Reply to ‘Comment on “The effect of single-particle charge limits on charge distributions in dusty plasmas”’

This content has been downloaded from IOPscience. Please scroll down to see the full text.
(http://iopscience.iop.org/0022-3727/49/38/388002)
View the table of contents for this issue, or go to the journal homepage for more

Download details:

IP Address: 134.84.192.102
This content was downloaded on 24/10/2016 at 23:20

Please note that terms and conditions apply.

You may also be interested in:

The effect of single-particle charge limits on charge distributions in dusty plasmas
Romain Le Picard and Steven L Girshick

Comment on ’The effect of single-particle charge limits on charge distributions in dusty plasmas’
L C J Heijmans, F M J H van de Wetering and S Nijdam

Sectional modeling of nanoparticle size and charge distributions in dusty plasmas
Pulkit Agarwal and Steven L Girshick

Temperature Rise of Small Silicon Particles During Laser Irradiation
Tadashi Okada and Keiichi Yamamoto

Dynamics of Silicon Particles in DC Silane Plasmas Transported by a Modulated Magnetic Field
Hiroshi Fujiyama, Hiroharu Kawasaki, Sung-Chae Yang et al.

Three-Dimensional Quantum Well Effects in Ultrafine Silicon Particles
Shoji Furukawa and Tatsuro Miyasato

Time of relaxation in dusty plasma model
A V Timofeev
Reply to ‘Comment on “The effect of single-particle charge limits on charge distributions in dusty plasmas”’

Romain Le Picard and Steven L Girshick

Department of Mechanical Engineering, University of Minnesota, Minneapolis, MN 55455, USA

E-mail: slg@umn.edu

Received 3 August 2016
Accepted for publication 10 August 2016
Published 30 August 2016

We thank Heijmans, van de Wetering and Nijdam for their Comment [1] on our article [2]. The Comment, which helps to reconcile seemingly disparate expressions in the literature for charge limits in dusty plasmas, focuses on the importance of electron tunneling from dust particles, and makes the point that tunneling, and consequently charge limits, are likely to be important only for very small (<10 nm-diameter) nanoparticles [1].

We have no disagreement with the Comment, at least for the case of silicon particles. Our article does not claim to propose any new physics for the existence of charge limits, but simply reviews some of the pertinent literature on the subject, and then addresses the question, if charge limits exist, what are the implications for particle charge distributions? [2] And, as we state in the Introduction of our article, ‘we focus on particles with sizes in the nanoscale regime, where stochastic charging is most important and the existence of charge limits is likely to be most consequential’, and the numerical examples we present consider only silicon particles with diameters of 5 or 10 nm [2]. In addition, from the current strong interest in sub-10 nm nanoparticles for practical applications, the existence of charge limits may significantly affect the fractions of these particles that are negatively-charged, neutral, and positively-charged, with important implications for phenomena such as nanoparticle transport (including confinement in the plasma versus deposition on walls) and coagulation.

In both our article and the Comment all numerical examples involve silicon [1, 2]. However, the material of which the particles are composed may affect the range of particle size for which electron tunneling and charge limits are likely to be important. For example, as we note in the article, the electron affinity of bulk SiO₂ (1.0 eV) is approximately four times smaller than that of Si (4.05 eV) [2]. Based on the simple analysis presented in the Comment [1], this implies that, for particles of given size, the potential well from which electrons tunnel will be approximately four times shallower for SiO₂ than for Si. The tunneling probability from equation (6) in the Comment will thus be much larger for SiO₂ than for Si, because of the exponential form of that equation [1]. Simply put, a smaller electron affinity strongly increases the probability of electron tunneling from a particle of given size. Consequently, the particle size for which electron tunneling and charge limits are important for SiO₂ particles may be several times larger—i.e. several tens of nm—than in the case of Si particles.

Finally, we thank the authors of the Comment for pointing out the small error in equation (2) in our article [2]. As they note, we still used the correct form of this equation to derive our equation (3) for the charge limit [1].

Acknowledgment

This work was partially supported by the U.S. National Science Foundation (CHE-124752) and the U.S. Dept. of Energy Office of Fusion Energy Science (DE-SC0001939).

References