doi:10.1017/S1431927620023405
Microsc. Microanal. 26 (Suppl 2), 2020

Investigation of Vortex Pinning in Ni Doped $BaFe_2As_2$ Superconductor with Machine-learning

Yueming Guo, Qiang Zou, Mingming Fu, Zheng Gai, Athena Sefat and Sergei Kalinin

Oak Ridge National Laboratory, Oak Ridge, Tennessee, United States

In the presence of magnetic field, type II superconductors exhibit a vortex structure, which consists of mixed normal and superconducting phases. The magnetic field is expelled from the superconducting regions but transmits through the normal phases [1]. Vortex structures have attracted a lot of research interest not only because of the phenomenon that can testify theories of high temperature superconductivity (HTS), but also because of the technological importance that an HTS with pinned vortices can give rise to dissipation-free currents at relatively strong magnetic fields [2].

In the current study, scanning tunneling microscopy/spectroscopy (STM/S) experiments were carried out at T = 4 K to study the vortex structure in Ni doped $BaFe_2As_2$ under three different magnetic fields, H = 2, 4 and 6 T. Three vortex images were reconstructed by subtracting STS maps at the Fermi level for H =2, 4 and 6 T from the counterpart for H = 0 T. Then, the three vortex images were compared to search for vortices that stay in the same places. We assume that those vortices are physically pinned. The spectra across the pinned vortices were compared with the spectra across the rest of the vortices. The spectra across the cores were averaged over the pinned, unpinned and all of the vortices. Principle component analyses (PCA) were also carried out for each group.

From comparison between vortex images of 2 and 4 T, it was found that the pinned vortex cores tend to have increased density of states (DOS) at the Fermi level than the rest. This phenomenon was also observed for the pinned vortices from comparison of three vortex images (the number of pinned vortices is fewer than the previous case). However, from comparison between vortex images of 4 and 6 T, no significant change in the averaged DOS was observed. PCA analyses also agree with this trend about the DOS associated with the pinned vortices.

If our assumption about the pinned vortices (that the vortices which appear in the same locations between two vortex images are physically pinned) is true, we could investigate possible mechanisms for vortex pinning in the current system from the machine-learning based data analyses [3].

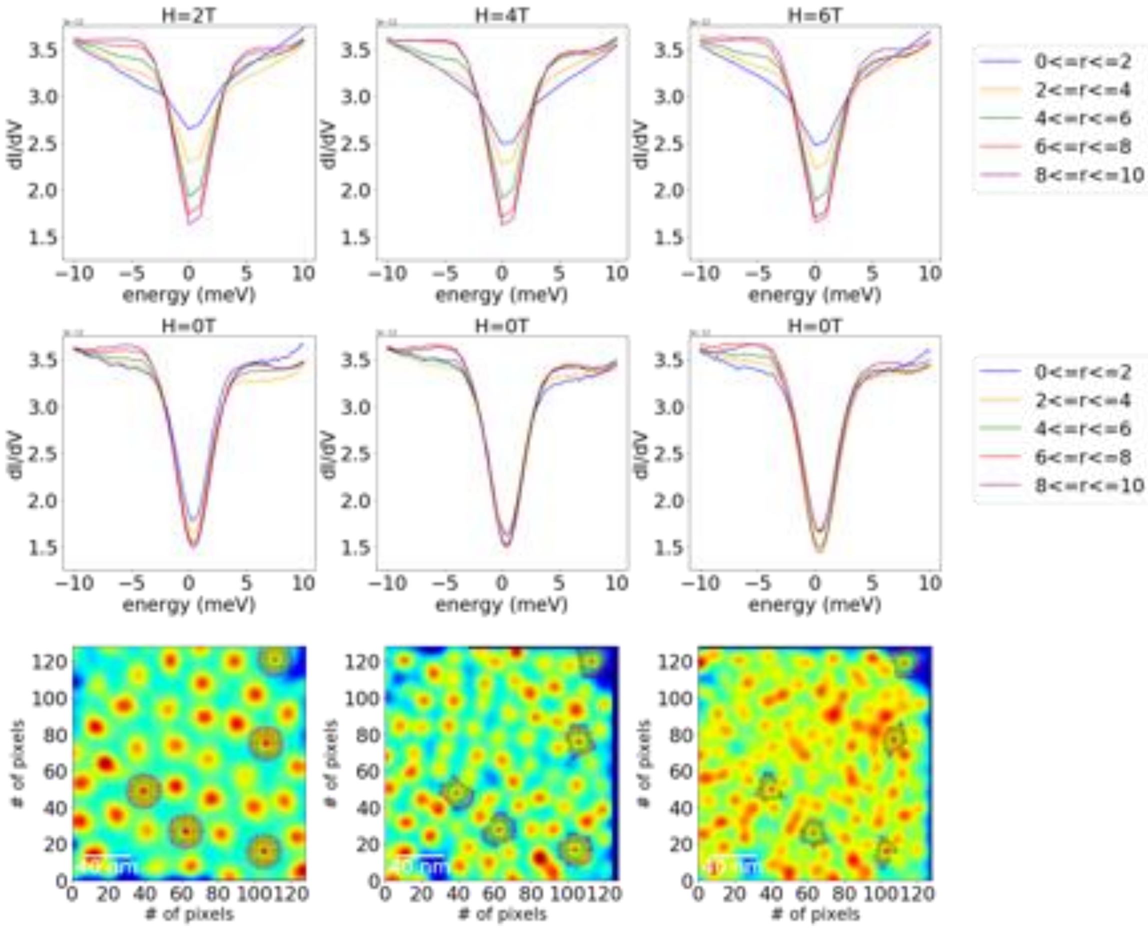

Figure 1. (The first row) The averaged scanning tunneling spectra across vortices are plotted for the pinned plus vortices for H = 2, 4 and 6 T. The distances from the core centers are in the unit of number of pixels (where 1 pixel=1.56 nm). (The second row) For comparison, the averaged spectra for H= 0 T are plotted for the same locations. (The last row) The pinned vortices are highlighted in the vortex images with rings of multiple colors, where each color represents the corresponding distance away from the core centers

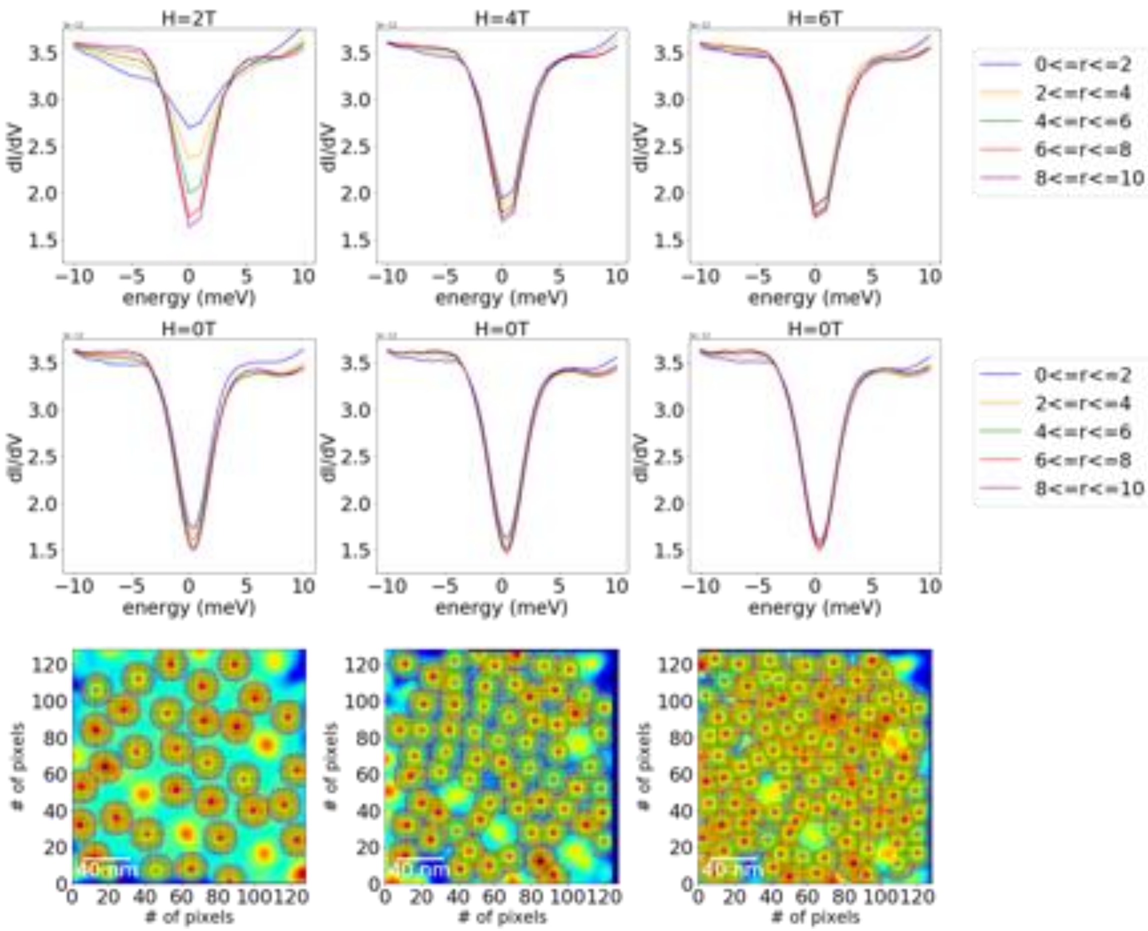

Figure 2. (The first row) The averaged scanning tunneling spectra across vortices are plotted for the depinned plus newly nucleated vortices (complementary to the pinned vortices) for H = 2, 4 and 6 T. The distances from the core centers are in the unit of number of pixels (where 1 pixel=1.56 nm). (The second row) For comparison, the averaged spectra for H= 0 T are plotted for the same locations. (The last row) The depinned plus newly nucleated vortices are highlighted in the vortex images with rings of multiple colors, where each color represents the corresponding distance away from the core centers

References

[1] A.A. Abrikosov, *J. Phys. Chem. Solids* **2**, (1957) 199–208.
[2] B. Rosenstein, D. Li, *Rev. Mod. Phys.* **82**, (2010) 109-168
[3] This effort is based upon work supported by the U.S. Department of Energy (DOE), Office of Science, Basic Energy Sciences (BES), Materials Sciences and Engineering Division and was performed at the Oak Ridge National Laboratory's Center for Nanophase Materials Sciences (CNMS), a U.S. Department of Energy, Office of Science User Facility.

https://doi.org/10.1017/S1431927620023405 Published online by Cambridge University Press