Optimization of the thermal field of 8-inch SiC crystal growth by PVT method with "3 separation heater method"

Binjie Xu[1,2*], Xuefeng Han[1,2], Deren Yang[1,2], Xiaodong Pi[1,2].
*lead presenter: xubinjie@zju.edu.cn
1 State Key Laboratory of Silicon Materials and School of Materials Science and Engineering, Zhejiang University, Hangzhou 310027, China
2 Zhejiang Provincial Key Laboratory of Power Semiconductor Materials and Devices, ZJU-Hangzhou Global Scientific and Technological Innovation Center, Hangzhou 311215, China

In this study, we propose a resistance heating method called the "3 separation heater method" with 3 heaters separated by the graphite foam insulations so that 3 important parts (the SiC powder source area, the SiC seed area, and the seed holder) of the growth cell can be heated independently through thermal radiation from each separated heater, as shown in Fig. 1(a). Further, the insulation separators play an important role as a switch of the heat flux. In this work, 6 optimizing parameters (L, d, R_1, R_2, P_2, and P_3) and 2 target parameters (radial temperature difference: RTD and edge temperature gradient: ETG) that significantly affect the radial temperature distribution on the seed crystal surface are investigated, as shown in Fig. 1(b). The numerical studies of the thermal field design for this model are conducted with the help of the software COMSOL Multiphysics, by adjusting the structural parameters and the power parameters of the 3 heaters, a series of different temperature distribution results are obtained.

For the exploration of appropriate parameters, the complex non-linear relationship between optimizing parameters and target parameters is mapped by BP neural network, with an average relative error of less than 0.1% and correlation coefficients of 1 for RTD and ETG. Then, the Pareto frontier solutions are obtained by using NSGA-II and the optimal candidate is selected. The selected candidate solution gives birth to a slightly convex temperature distribution curve on the seed crystal, with an RTD of 10.9 K and an ETG of 1447.7 K/m. Finally, under the thermal field of the optimal parameters, and a SiC single crystal ingot with a slightly convex surface, smooth surface, and low-defect is obtained, as shown in Fig. 2a. And a polished wafer is obtained from this ingot (Fig. 2b).

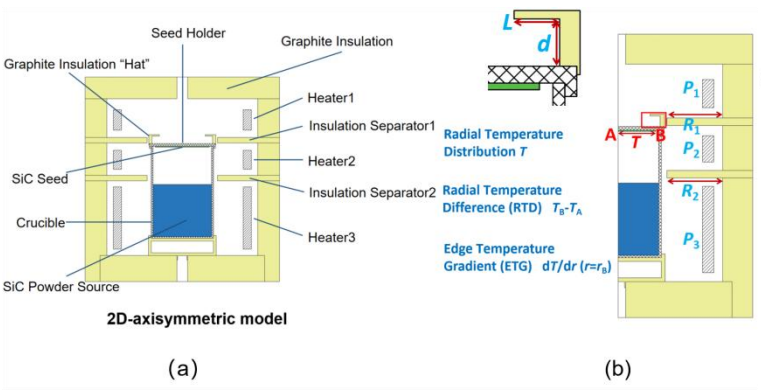

Fig. 1 (a) Configuration of the designed " 3 separation heater method" PVT furnace; (b) Schematic diagram of each parameter that can be adjusted in this system.

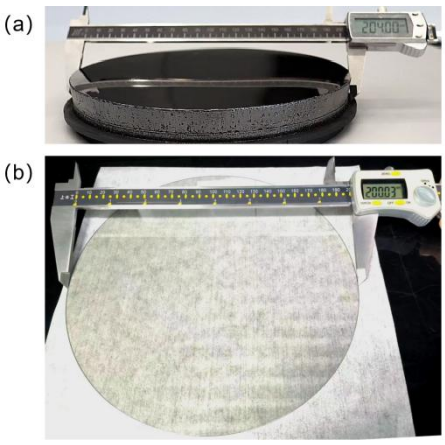

Fig. 2 (a) The SiC single crystal grown under the thermal field of the optimal parameters; (b) The wafer of the single crystal.