

Seminar über Quanten-, Atom- und Neutronenphysik (QUANTUM)

July 8, 2021 at 2 p.m.
None

Prof. Dr. Hiroshi Kawarada
School of Fundamental Science and Engineering,
Waseda University, Japan

Diamond Superconductivity for New SQUID and Quantum Application

With heavily boron doping (10^{22} cm^{-3} , $\sim 6\%$) diamond [1,2] exhibits type II superconducting with T_c offset $> 10 \text{ K}$. Its high upper critical field which is estimated to be $H_2(0) = 11.5 \text{ T}$ [3]. These diamonds are produced from gas phase such as CH_4 , CO_2 with the addition of boron during plasma assisted chemical vapor deposition. Boron behaves as acceptor in diamond lattice as it does in Si and changes semiconducting diamond to metallic diamond in the degenerated semiconductor. We have demonstrated diamond superconducting quantum interference device (SQUID) has been demonstrated [4,5]. SQUID is a sensor for extremely small magnetic field used in material science, medical equipment, mineral exploration. In addition, it has also been used in qubit. Especially in Xmon qubit [6] which is a kind of transmon qubit [7] used for quantum computer. It is an important component enabling to tune qubit frequency. General problems with SQUID's materials are temperature change, natural oxidation, and deterioration due to collision. Hence, we have fabricated a highly robust SQUID. Among such demonstrations, the SQUID composed of the trench-type or step-type Josephson junctions (JJs), which were formed in the boundary of discontinuous (111) sectors, operated at 10 K above liquid helium temperature (4.2 K) [5]. Unlike the previous structure included (001) surface ($T_c < 4.2 \text{ K}$) [4], these trench or step-type JJs were composed of only (111) surface ($T_c = 10 \text{ K}$) [1,4]. At present $V_p-p = 47.7 \mu\text{V}$ at 1.6 K is the highest value in diamond SQUIDs.

One of the unique properties of diamond is the close coexistence of superconductivity and two-dimensional Hall gas (2DHG) in a transistor

structure [8]. 2DHG diamond field effect transistors (FETs) exhibit high power microwave operation [9]. All diamond Josephson (Jo) FET that exhibits gate control on the Josephson coupling ultimately leads to the realization of electrically tunable transmon qubits [10] (gatemon).

- [1] A. Kawano HK et al. Phys. Rev. B, 82 (2010) 085318
- [2] M. Watanabe, HK, Phys. Rev. B, 85 (2012) 184516
- [3] T. Kageura, HK et al., Diamond and Related Materials 90 (2018) 181.
- [4] T. Kageura, HK et al., Sci. Rep. 9, (2019) 15214
- [5] A. Morishita, HK et al., Carbon 181, (2021) 379.
- [6] R. Barends, C. Neill et al., Phys. Rev. Lett. 111 (2013) 080502.
- [7] J. Koch, R.J. Schoelkopf et al., Phys. Rev A 76 (2007) 042319.
- [8] S. Imanishi HK et al. IEEE Elec. Dev. Lett. 42 (2021) 204.
- [9] S. Imanishi HK et al. IEEE Elec. Dev. Lett. 40 (2019) 279.
- [10] T. Larsen, C. M. Marcus et al. Phys. Rev. Lett. 115 (2015) 127001.