Characterization and control of boron nitride film deposition by a reactive plasma-assisted coating

K. Urabe[1], T. Matsuda[1], T. Hamano[1], Y. Asamoto[1], M. Noma[2], M. Yamashita[3], S. Hasegawa[4], and K. Eriguchi[1]
[1] Department of Aeronautics and Astronautics, Kyoto University, [2] SHINKO SEIKI CO., LTD., [3] Hyogo Prefectural Institute of Technology, [4] Osaka University
e-mail (speaker): urabe.keiichiro.3x@kyoto-u.ac.jp

Boron nitride (BN) has been attracted interests for the use in surface coating of electronic and mechanical devices exposed to harsh environments (e.g. high-temperature gases and plasmas). An application is inner wall coating of a plasma source in electric propulsion systems. [1] Various plasma-assisted processes to fabricate BN thin films, especially targeting to obtain cubic-BN films consisting of sp^3 bonding network with a high hardness, have been demonstrated. [2,3]

Our research group develops a reactive plasma-assisted coating (RePAC) system to deposit the BN films with wide flexibility in the film properties. [4] In order to independently control the atomic composition (B/N ratio) and the microscopic structure (sp^2/sp^3 ratio), the RePAC has (1) electron-beam evaporation for B-atom supply, (2) magnetically confined vacuum-arc discharge for N_2 excitation/dissociation and Ar ionization, and (3) substrate RF biasing for ion-bombardment energy control as shown in Fig. 1.

Mechanical, optical, and electrical characterization of the BN films were performed to provide the controllable range of BN-film properties in the RePAC. Interactions between the plasma and BN surface during and after the deposition are also investigated by experimental and numerical approaches. [5] Figure 2 shows indentation hardness of the BN films deposited by the RePAC and other systems. The RePAC achieves wide-range control of the BN hardness, i.e. sp^2/sp^3 ratios. Our current conclusion is that an ion flux to the substrate is a critical parameter in the control of BN-film properties.

We have diagnosed the vacuum-arc discharge installed in the RePAC system to understand decision mechanisms of the ion flux during the deposition. Optical diagnostics revealed that the ion flux is varied by the Ar/N_2 ratio due to the difference in ionization probability. [6] Theoretical limitation of maximum ion flux in the RePAC are also investigated. These understandings based on the fundamental plasma physics are expected to achieve further design optimization and advanced control of the BN-film deposition by the RePAC.

This work is supported by "Network Joint Research Center for Materials and Devices" in ISIR, Osaka Univ., JSPS KAKENHI (20H02581), Iketani Science and Technology Foundation, and O.S.G. Foundation. Film characterization is partly performed under supports of Nanotechnology Hub Platform in Kyoto University.

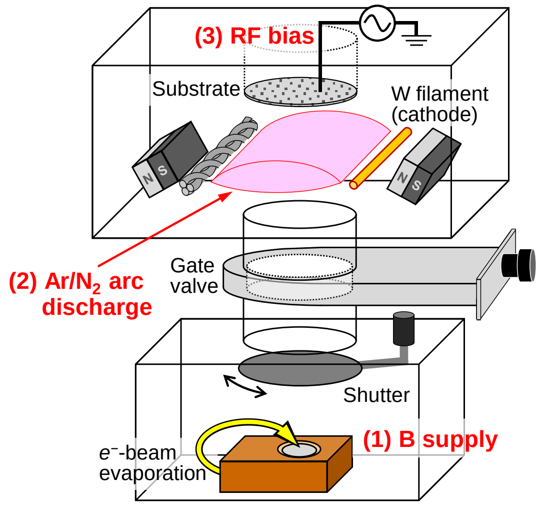

Figure 1. Schematic of BN film deposition by a reactive plasma-assisted coating (RePAC) system.

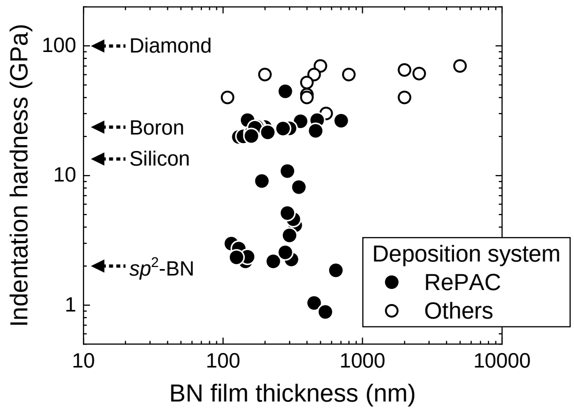

Figure 2. Thickness and indentation hardness of BN films deposited by the RePAC, in comparison with BN films obtained by other deposition systems.

References

[1] T. Burton *et al.*, J. Propul. Power **30**, 690 (2014).
[2] T. Ichiki and T. Yoshida, Appl. Phys. Lett. **64**, 851 (1994).
[3] M. Mieno and T. Yoshida, Jpn. J. Appl. Phys. **29**, L1175 (1990).
[4] M. Noma *et al.*, Jpn. J. Appl. Phys. **53**, 03DB02 (2014).
[5] T. Higuchi *et al.*, Surf. Coat. Technol. **377**, 124854 (2019).
[6] Y. Asamoto *et al.*, Proc. SPP-38/SPSM-33 (2021) p. 112.