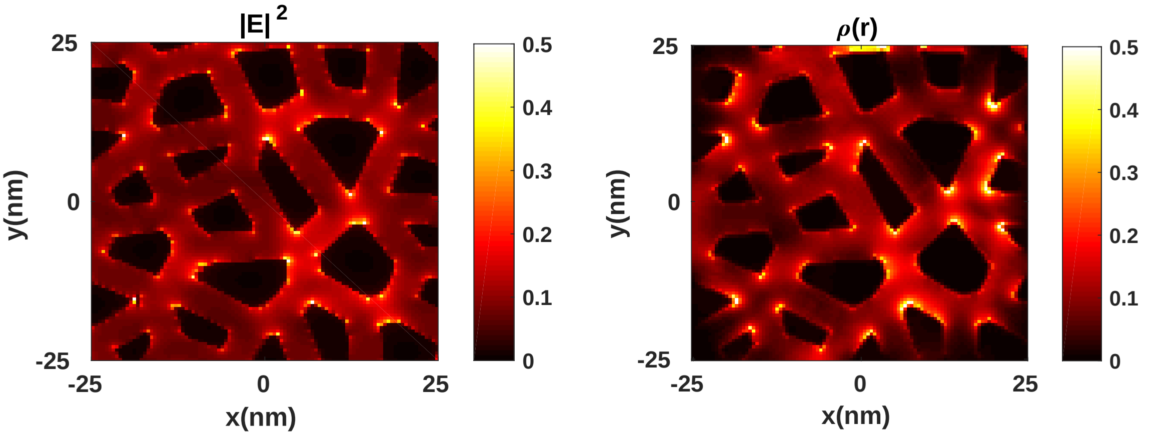

Fig. 1 a) weighted density of states for depolarization modes in recording media, b) normalized electrical field intensity inside the same recording media as calculated by the FDTD method [7].