Hideki Matsuoka
M. Nakano, Y. Kohama, Y. Wang, Y. Kashiwabara, S. Yoshida, K. Matsui, T. Shitaokoshi, T. Ouchi, K. Ishizaka, T. Nojima, M. Kawasaki, Y. Iwasa
The University of Tokyo, 7-3-1 Hongo, Bunkyo-ku, Tokyo 113-8656, Japan

matsuoka@mp.t.u-tokyo.ac.jp

Angle dependent Pauli-paramagnetic limit in ultra-thin $NbSe_2$

Transition metal dichalcogenides (TMDs) are layered materials of abundant variety, providing the emergence of two-dimensional (2D) physical phenomena such as 2D superconductivity in $NbSe_2$. Main fabrication methods of TMDs have been mechanical exfoliation[1] and chemical-vapor deposition[2], but current attractive method for TMDs is Molecular-beam epitaxy (MBE), which leads to design broad platform for solid-state physics research.
Limited in MBE thin film growth, some groups reported the growth of superconducting $NbSe_2$ only on conducting graphene[3, 4, 5]. Here we report layer-by-layer MBE growth of $NbSe_2$ on insulating sapphire substrates, achieving the superconductivity. In the ultra-thin $NbSe_2$ films down to monolayer limit, we achieved superconductivity and confirmed the Ising superconductivity, the coupling of superconductivity and Zeeman-type spin-orbit interaction, through the enhanced Pauli-paramagnetic limit of H_{c2}.
Furthermore, we report the angle dependence of H_{c2} at low temperature in a $NbSe_2$ bilayer film, where the in- and out-of-plane H_{c2} of magnetic Pauli-paramagnetic and orbital limit, respectively. The experimentally observed cusp-like angle dependence of H_{c2}, which is usually regarded as a signature of orbital limit was well explained by the Pauli-limit within the Ginzburg-Landau formalism for 2D superconductors.

References

[1] X. Xi *et al*, *Nat. Phys*., **12** (2016) 139
[2] H. Wang *et al*, *Nat. Commun*., **8** (2017) 394
[3] M. M. Ugeda *et al*, *Nat. Phys*., **12** (2016) 92
[4] Y. Tanaka *et al*, *NPG Asia Materials*, **8** (2016) e321
[5] Y. Xing *et al*, *Nano Lett.*, **17** (2017) 6802

Figures

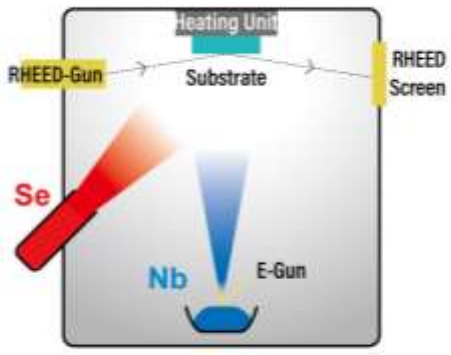

Figure 1: Schematic image of MBE experimental setup.

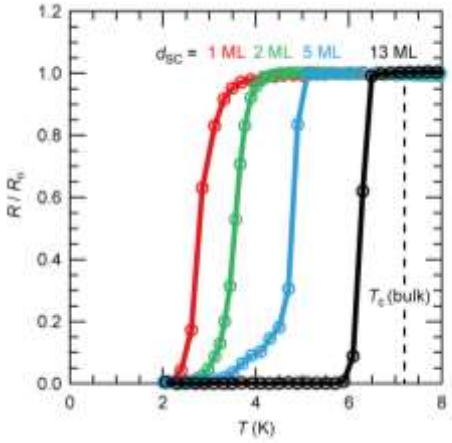

Figure 2: In-plane resistance versus temperature curves of $NbSe_2$ thin films with several thickness.