High Cutoff Frequency Achieved in van der Waals Schottky Diodes via Air Gap Engineering

Gyu Lee
Seongil Im
Van der Waals Materials Research Center, Department of Physics, Yonsei University, Seoul, Republic of Korea

semicon@yonsei.ac.kr, neri96@yonsei.ac.kr

Abstract

Radio-frequency (RF) electronics operating from the MHz to sub-THz range are becoming increasingly important for next-generation technologies such as 5G/6G communications. Among emerging electronic materials, two-dimensional van der Waals materials have attracted significant attention for RF devices due to their unique electronic properties and potential for ultrahigh-frequency operation [1-2].

In this work, we investigate ultrahigh cutoff frequency (f_C) characteristics of a vertical van der Waals Schottky diode based on rhenium diselenide ($ReSe_2$) using air-gap engineering at the Ohmic contact interface. By air-gap engineering, capacitance is significantly modulated, resulting in enhanced high-frequency performance. The fabricated devices exhibit intrinsic cutoff frequencies up to 430 GHz, among the highest reported for thin-film-based RF diodes.

As the air-gap size increases, the intrinsic f_C improves from approximately 30 GHz in conventional structures to 310–430 GHz in air-gap-engineered devices. Also, equivalent circuit analysis shows good agreement with the experimental results and reveals that the air-gap structure effectively modulates the capacitance while maintaining rectifying characteristics. In addition, RF rectifier circuits demonstrate an increase in extrinsic f_C from 2 GHz to 40 GHz. These results suggest strong potential of high-frequency RF electronics based on two-dimensional van der Waals materials [3].

References

[1] Yang, Sung Jin, et al. Nature communications 11 (2020) 1574.
[2] Hong, Sungjae, et al. Science Advances 9 (2023) eadh9770.
[3] Hong, Sungjae, et al. Advanced Functional Materials (2026): e27171.

Figures

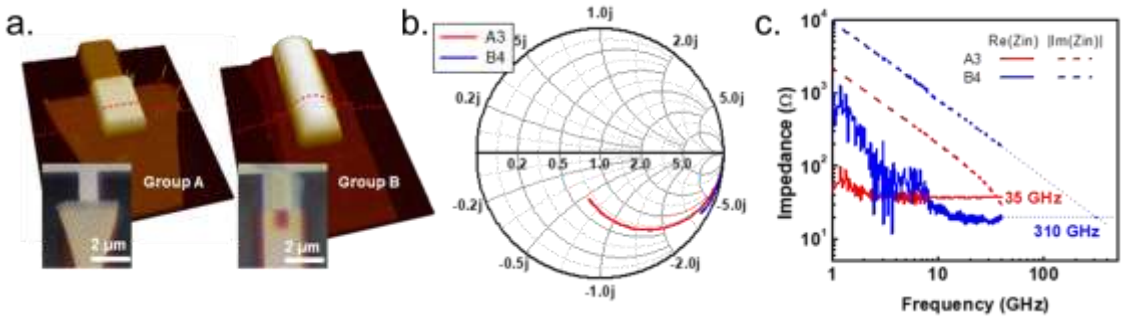

Figure 1: (a) Flat diode and Air-gap diode's AFM Image and back side OM image. (b) Smith chart RF characteristics and (c) S_{11} parameter with Cut off frequency of Flat diode and Air-gap diode.