Core-Shell Morphology and Thermal Stability of Fe/Si Composite Clusters Prepared by Double Cluster Sources

Kenji Sumiyama[1)], Yuichiro Kurokawa[2)], Satoshi Kadowaki[2)], Ryoji Katoh[2)], Naokage Tanaka[2)], Takehiko Hihara[2)] and Yasuhiro Fukunaka[3)]

[1)]School of Science and Engineering, Tokyo Denki University, Saitama 350-0394, Japan
[2)]Department of Materials Science and Engineering, Nagoya Institute of Technology, Nagoya 466-8555, Japan
[3)]Department of Energy Science and Technology, Kyoto University, Kyoto, Japan

Abstract:

Using plasma-gas-condensation cluster deposition systems with two glow discharge sources, we can prepare several hybrid clusters: juxtaposition of two different clusters, formations of core-shell and alloy clusters. As the collision times are expedited, bcc Fe-Si cores are surrounded by amorphous Si-O shells or by diamond-like Si shells depending on the back ground vacuum conditions. Since the surface energy of Si is much lower than that of Fe, Si cluster nuclei cover Fe cluster nuclei and they merge at around their contact interfaces. The bcc Fe-Si alloy cores are chemically heterogeneous, where a bcc ordered phase Fe_3Si and intermetallic compound phases, Fe_5Si_3, FeSi and $FeSi_2$ are not obtained probably because Fe and Si cluster nuclei are effectively extracted their cohesive energy via collisions with inert gas atoms and diffusions of Fe and Si atoms are depressed.

Si shell surfaces are oxidized when they are exposed to ambient atmosphere, but SiO_X thin layers are rather stable and protect further oxidations of Si shells and Fe-Si cores. When such core-shell clusters are annealed up to 700 K, the diffusions of Fe and Si atoms in the core regions leave their vacancies and form voids between Fe-Si cores and Si-shells, leading to multiply-layered clusters.