

Magnetic imaging of vortices in superconducting β -Bi2Pd

A. Correa-Orellana,¹ R.F. Luccas,¹ J. Azpeitia,¹ E. Herrera,² A. Fente,² F. Mompean,^{1,3} M. García-Hernández,^{1,3} S. Vieira,^{2,3} I. Guillamón,^{2,3} L. Embon,⁴ Y. Anahory,⁴ and E. Zeldov,⁴
H. Suderow,^{2,3} C. Munuera,^{1,3}

¹*Instituto de Ciencia de Materiales de Madrid, Consejo Superior de Investigaciones Científicas (ICMM-CSIC), Sor Juana Inés de la Cruz 3, 28049 Madrid, Spain*

²*Laboratorio de Bajas Temperaturas, Departamento de Física de la Materia Condensada, Instituto Nicolás Cabrera and Condensed Matter Physics Center (IFIMAC), Universidad Autónoma de Madrid, E-28049 Madrid, Spain.*

³*Unidad Asociada de Bajas Temperaturas y Altos Campos Magnéticos, UAM, CSIC, Cantoblanco, E-28049 Madrid, Spain.*

⁴*Department of Condensed Matter Physics, Weizmann Institute of Science, Rehovot 76100, Israel.*

E-mail: alexandre.correa.orellana@icmm.csic.es

Direct visualization and manipulation of magnetic structures in superconductors with high spatial resolution and sensitivity is at the aim of state-of-the-art research in fundamental and applied physics. The possibility of imaging the evolution of the vortex lattice provides valuable information on microscopic properties such as the symmetry of the superconducting order parameters or the pinning strength.

Here we discuss the **observation of superconducting vortices in β -Bi2Pd** ($T_c=5K[1]$) up to **fields of 600 Oe combining Magnetic Force Microscopy (MFM) and Squid On the Tip Microscopy (SOT)**. The combination of both techniques allows investigating the vortex lattice in two different regimes, not accessible with each microscopy alone: from very low fields (~ 1 Oe) up to higher fields (~ 600 Oe). We use a commercial MFM (Nanomagnetics Ltd.) in a home-made three axis superconducting coil system [2] that cools down to 2K. Experiments at Weizmann are made at 4.2K in a SOT [3]. We discuss in detail the **pinning process of the vortex lattice**, the evolution of the magnetic contrast with the temperature and the applied magnetic field.

We find that the superconducting parameters of β -Bi2Pd are excellent to allow vortex lattice observation in a large field range. Furthermore, in MFM experiments, **interesting new vortex shapes have been observed in the images**, that will be discussed in terms of the magnetic interaction between tip and sample, and the different magnetic domain configuration of the MFM tip.

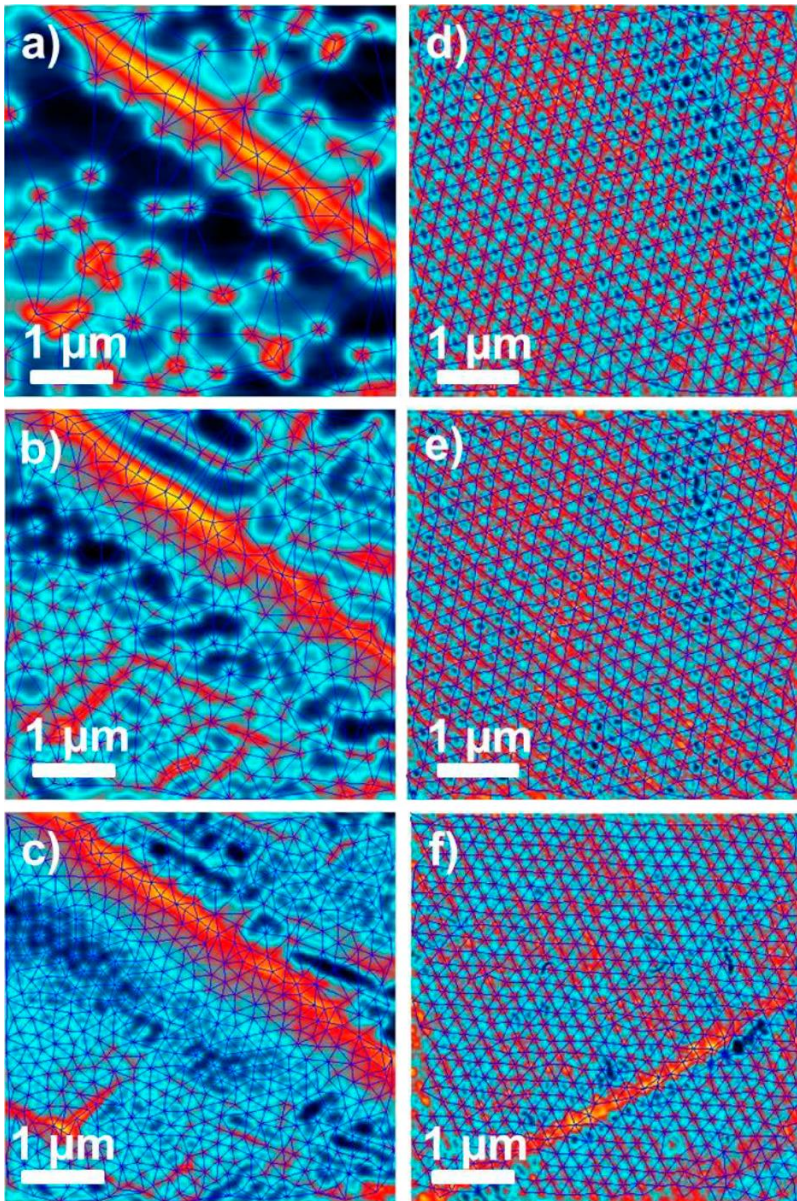


Fig 1. Delaunay triangulated images of the vortex lattice, taken with SOT at low fields, 5 Oe (a), 12.5 Oe (b) and 25 Oe (c) and with MFM at 300 Oe (d), 400 Oe and 500 Oe (f) to study intervortex distance evolution with applied field.

References

1. Y. Imai et al., J. Phys. Soc. Jpn. 8, 113708 (2012).
2. J. A. Galvis et al., Rev. Sci. Instrum. 86, 013706 (2015)
3. D. Vasyukov. et al., Nature Nanotech. 8, 639 (2013).