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Versatile, All-Diamond Scanning Probes for High-Performance Nanoscale Magnetometry

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Abstract *In recent years, probing magnetic field and magnetization of materials at the nanoscale has received significant attention as fields such as MRAM and 2D materials evolve. To deliver on this, scanning NV microscopy has been developed and the advances of this technique will be explored here.*

Sections of a Paper

Nitrogen-vacancy (NV) centers in diamonds have emerged as a powerful platform for quantum sensing enabling highly sensitive and quantitative measurements of magnetic fields both at room and cryogenic temperatures. To achieve nanoscale magnetic field imaging resolution, a scanning NV-based magnetometer has been developed where a single NV center is used as a sensor to locally probe surface magnetic fields revealing nanoscale domains in multiferroics[1] and antiferromagnets[2] or even enable imaging of single-electron spins[3]. At the core of this technique is an all-diamond scanning probe hosting a single negatively charged NV center at the apex of its tip[4]. Since NV acts as a single-axis vector magnetometer along the NV binding axis, projections of measured magnetic fields depend on the orientation of the NV center in the diamond probe. So far, most of the probes are made from commercially available (100)-oriented high purity diamonds. This yields the NV axis being oriented at 54,7° to the scanning plane. Even though this oblique measurement angle still allows for high-resolution surface magnetic field imaging, data interpretation and calculation of sample magnetization bear large uncertainties.

To facilitate data analysis and especially the quantitative determination of magnetization, we have developed diamond scanning probes that host NV centers with their axis aligned perpendicular (out-of-plane[5]) or parallel (in-plane) to the sample surface. In addition, such probes open more avenues to explore in-plane or our-of-plane magnetization of various samples under applied external magnetic bias fields. We also show that sensitivities of all-diamond probes can be highly improved by coupling NV emitted photons into parabola-shaped scanning tips[6]. Our probe developments permit more robust and reliable magnetometry at the nanoscale.

References

[1] I. Gross, W. Akhtar, V. Garcia, L. J. Martınez, S. Chouaieb, K. Garcia, C. Carrétéro, A. Barthélémy, P. Appel, P. Maletinsky, J.-V. Kim, J. Y. Chauleau, N. Jaouen, M. Viret, M. Bibes, S. Fusil, and V. Jacques, "Real-space imaging of non-collinear antiferromagnetic order with a single-spin magnetometer." Nature 549, no. 7671 (2017): 252-256. DOI:

[2] P. Appel, B. J. Shields, T. Kosub, N. Hedrich, R. Hübner, J. Fasbender, D. Makarov, and P. Maletinsky, "Nanomagnetism of magnetoelectric granular thin-film antiferromagnets." Nano letters 19, no. 3 (2019): 1682-1687

[3] M. S. Grinolds, S. Hong, P. Maletinsky, L. Luan, M. D. Lukin, R. L. Walsworth, and A. Yacoby, "Nanoscale magnetic imaging of a single electron spin under ambient conditions." Nature Physics 9, no. 4 (2013): 215-219.

[4] P. Maletinsky, S. Hong, M. S. Grinolds, B. Hausmann, M. D. Lukin, R. L. Walsworth, M. Loncar, and A. Yacoby. "A robust scanning diamond sensor for nanoscale imaging with single nitrogen-vacancy centres." Nature nanotechnology 7, no. 5 (2012): 320-324.

[5] D. Rohner, J. Happacher, P. Reiser, M. A. Tschudin, A. Tallaire, J. Achard, B. J. Shields, and P. Maletinsky, "(111)-oriented, single crystal diamond tips for nanoscale scanning probe imaging of out-of-plane magnetic fields." Applied Physics Letters 115, no. 19 (2019): 192401.

[6] N. Hedrich, D. Rohner, M. Batzer, P. Maletinsky, and B. J. Shields, "Parabolic diamond scanning probes for single-spin magnetic field imaging." Physical Review Applied 14, no. 6 (2020): 064007.