The bulk lifetime of Czochralski silicon (CZ-Si) crystal is shortened by the oxygen (O) precipitates, which are enhanced by the carbon (C) contamination. Reduction of C contamination in the grown crystal is required for the production of Si wafer with long carrier lifetimes. Contamination of C in Si crystal mainly originates from carbon monoxide (CO) generation on the graphite component, which is triggered from the preheating stage and reaches the maximum during the melting stage. Therefore, it is essential to control the CO generation and C incorporation from the preheating to the tailing stage. The packed Si chunks experience the collapsing and volume shrinking during the melting process. Axial movement of the crucible is generally applied to adjust the level of Si feedstock. Melting process, as well as the species transport, must be modeled by transient global simulation according to the crucible movement and the Si volume change.

Axial movements of the crucible and the melting of Si feedstock in CZ-Si crystal growth lead to the dynamic thermal and flow field, as well as the affected species transport. To study the effect of crucible movement control on the melting process and C contamination, the fixed and lifting crucible cases were investigated by the transient global simulation with dynamic mesh. The gap width between the gas-guide and the top surface of Si feedstock was kept constant during the crucible lifting process. Heat and impurity transport and accumulation of C in Si feedstock were compared for the fixed and lifting crucible cases. Comparison of C accumulation for the fixed and lifting crucible cases indicate that the lifting crucible case resulted in higher C contamination than the fixed crucible case, as shown in Fig. 1. Furthermore, different gap width cases with the lifting crucible were also investigated to clarify the control strategies of crucible movement on the melting process and C contamination in CZ-Si crystal growth. It is found that optimum gap width for C reduction exists according to Péclet number of gas flow and diffusion distance of CO, as shown in Fig. 2.

Fig. 1 C levels for fixed and lifting crucible cases
Fig. 2 C levels for different gap width cases

Acknowledgements
This work was partly supported by the New Energy and Industrial Technology Development Organization under the Ministry of Economy, Trade and Industry (METI).