機械学習モデルを援用した 300 mm SiC 溶液成長炉の構造最適化

Optimization of furnace structure for 300 mm SiC solution growth by machine learning

名大未来研 [1]、名大院工 [2]、産総研 GaN-OIL[3]

○郁万成 [1]，朱燦 [1]，原田俊太 [1,2]，田川美穂 [1,2]，宇治原徹 [1,2,3]

IMaSS, Nagoya Univ.[1], Graduate School of Engineering, Nagoya Univ.[2], GaN-OIL, AIST[3]

○Wancheng Yu [1], Can Zhu [1], Shunta Harada[1,2], Miho Tagawa[1,2], Toru Ujihara[1,2,3]

E-mail: yuwancheng@unno.material.nagoya-u.ac.jp

Silicon Carbide (SiC) is a leading choice among semiconductors for high-power and high-efficiency devices. Nowadays, top-seed solution growth (TSSG) method has attracted an increasing amount of attention as it can reduce the threading dislocation density in SiC crystal by a high-efficiency dislocation conversion mechanism [1] and realize 4-inch diameter SiC crystal growth [2]. In our group, high-quality 3-inch SiC crystal has been fabricated by TSSG method through the switching flow technique [3] and 6-inch SiC growth is in progress. Therefore, we should consider the design of a larger scale SiC TSSG furnace for the next generation SiC growth.

To design a new furnace, many parameters, such as the diameter and frequency of RF coil, the diameter and power of resistivity heater, the thickness and height of insulation and crucible wall, crucible shape, and the length and height of Si-Cr solvent (as shown in Fig.1) must be simultaneously optimized. Although numerical simulation is a powerful tool to examine the growth process, it takes an average time of 15,000 s to calculate the heat transfer, carbon mass transport and convection in Si-Cr solvent of a 300 mm SiC TSSG growth by software CGSIM. Consequently, machine learning was induced to accelerate the simulation process [4]. A machine learning model was trained by 250 simulations with randomly selected values form 12 variable parameters as mentioned before. As a result, the calculation time for one simulation reduced to 10^{-3} s, making it possible to optimize these numerous parameters required for furnace design.

We used genetic algorithm to find out the optimized parameters with temperature difference at seed surface (Ts), temperature difference at crucible sidewall and bottom (Tc) and number of points with negative supersaturation at seed surface (Ns) set as objective functions. The temperature distribution in Si-Cr solvent of the optimized 300 mm SiC TSSG condition is shown in Fig 2. Under this condition, Ts is 0.4 K while Tc is 1.1 K which are even smaller comparing with current 3-inch TSSG furnace (1 K and 3 K). Therefore, a better growth condition comparing with conventional furnace was found out with powerful tool of machine learning, even for the 300 mm SiC TSSG furnace.

Except for furnace design, machine learning is also powerful in the optimization of growth receipt. The growth of 6-inch SiC crystals in our group is in progress under the guidance of machine learning, high quality crystal with a large thickness can be expected in a short time.

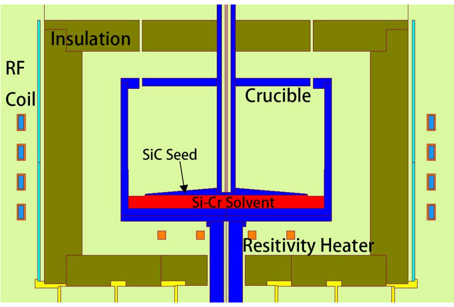

Figure 1 Sketch of 300mm SiC TSSG furnace

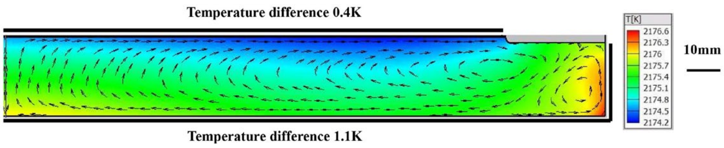

Figure 2 Temperature and flow rate distribution in Si-Cr solvent of 300mm SiC TSSG furnace

[1] Y. Yamamoto, et al., Appl. Phys. Express, 7, 065501 (2014).
[2] K. Kusunoki, et al., Mater. Sci. Forum, 963, 85-88(2019)
[3] T. Endo, et al., Presented in ECSCRM MO.P.SG5 (2018).
[4] Y. Tsunooka, et al., CrystEngComm, 20, 6546-6550 (2018).