J Mater Sci (2012) 47:100–103
DOI 10.1007/s10853-011-6031-5

LETTER

Comments on the article: "Enhancing the photovoltaic effect in the infrared region by germanium quantum dots inserted in the intrinsic region of a silicon p-i-n diode with nanostructure" by H. M. Tawancy (Journal of Materials Science DOI: 10.1007/s10853-011-5728-9)

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Received: 5 September 2011 / Accepted: 4 October 2011 / Published online: 27 October 2011

This comment letter report on a critical reading of an article published in Journal of Materials Science [1]. As stated in the acknowledgements, the silicon-based solar cells described in the article under question were contractually fabricated at the Institut d'Electronique Fondamentale, by using the technological facilities of the University Technology Center (CTU IEF-Minerve) of the University Paris Sud, France. The fabrication of prototype devices on request of external research institutions is part of the current assignments of this Center. The corresponding invoice was received from the author of Ref [1] in April, 2009. Using our previous know-how in epitaxial growth, a number of structures have been fabricated, consisting of a stack of Ge quantum dots, a Si layer and a highly doped Si layer, as described in Fig. 1 of ref. [1]. The solar cell devices based on these structures were completed with back and front contacts, as seen in Fig. 8 of Ref [1]. In addition, structural and optical routine characterizations were done in order to calibrate the areal quantum dot density and check the quality of the grown material, consisting in scanning electron microscopy imaging, and photoluminescence (PL) measurements made at room temperature. In collaboration with Prof. O. Aboelfotoh, we also checked the current voltage characteristics of the whole devices in the dark and under AM 1.5 standard illumination by using the dedicated facility of the Laboratoire de Génie Electrique de Paris, France. These devices and attached data were finally provided in 2010 to the King Fahd University of Petroleum & Minerals, Saudi Arabia. At this step, Dr H.M. Tawancy was of course free to act in his own way, like publishing results obtained from these devices. The corresponding article, entitled "Enhancing the photovoltaic effect in the infrared region by germanium

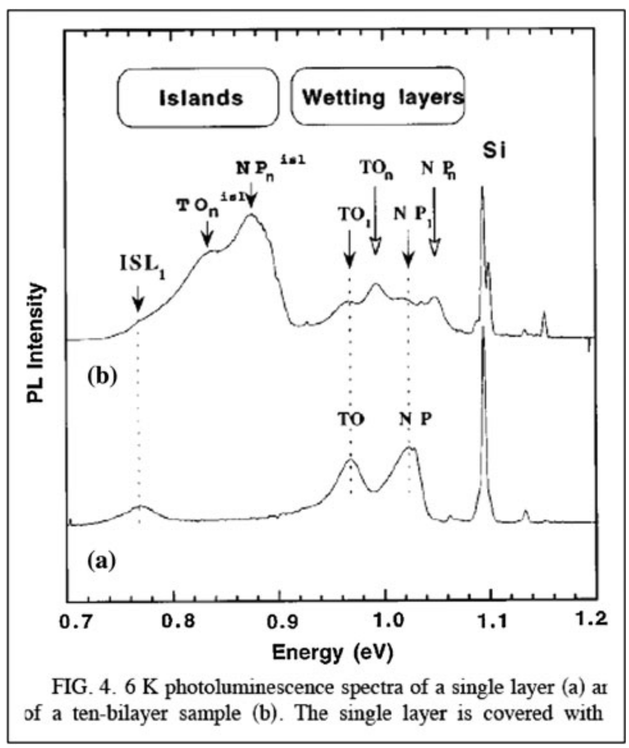

Fig. 1 Reproduction of Fig. 4 published in Ref. [3]

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quantum dots inserted in the intrinsic region of a silicon p-i-n diode with nanostructure" and published in this Journal, is under question in this Letter.

The most obvious issue concerning this article stems from an improper use of data previously published in Ref. [2–5]. These data are illustrated by Figs. 1, 2, and 3 which are copies of the Fig. 4 of Ref. [3], and of Figs. 1 and 3 published in Ref. [4]. As the reader can note, Fig. 3, Fig. 6-a, b of Ref. [1] are "copy-paste assemblies" made from these three figures. The PL signal in Fig. 3 of Ref. [1] is the curve (a) shown in Fig. 4 of Ref. [3] (Fig. 1). Two sets of three PL spectra have been copied from Ref. [4] to fabricated the Fig. 6 a, b of Ref. [1]. As it can be seen from Figs. 2 and 3, the curves are strictly identical, including noise signal and spacing between them, but the temperatures and thicknesses indicated on the original figures have been altered. These PL spectra recorded at low temperature were significant of specific behaviors thoroughly discussed in Ref. [2, 3] and do not of course relate to the structures described in Ref. [1]. The 3D AFM image in Fig. 5b of Ref. [1] has also been tinkered; the original was published in Ref. [2] as Fig. 5a (see its reproduction in Fig. 4). At last, Fig. 7 of Ref. [1] was copied from a conference paper presented in 2006 [5], i.e., far before the delivery of the devices which are supposed to be studied in this article. These transmission electron microscopy images were taken at the Condensed Matter Science Division, Oak Ridge National Lab, USA, from a stack of Ge QDs grown at IEF, as part of a collaborative effort between Prof. O. Aboelfotoh and Dr D. Bouchier and his team. Figure 1, Fig. 2 in which the diffracted lines are not correctly indexed, Figs. 3a, 4, and Fig. 8 in Ref. [1] were made from matter which effectively accompanied the

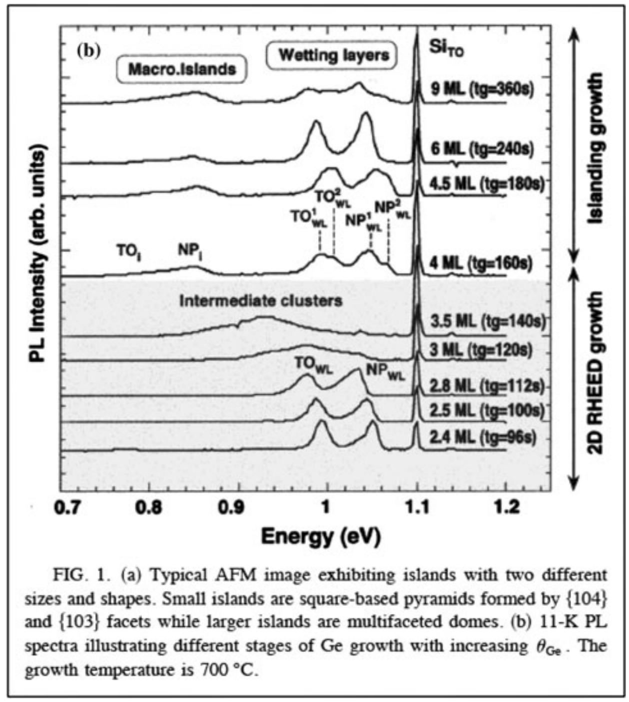

Fig. 2 Reproduction of Fig. 1 published in Ref. [4]

provided devices, although not explicitly intended for being published.

The second issue relates to the current–voltage characteristics shown in Figs. 9 and 10 of Ref. [1]. A close examination of the dark current–voltage characteristics in Fig. 9 of the article clearly shows that these characteristics are similar in shape (but not in amplitude) to those in our report in the voltage range of +1 to 1 V. A noticeable

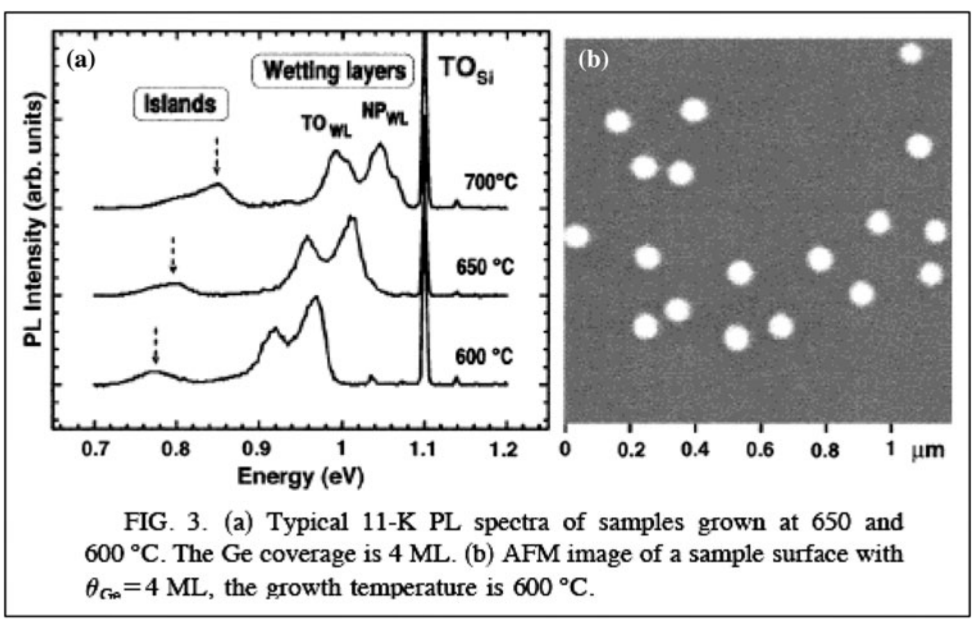

Fig. 3 Reproduction of Fig. 3 published in Ref. [4]

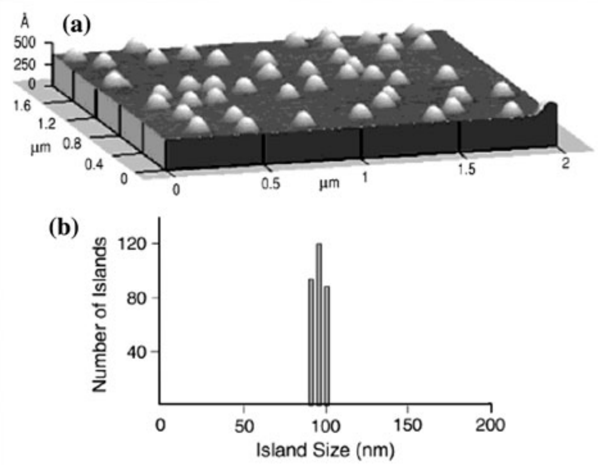

FIG. 5. A three-dimensional AFM image of a sample taken just after the 2D-3D transition at 550 °C (t_g=240 s). The precursor clusters have completely disappeared. The surface exhibits islands which are highly uniform both in *size* and *height*, in contrast to the inhomogeneous surface observed at 700 °C (Fig. 3). (b) Island size distribution.

Fig. 4 Reproduction of Fig. 5 published in Ref. [2]

positive current is, however, visible in reverse bias, what is more difficult to understand. Is the current plotted in absolute value? In any case, a current signal visible at the mA/cm^2 scale cannot lie in the picoampere range, as it is stated in the article. This statement is also in complete contradiction with our own measurements which, as seen in Fig. 5a, indicated a much higher reverse current density at −1 V. The plot in Fig. 5b of the dark current–voltage (I–V) characteristics on a logarithmic current scale clearly shows that the forward (I–V) characteristics exhibit an ideality factor close to 2, indicating that recombination current dominates. These recombination effects are known to result in both low open circuit voltage and fill factor [6]. Extensive measurements on the p-i-n type solar cell shown in Fig. 1 of the article under air mass 1.5 (AM 1.5, 100 mW/cm^2) illumination reveal an low open circuit voltage $V_{oc} = 0.12$ V, a short circuit current $J_{sc} = 2.4$ mA/cm^2 and a low fill factor FF = 0.25, to be compared to $V_{oc} = 0.6$ V, $J_{sc} = 24$ mA/cm^2 and FF = 0.8 reported in Ref. [1], respectively.

It is worth noting that these data were included in the report accompanying the devices provided to the author of Ref. [1]. He could argue that his own measurements made on the same devices have revealed the outstanding behavior he has reported. Admitting that we had underestimated the current density J_{sc} by a factor of 10 and the voltage V_{oc} by a factor of 5, inconsistencies between some assertions reported in Ref. [1] must nevertheless be discussed. Notably, how can be explained the absence of any photovoltaic response from the pure Si cell, when the Ge/Si cell exhibits such a high conversion efficiency? As the incorporation of multi layers of Ge/Si quantum dots in the intrinsic region of Si-based p-i-n solar cell is expected to improve the cell quantum efficiency in the infrared region, this assertion is all the less realistic because the infrared region around 1.5 μm represents only 10% of the standard AM 1.5 illumination in terms of energy. Moreover, based on spectral measurements reported in Ref. [7], a p-i-n cell with only 15 layers of Ge/Si quantum dots in the intrinsic region should have a quantum efficiency in the infrared region of much less than 1%. It should be also pointed out that the “effective” band gap of the multi layer structure of Ge/Si quantum dots is lower than that of pure Si. A p-i-n solar cell with an intrinsic region comprising of 1-μm-thick layer of Si with very high crystal quality can have an open circuit voltage of 0.6 V under AM 1.5 illumination [8]. For a quantum dot solar cell, an open circuit voltage of 0.4–0.5 V is estimated, a value that exceeds that of a p-i-n solar cell formed from only Ge, by slightly more than the shift in the absorption edge [9]. It is therefore not possible for the p-i-n cell shown in Fig. 1 of the paper to have an open circuit voltage equal to that of a comparable p-i-n cell made only from the wider band gap Si, as shown in Fig. 10

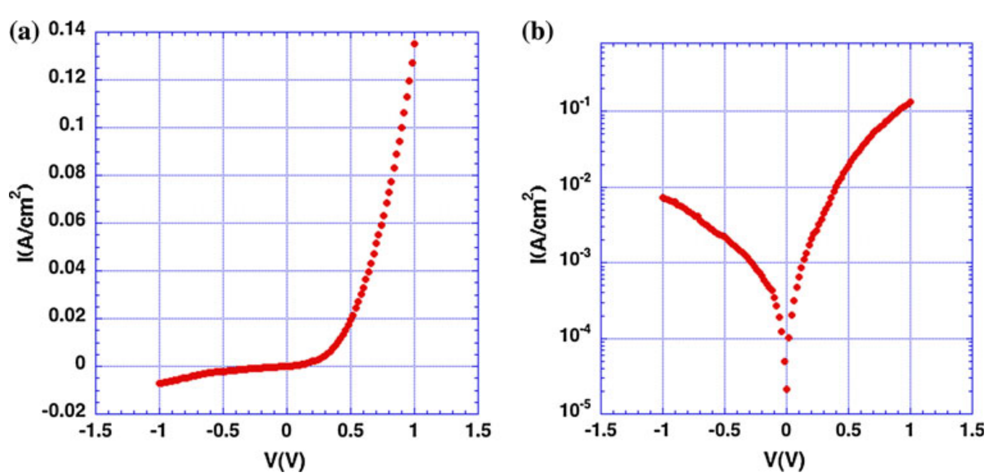

Fig. 5 Linear (**a**) and logarithmic (**b**) plots of the current density measured in the dark on a 2 mm^2 p-i-n type solar cell shown in Fig. 1 of the article [1]

of Ref. [1]. In addition, the increase in short circuit current due the incorporation of only 15 layers of Ge/Si quantum dots into the intrinsic region is not sufficient to compensate the decrease in open circuit voltage, hence the unrealistic value of the overall quantum efficiency reported in the article.

In conclusion, we have evidenced in this Letter that previously published results has been shameless plagiarised, and, in addition, used in an improper way as the corresponding data does not apply to the structures which are supposed to be studied in Ref. [1]. In addition, we argue that the PV characteristics reported in this article are the least deeply inconsistent with previous findings and even with semiconductor Physics, and, presumably, have been completely fabricated. We think that this paper doesn't meet the ethical rules unanimously followed in scientific publication and gives an erroneous report on the actual effect of Ge QDs in Si-based PV cells. This is the reason why we wished to publish this Letter, with the aim that us and our Research Institutions be not believed as being involved in a scientific fraud.

Acknowledgements The authors wish to thank the Editor-in-chief of the Journal of Materials Science for giving them the opportunity to express their point of view.

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