Research Center for Photovoltaics

Low cost atmospheric plasma synthesized and surface engineered Si-/C-nanocrystals for next generation PV

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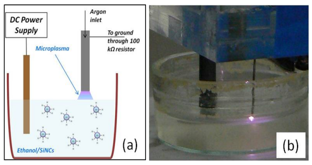
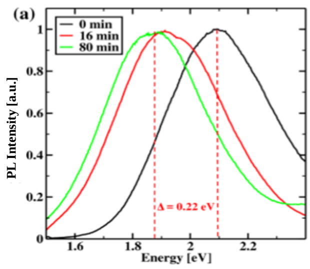
Motivation

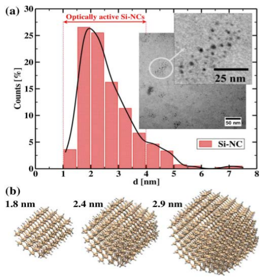
- Silicon (Si) and carbon (C) abundant and non toxic material.
- Significantly enhanced efficiency of solar cells in Si and C based quantum nanocrystals.
- Surface @ quantum confinement (< 10 nm) (V_{OC}).
- Carrier multiplication and hot carriers (J_{SC}).
- Low cost atmospheric DC microplasma based synthesis and surface engineering Si- and C-based quantum nanocrystals in liquid solutions.



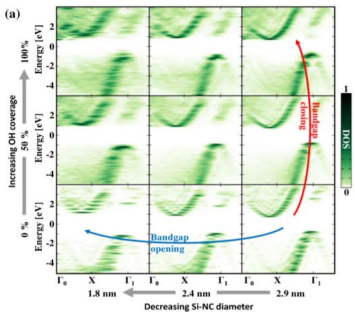
V. Švrček et al., *Appl. Phys. Lett. 97, 161502 (2010).*

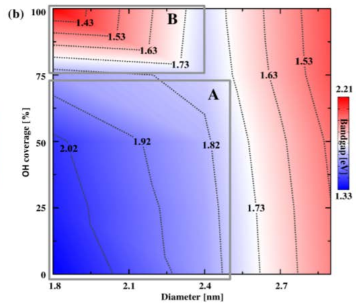
Microplasmas induced surface engineering of silicon nanocrystals (Si NCs)





- Photoluminescence (PL) maxima is red shifted Si NCs (<3 nm) after plasma induced surface engineering.
- As prepared Si NCs are passivated by Si-H_x .
- Plasma generates e- and radicals that remove the H.
- Si-H is replaced by Si-O-Si, Si-$H_2(O_2)$ and Si-$H(O_x)$.
- Broad OH absorption peak (3000 cm^{-1}) in FTIR is observed.

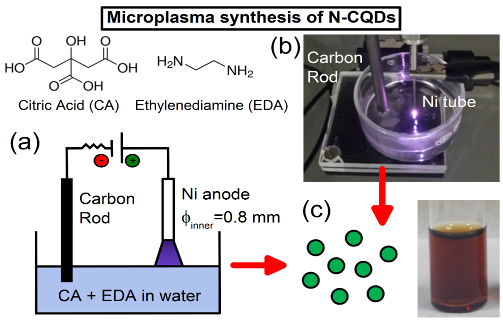


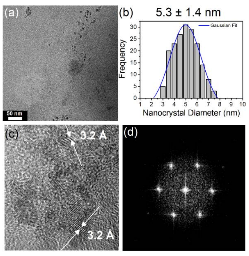


- Relative PL shifts obtained from theory, experiment for different OH coverage and size.
- Dependence on the Si NC size and OH coverage.
- The two regions A and B favorable for E_g engineering.

M. Bürkle et al., *Adv. Funct. Mater. 27*, 1701898 (2017).

Carbon nanocrystals (C NCs) and C NCs thin film solar cells

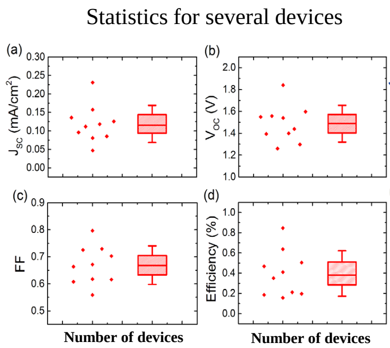


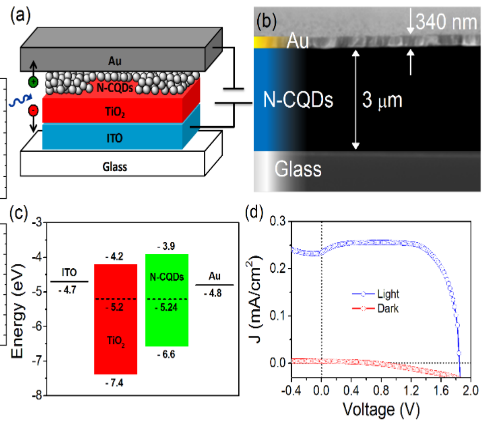


crystalline phase
lattice fringes spacing for graphite

- Plasma anode transfers positive charges into solution and enhances condensation reaction between OH containing C precursor.
- The C molecules can self-assemble and condensation reactions occur to form an extended C framework.

Statistics for several devices





- C NCs were sprayed on ITO/glass @ room temperature.
- Quantum confinement (QC) size effect (PL at 620 nm, E_g= 2 eV).
- QC contributes to a large e–h quasi Fermi level splitting.
- Solar cells with large V_{OC} >1.8 eV.

D. Carolan et al., *Sustainable Energy Fuels, 1, 1611–1619 (2017).*

Conclusions

- DC microplasma surface engineering of Si NCs and synthesis of C NCs.
- Decreased E_g for OH-terminated Si NCs whereby the calculations show two regions favorable for E_g engineering.
- Synthesis of C NCs with bright photoluminescence in wide spectral region 300-800 nm at room temperature.
- Solar cells with large V_{OC} >1.8 eV (efficiency 0.8% amongst the highest for group IV and C materials).