論文 / 著書情報
Article / Book Information

題目(和文)	
Title(English)	Study on silicon nanoparticle formation by laser ablation in liquid
著者(和文)	P.CHEWCHINDA
Author(English)	Pattarin Chewchinda
出典(和文)	学位:博士（工学）, 学位授与機関:東京工業大学, 報告番号:甲第9992号, 授与年月日:2015年9月25日, 学位の種別:課程博士, 審査員:和田　裕之,小田原　修,吉本　護,北本　仁孝,中村　一隆
Citation(English)	Degree:Doctor (Engineering), Conferring organization: Tokyo Institute of Technology, Report number:甲第9992号, Conferred date:2015/9/25, Degree Type:Course doctor, Examiner:,,,,
学位種別(和文)	博士論文
Category(English)	Doctoral Thesis
種別(和文)	論文要旨
Type(English)	Summary

（博士課程）
Doctoral Program

論 文 要 旨
THESIS SUMMARY

専攻： Department of	物質科学創造　専攻	申請学位（専攻分野）： Academic Degree Requested	博士 Doctor of　（Engineering）
学生氏名： Student's Name	Pattarin CHEWCHINDA	指導教員（主）： Academic Advisor(main)	和田　裕之
		指導教員（副）： Academic Advisor(sub)	小田原　修

要旨（英文 800 語程度）
Thesis Summary（approx.800 English Words ）

Silicon nanoparticles have drawn much attention from researchers owing to their several advantages. For example, the bulk material is abundant and cheap. Besides, their optical emission can be tuned by varying the particle size. Moreover, it was showed that their multiple exciton generation (MEG) occurs at high rate and also high efficiency. In addition, silicon nanoparticles were proved to be non-toxic. According to their outstanding properties, silicon nanoparticles are suitable for broad range of applications including bioimaging, optoelectronic devices, and drug delivery.

Several attempts have been made in order to prepare silicon nanoparticles. Among them, laser ablation in liquid is considered as one of the promising technique. With this process, nanoparticles can be obtained in a single step with no requirement for chemical precursors. As a result, the purity of the product is exceptional. However, the variation in experimental conditions including laser pulse width, liquid media, or irradiation time can dramatically affect the resultant product. Therefore, in order to efficiently control size, structure, and properties of nanoparticles, a study on nanoparticle formation process under various experimental conditions must be thoroughly investigated.

In chapter 2, the effect of laser wavelength on the formation of silicon nanoparticles is studied. The result indicates that shorter laser wavelength (532 nm) can prepare smaller particles with higher concentration than those prepared at longer wavelength (1064 nm). This effect is due to the better absorption of silicon target at shorter wavelength, which provides more energy to detach the target material from its surface. Plasma plume consisted of ablated material is generated and expanded, while inducing nucleation process. According to nucleation and growth theory, high solute concentration favors nuclei formation and reduces nuclei size. As a result, large amount of small nuclei are formed at short laser wavelength. These nuclei grow slowly inside the cavitation bubble and eventually leads to small nanoparticles. With long laser wavelength, the situation is reversed and large nanoparticles are prepared. From this chapter, the formation mechanism of silicon nanoparticles at different laser wavelength can be elaborated.

In chapter 3, the effect of laser energy density on the productivity of silicon nanoparticles is studied. The result shows that particle productivity increases with laser energy density owing to an increase in optical absorption heat at the target. As a consequence, more material can be removed from the target surface. In addition, particle size reduction is observed as laser energy density enhances. This phenomena occurs because higher particle yield leads to large amount of small nuclei, according to nucleation and growth theory. In addition, laser fragmentation possibly occurs at high laser energy density, which also leads to small particles. Those prepared particles are further utilized for the fabrication of quantum dot-sensitized solar cell. The addition of silicon nanoparticles is proved to enhance the device efficiency compared with the one without them. Thus, with optimum laser energy density, the productivity of silicon nanoparticles can be enhanced and the potential application of these particles is verified by an increase in solar cell efficiency.

In chapter 4, the effect of inorganic salt on the stability of silicon nanoparticles is studied. For comparison, the experiment is performed in DI water and severe aggregation is observed along with micron-sized particles. For the particles prepared in NaCl solution, an increase in electrolyte concentration leads to particle instability and large particle size. On the other hand, those prepared in NaBr and NaI solution are stable within the experimental range, and the concentration seems to have no significant effect on particle size. In the absence of ions, only oxygen and water molecules interact with the particle surface. The generation of O^-/OH group delivers some charges to the particle surface but these charges are insufficient for particle stabilization. This effect finally leads to particle aggregation. With the addition of ions, the particle stability can be improved. In the case of Cl^-, owing to its low polarizability, it loosely binds to the particle surface. As a consequence, the charge transfer process is inefficient. As the electrolyte concentration increases, Debye length becomes smaller and the attractive potential can overcome the electrostatic repulsion. Subsequently, the particles start to interact, grow, and agglomerate. In the case of Br^- and I^-, they can efficiently transfer charge to the particle surface. As the electrolyte concentration increases, the repulsive potential is still sufficient to prevent subsequent growth and agglomeration. Therefore, the particles prepared in NaBr and NaI solution remain small and stable. In addition, since oxygen solubility and its polarizability is low, an increase in electrolyte concentration also prevents oxygen adsorption on the particle surface. As a consequence, the oxidation state of silicon decreases since the particle binds to lower electronegativity element, which in this case is halide ions. For the particles prepared in DI water, they interact with only oxygen and water molecules. Thus, the particles bind with only oxygen resulting in the highest binding energy compared with the particles prepared in electrolyte solution. From this chapter, silicon nanoparticles can be stabilized by the addition of suitable inorganic salt with proper concentration while tuning their size simultaneously.