Electrical characteristics of n-type diamond contacts with Ti, Ni, NiSi$_2$ and Ni$_3$P electrodes

A. Takemasa$^1$, K. Kakushima$^2$, Y. Kataoka$^2$, Nishiyama$^2$, N. Sugii$^2$, H. Wakabayashi$^2$, K. Tsutsui$^2$, K. Natori$^1$, H. Iwai$^1$

$^1$Frontier Research Center, $^2$Interdisciplinary Graduate School of Science and Engineering, Tokyo Institute of Technology, takemasa.a.aa@m.titech.ac.jp

Introduction

Diamonds draw an attention as future semiconductor materials for power devices. The main issue for the diamonds for the power devices is a high contact resistance of the metal/n-diamond contacts.

Contact resistance

\[
\rho \propto \exp\left(\frac{q\phi_h}{E_{\infty}}\right)
\]

\[
E_{\infty} = \frac{qh}{4\pi} \sqrt{\frac{N_d}{m^*\varepsilon}}.
\]


It is considered that this pinning at metals/n-diamond makes contact resistance high.

Key process about this issue is needed.

Purpose of this research

Propose graphite electrodes process at lower annealing temperature than the prior research.

Prior research 1

Recently graphite electrodes were reported as key process for metal/n-diamond contacts.

A n-diamond was annealed at 1300°C for 10 min. After that, graphite was formed on the n-diamond. And then, Ti was deposited on the graphite with EB.

Annealing temperature of this fabrication process is high of 1300°C, so it needs to be decreased.

Prior research 2 and our method

Graphite formation on diamonds with annealing after ion plantation was reported

First, the ion implantation formed defects in diamonds

Second, annealing at ~800°C turned the area of these defects into graphite.


Defects formation in diamonds and annealing could be key process of graphite formation at lower annealing temperature.

Our method

We aimed that defects formation caused by phosphorus thermal diffusion into diamonds, but diffusion coefficients of impurities for diamonds are not reported yet.

Experimental process

A diamond substrate with phosphorus concentration of 5 x 10$^{19}$ cm$^{-3}$

- Hot H$_2$SO$_4$ and HNO$_3$ (3:1) treatment
- Photoreist coating and photolithography
- Metal deposition with RF sputtering (Ti, Ni, NiSi$_2$, Ni$_3$P)
- Electrode’s patterns formation of Circular Transmission Line Model (CTLM) by lift off process
- Annealing in N$_2$ atmosphere at a variety of temperature

Measure current-voltage characteristics and TEM observation

Results

- TEM observation

Graphite

Ni$_3$P/n-diamond turned into graphite/n-diamond by annealing at 800°C.

- I-V characteristics

The Ni$_3$P/n-diamond annealed at 800°C (graphite/n-diamond) flowed larger current than other contacts under low bias voltage.

Conclusion

The Ni$_3$P/n-diamond decreases annealing temperature of graphite formation on diamonds by 500°C than the prior research 1, which does not need the ion plantation the prior research 2 has.