SEM Charging of Floating Metal Structures in Dielectric

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SEAGATE

KLA

HAMR Background

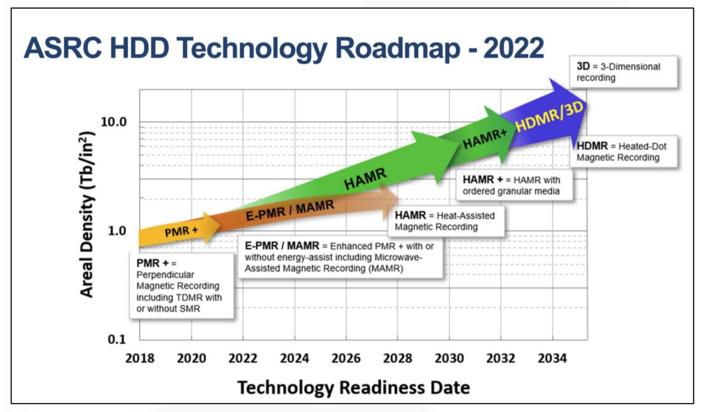

Figure 1. Technological Roadmap of HDD Technologies

Hard Disk Drives (HDD) are transitioning to Heat Assisted Magnetic Recording (HAMR) to achieve greater aerial densities. HAMR writing heads incorporate plasmonic resonators that can locally heat up the recording media with high spatial resolution, yielding smaller written bits.

The plasmonic resonators are metal features, often with sharp corners, floating in dielectric material. The ungrounded nature of the metal structures makes them susceptible to charging when imaged in the Scanning Electron Microscope (SEM).

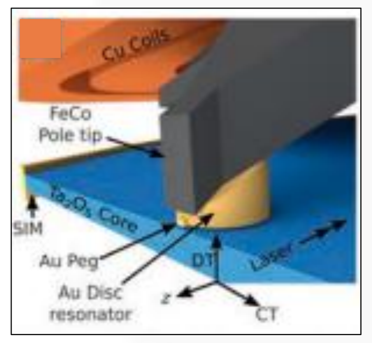

Figure 2. Diagram of HAMR Writing Head

Blaber, M. and Kautzky, M. Materials for heat-assisted magnetic recording heads. MRS Bulletin. 43, 100-105 (2018).

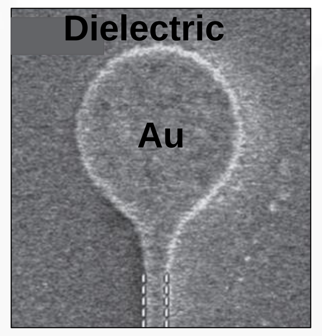

Figure 3. SEM of Au Resonator

W. A. Challener, C. Peng, A. V. Itagi, D. Karns, W. Peng, Y. Peng, X. Yang, X. Zhu, N. J. Gokemeijer, Y.-T. Hsia, G. Ju, R. E. Rottmayer, M. A. Seigler and E. Gage, "Heat-assisted magnetic recording by a near-field," *Nature Photonics*, pp. 220-224, 2009.

The ability to successfully image the metallic structures in the SEM is critical for defect detection and critical dimension measurements. Developing experimental systems to understand optimal imaging conditions for floating features will improve both tool health and the HAMR technology.

Sheetfilm Electron Beam Simulations

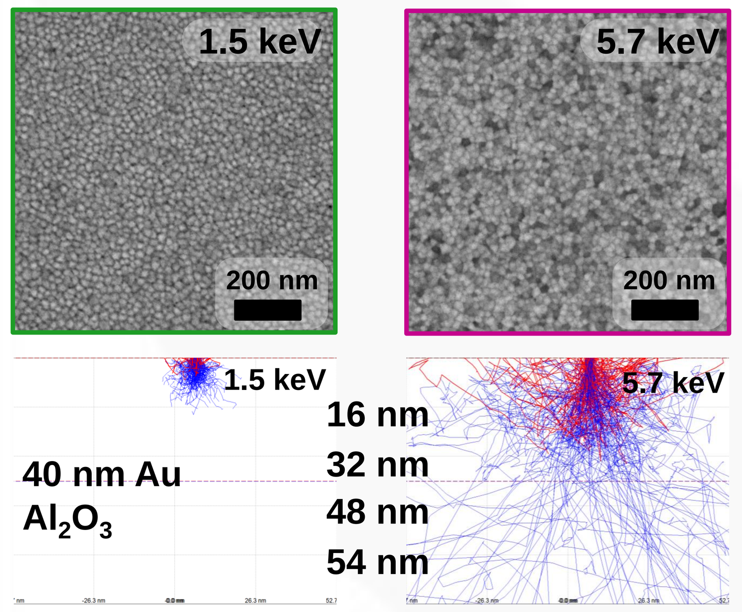

Figure 4. SEM Backscatter Images and Casino Simulations of Au Sheetfilms

As a starting point for understanding the electron beam interaction with gold structures floating in dielectric, gold sheet films were investigated. SEM back scatter imaging at different landing energies was compared with Casino electron beam simulations. The gold films were 40 nm thick. The landing energy controls the depth of electron beam penetration, so the same observed grain size at 1.5 keV and 5.7 keV suggests the grains were columnar in geometry.

Simulating electron beam landing energies up to 5.7 keV shows that only the top 5 nm is being imaged at 1.5 keV while 5.7 keV samples almost the entire 40 nm of Au. The average spatial distance of the backscatter event from the center of the electron beam also increases with landing energy, going from 2 nm average spatial spread at 1.5 keV to 12 nm average spatial spread at 5.7 keV.

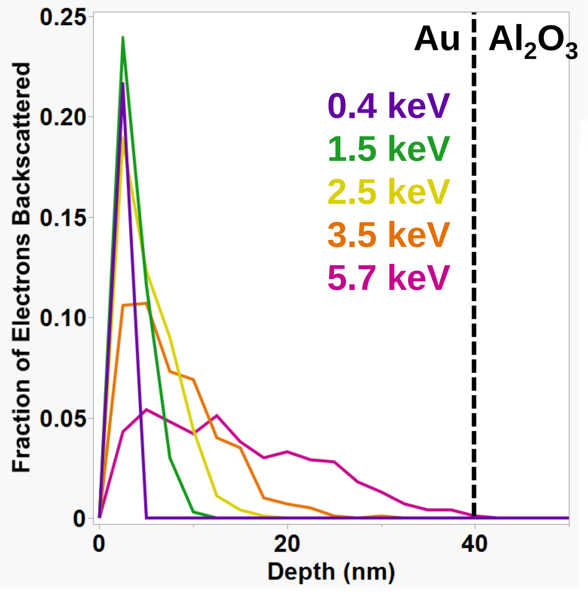

Figure 5. Penetration Depth in Au Sheetfilm

Drouin, D.; Couture, A. R.; Tastet, X; Aimez, V.; and Gauvin, R., "CASINO V2.42—A Fast and Easy-to-use Modeling Tool for Scanning Electron Microscopy and Microanalysis Users," *Scanning*, pp. 92-101, 2007.

Floating Gold Structures in Dielectric

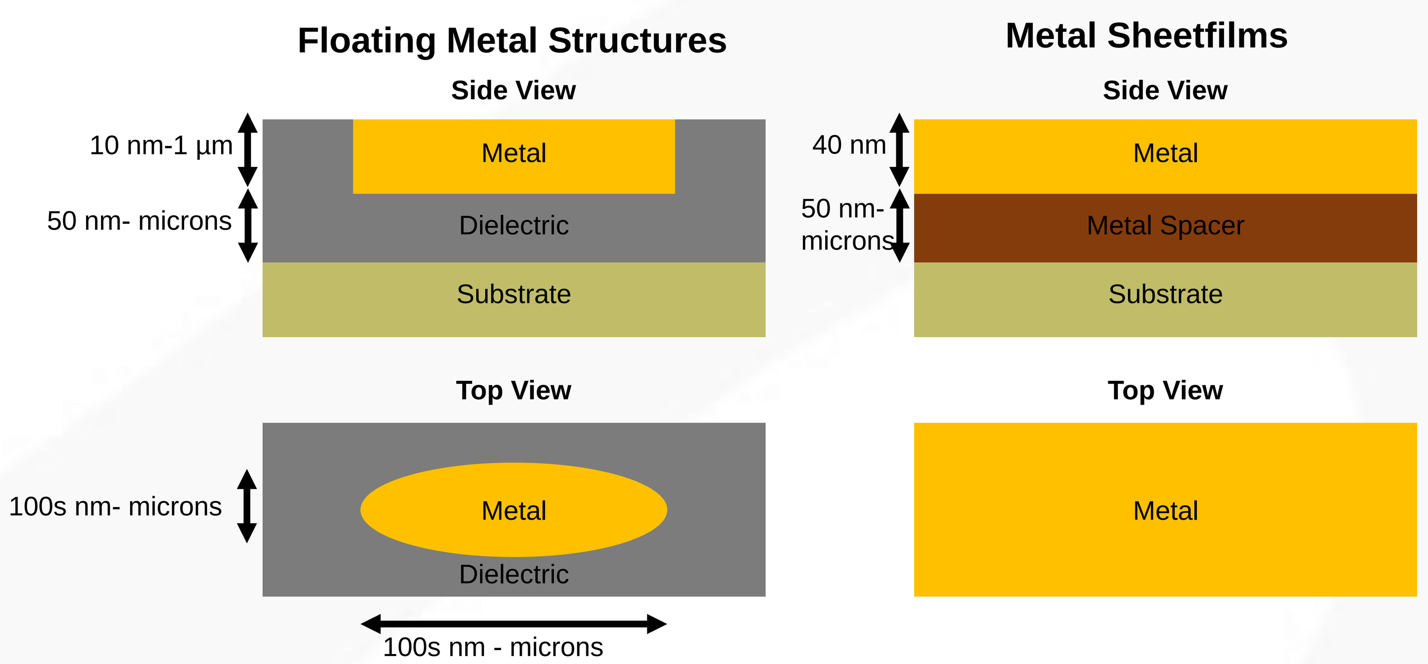

Figure 6. Schematics of floating metal structure often produced when making HAMR recording heads and sheetfilm wafers used to understand electron beam interaction with metal films

The floating metal features needed for HAMR present charging challenges when imaging in the SEM. The ungrounded metal features build up charge under the electron beam causing charging. This built-up charge can cause unseen but destructive discharge events within the device or tool-damaging arcing events.

Simulating SEM Imaging of Floating Au Structures

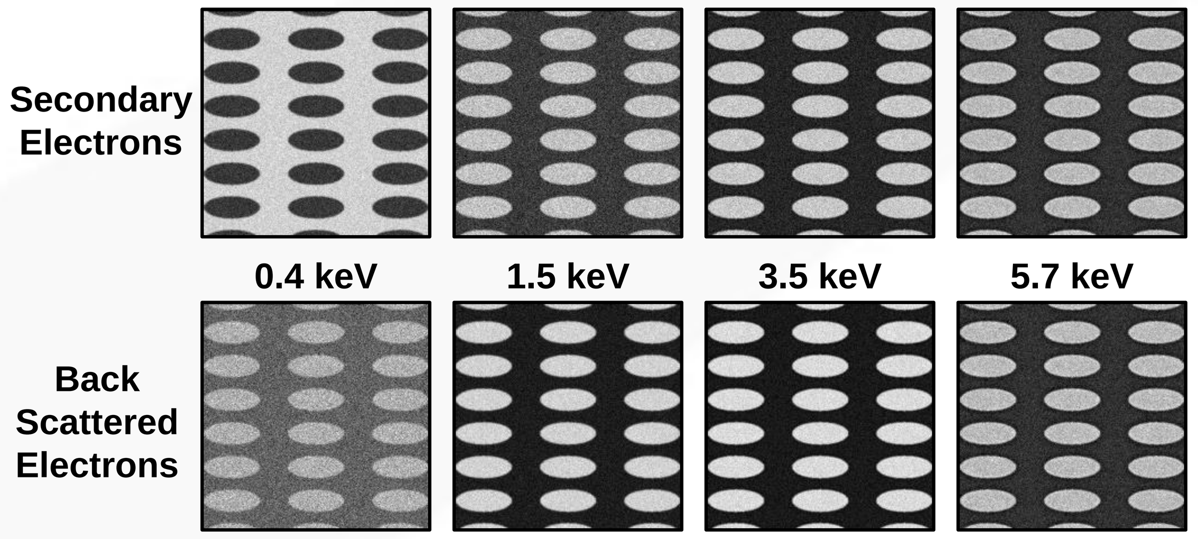

Figure 7. Simulated SEM images without charging effects for floating Au features in Aluminum Oxide.

Simulations of the full floating structures show the optimal landing energies for the greatest Au/Aluminum Oxide contrast. The simulations also show the high electric field and voltage of the ungrounded Au structures after SEM imaging. This high electric field is leading to the problematic arcing events.

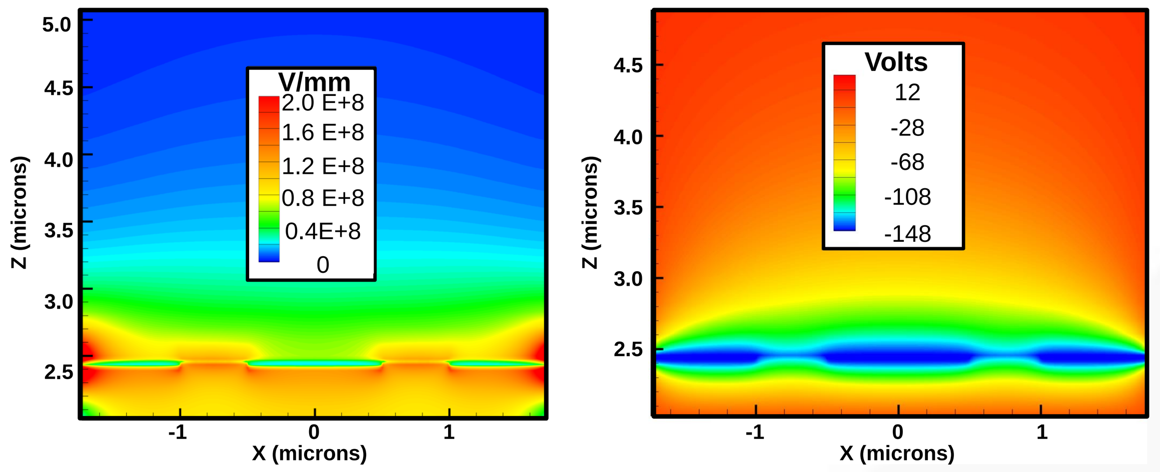

Figure 8. The simulated electric field around ungrounded Au features and the voltage of floating Au features.

Testing Effects of Metallic Shape and Dielectric Thickness

Test wafers can be built with controllable dielectric thicknesses separating the metal feature from grounded features underneath. This setup enables both an understanding of how charge is dissipating from the floating metal feature and a means to safely test new floating shapes.

Hauwiller, M.; Mann, C.; Mach, P.; Terry, K., "Electric Field Controller of Ungrounded Wafer Structures to Prevent Arcing in SEM," The *IP.com Journal*, 2022.

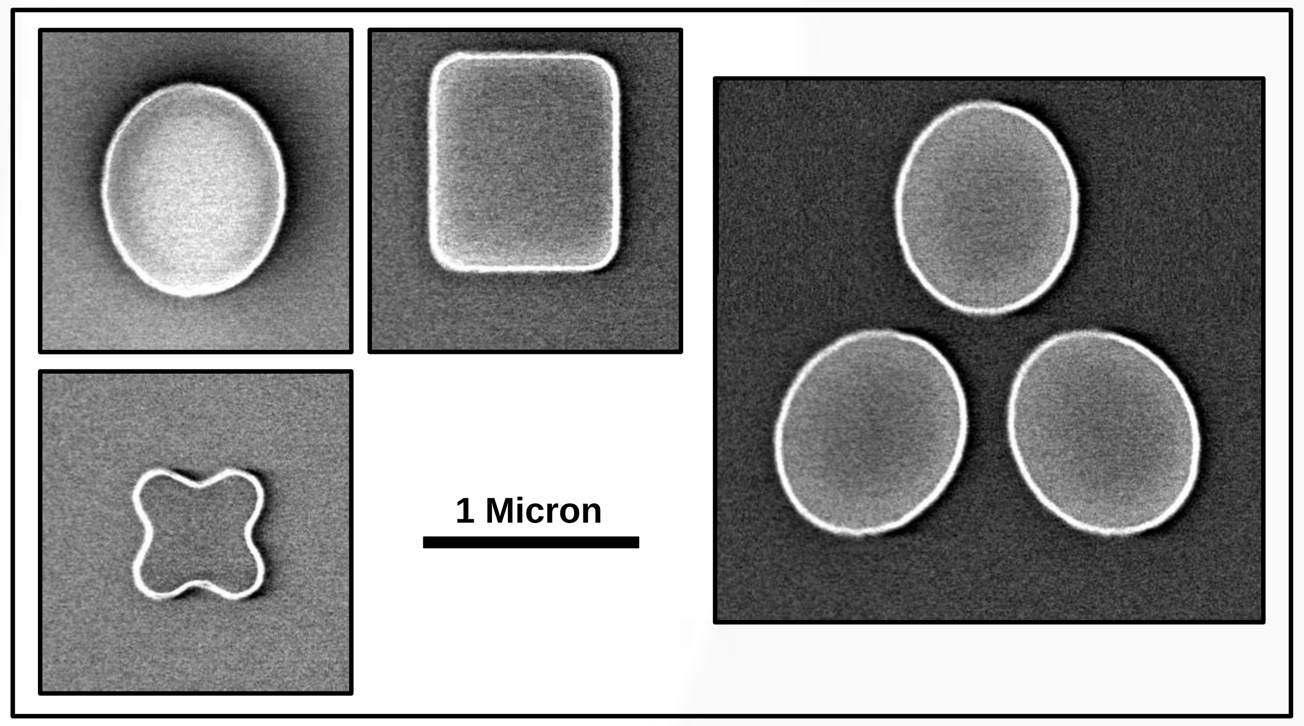

Figure 9. Example test shapes used to understand charging of floating features. For the images above, the gold structures were fully grounded, but varying the distance between them and the ground will reveal charging mechanisms.

The shape of the floating metal feature has a strong impact on the local electric field which influences whether the built-up charge dissipates in a safe or tool-damaging way. Although the sharpness of features cannot be controlled in the z-direction, the features can be controlled in the x and y-direction. Sharpness of tips, concave and convex angles, and closeness of neighboring structures can be investigated.

Future Work

The wafer system and simulation capabilities are now set up to provide quantitative understanding of the SEM charging of floating metal structures.

Experiments to determine the effects of shape, tip concavity, distance from nearest floating feature, and distance from grounded feature will be correlated with simulations to provide a model for how charging and discharge events occur for floating metal features.

If the controllable dielectric distancing from the grounded feature proves to reduce arcing events for floating metal features, this technique can be used to test the likelihood of arcing for new features without risking the tool.

Determining methods for reduction of charging would improve SEM imaging capabilities and enable Research & Development to deploy HAMR faster.

Acknowledgements

This work was made possible by the collaborative efforts of the Seagate and KLA teams.
All SEM imaging was performed on a KLA e-beam Wafer Defect Review (eDR®) tool.
On the Seagate side, CAD teams, production specialists, and equipment engineers helped build the necessary wafers and keep the tools in optimal shape.

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