

## Kinetics of the condensation of presolar SiC and its trace elements

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Equilibrium thermodynamic condensation calculations and collision theory were used to test whether the kinetics of trace element condensation, in an AGB star atmosphere, agree with the observed trace element abundances in presolar SiC grains (Kashiv et al., 2001, 2002). Condensation calculations of the major elements were done using D.S. Ebel's 'VAPORS' code. The kinetic calculations set lower limits on all the rates below (since nucleation and evaporation were ignored, and the sticking coefficient,  $s$ , was assumed to be unity).

Daulton et al. (2002) found that the presolar SiC polytypes condensed in the temperature range  $T_c \sim 1470$ -2000 K. This corresponds to a pressure range of  $p \sim 10^{-6}$ - $10^{-2}$  bar ( $10^4$  dyne/cm<sup>2</sup>). Calculations were performed for the limiting case (i.e., slowest rates) for a gas of solar composition (except for C) with  $C/O=1.05$  and  $p=10^{-6}$  bar (1 dyne/cm<sup>2</sup>) which give  $T_c=1460$  K for SiC.

The time it takes to grow a 1.5  $\mu\text{m}$  SiC grain (the average grain size in Kashiv et al., 2001, 2002) is  $t=1.9 \times 10^{-2}$  year, or  $t=5.8 \times 10^{-2}$  year if one assumes that  $CO_{(g)}$  and  $SiS_{(g)}$  are inert. Both times are well within the astrophysical upper limit of  $\sim 1$  year calculated by Sharp & Wasserburg (1995).

The trace element abundance patterns of Kashiv et al. (2001, 2002), combined with condensation calculations, indicate that trace elements condense mainly in solid solution in SiC. The relation  $dn_{te}/dn_{si} \sim (s_{te}/s_{si})(n_{te}/n_{si})(m_{si}/m_{te})^{0.5}$  (where  $n_i$ =number density of  $i$ ,  $m_i$ =mass of  $i$ ,  $te$ =trace element, and  $s_{te}=s_{si}=1$ ) was used to calculate whether there was a kinetic limitation on observed abundances in presolar SiC. The results are that there is no kinetic inhibition for condensation in solid solution.

For example: The abundances of the enriched s-process elements in the grains (group 4 in Kashiv et al., 2002) – Y, Zr, Nb, Mo and Ru, range from 1-146 ppma. The calculations show that under ideal conditions, including s-process enrichment, the collision rates for these elements will produce abundances in the grains of up to 530 ppma.

The possibility of condensation of trace element carbide sub-grains was also investigated. Of the four elements that start condensing before SiC – (a) condensation of Ti (as TiC) is not inhibited kinetically, (b) those of Zr (as ZrC), Nb (as Nb<sub>2</sub>C) and Mo (MoC) are kinetically inhibited (note that most of the Nb in the grains is the decay product of <sup>93</sup>Zr).

### References

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## Climate change in Cenozoic inferred from carbon cycle model

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A global carbon cycle model based on GEOCARB-type model (e.g., Berner, 1994) during Cenozoic, in which CO<sub>2</sub> degassing from island arc and back-arc basin are considered, the contribution of the silicate weathering in the HTP (Himalayan and Tibetan Plateau) region is reevaluated, and degassing and regassing parameters are revised.

Our results show that: (1) the contribution of the silicate weathering in the HTP region is relatively small; (2) the warming from late Oligocene to early Miocene is due to the CO<sub>2</sub> degassing from the back-arc basin; (3) the cooling event in middle Miocene is caused by large amount of the organic carbon burial; (4) the atmospheric CO<sub>2</sub> level after middle Miocene is relatively low.

The age discrepancy between the CO<sub>2</sub> peak in our model and the period of MCO (the Miocene Climatic Optimum) could be attributed to the uncertainty of estimate of the BAB production rate (Kaiho and Saito, 1994).

The global mean temperature in our model does not show the cooling trend from middle Miocene and the cooling event at the Eocene/Oligocene boundary which are often argued in association with oceanic environment. However, we could say that the global mean temperature itself is not largely affected in these periods because these events might have occurred mainly in high latitude. This assumption of the small effect of the temperature variations in high latitude on the global mean temperature might be supported by our numerical test of the latitudinal sea surface temperature distribution.

### Reference

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