Permalloy/*p*-type B-doped Diamond Schottky Contacts for Spintronic Applications

M. Kawano, K. Hirama, K. Kumakura, and Y. Taniyasu
NTT Basic Research Laboratories, NTT Corporation
3-1 Morinosato-wakamiya, Atsugi, Kanagawa 243-0198, Japan
makoto.kawano@ntt.com

Diamond is a promising semiconductor material for spintronics because it can transfer spin-polarized currents over long distances due to its weak spin-orbit coupling [1]. A prototype of a semiconductor spin transport device consists of ferromagnetic metal, a tunnel barrier (e.g., a thin Schottky barrier), and semiconductor [2]. Understanding the band alignment at a ferromagnetic metal/highly doped diamond interface is therefore essential in designing the device. In this study, we investigated the electrical properties of permalloy ($Ni_{80}Fe_{20}$)/*p*-type B-doped diamond Schottky barrier diodes (SBDs).

A IIb-type B-doped diamond (001) substrate with B concentration ([B]) of 2.0×10^{18} cm^{-3} was terminated with oxygen atoms by hot acid treatment at 350ºC. On the top of this, twelve SBDs were fabricated by conventional electron-beam deposition and lift-off processes. Each permalloy/Au Schottky contact pad with a diameter of 100−140 μm was surrounded by a Ti/Pt/Au ohmic contact pad.

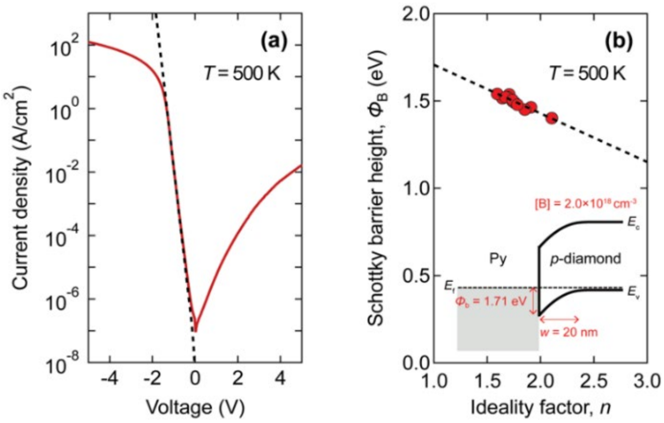

Fig. 1. (a) *J*-*V* characteristics and (b) Φ_B as a function of *n* of permalloy/*p*-type B-doped diamond SBDs. The inset in (b) shows the obtained band alignment at permalloy/*p*-type B-doped diamond contacts.

Figure 1(a) shows the *J*-*V* characteristics of a representative SBD measured at 500 K. This device showed rectification behavior with an on/off ratio of about five orders of magnitude at ±2 V. To extract the Schottky barrier height (Φ_B) and ideality factor (n), forward bias currents (J_F) for all the SBDs were fitted by the equation of thermionic emission (TE) theory, $J_F = A^*T^2\exp(-q\Phi_B/k_BT)\{\exp(qV/nk_BT)-1\}$, as shown by the dashed line of Fig. 1(a). Figure 1(b) shows Φ_B as a function of n. From the intersection of the fitting line of the data and the y axis, Φ_B when TE is dominant (n = 1) was estimated to be 1.71 eV. From *C*-*V* measurements, we also obtained Φ_B of 1.81 eV and depletion layer width (w) of around 20 nm under zero bias. From these results, we obtained the band diagram of the permalloy/*p*-type B-doped diamond contact when [B] = 2.0×10^{18} cm^{-3}, as shown in the inset of Fig. 1(b). This study provides an important design guideline for diamond-based spintronic devices such as spin metal-oxide-semiconductor field-effect transistors [3] and spin quantum buses [4].

[1] J. Park *et al*., Phys. Rev. B **101**, 045202 (2020).
[2] J. D. Albrecht and D. L. Smith, Phys. Rev. B **66**, 113303 (2002).
[3] S. Sugahara and M. Tanaka, Appl. Phys. Lett. **84**, 2308 (2004).
[4] M. W. Doherty *et al*., Phys. Rev. X **6**, 041035 (2016).