Industry Day Theme # Emerging Nano and Advanced Materials

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Boosting silicon solar cell efficiency through upconversion-assisted enhanced absorption in near infrared

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Abstract

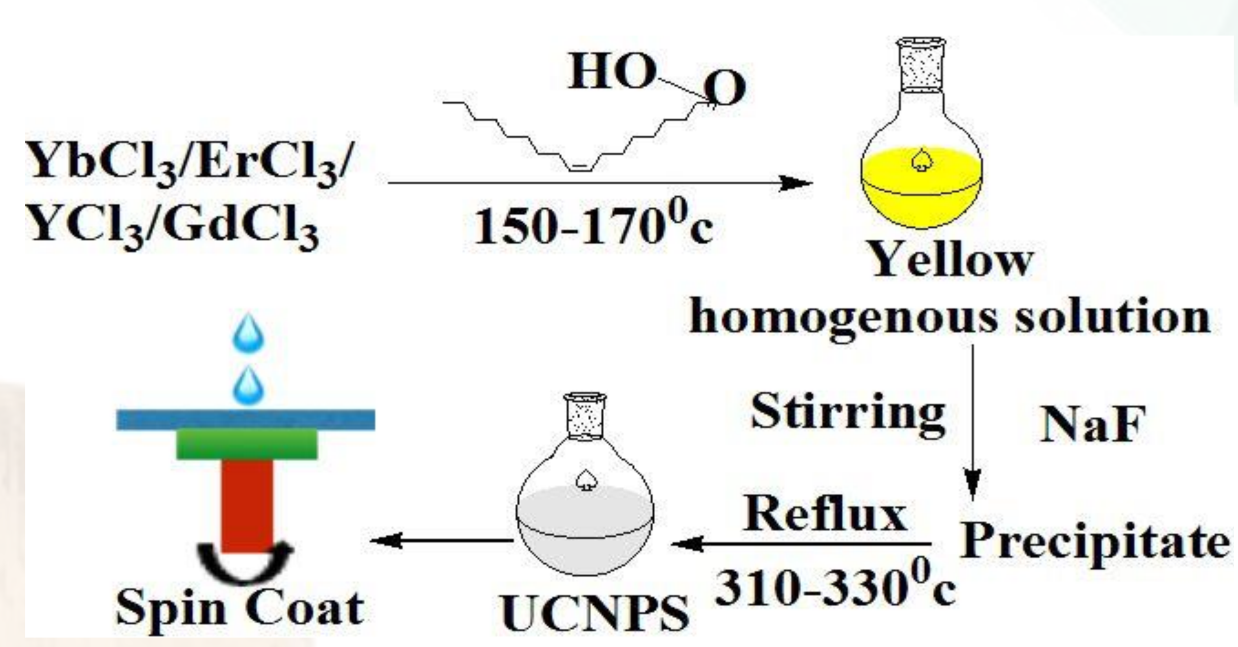
An upconversion based absorber (NaYF$_4$: Yb(18%), Er(2%), Gd(15%)) has been developed to work at 980 nm for increasing the sensitivity of a commercial solar cell by harvesting additional photons in near infrared in the form of an add-on postproduction film.

Introduction

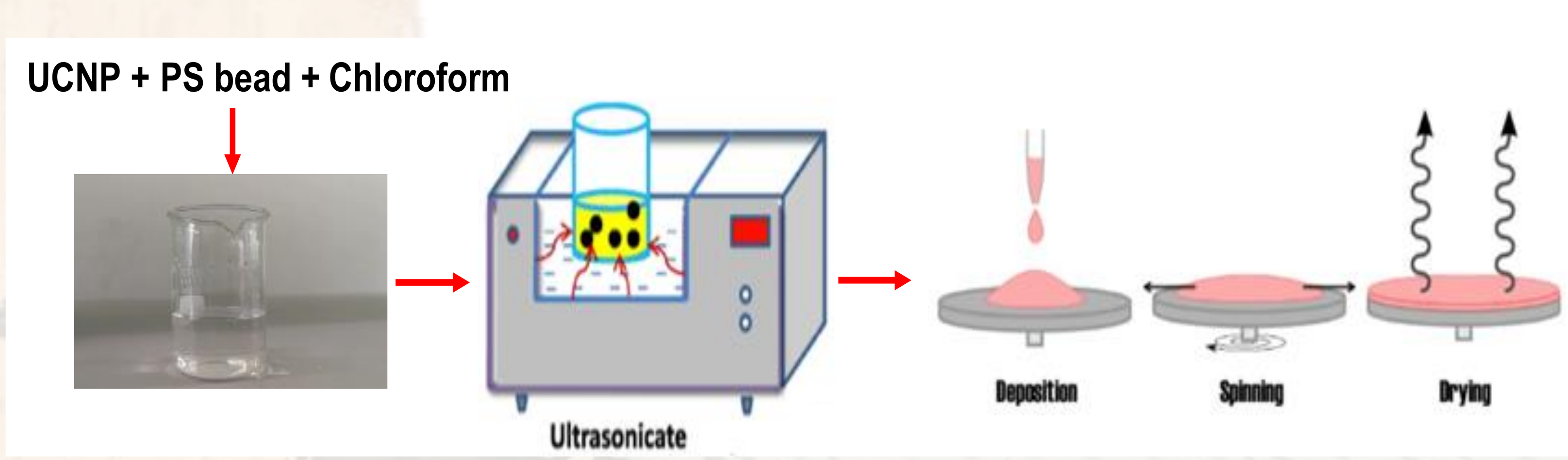
Power conversion efficiencies in silicon are impacted by bulk defects, contacts, solar spectrum mismatch, etc. Specifically, the absorption coefficient in silicon starts declining below 10^3 cm^{-1} above around 800 nm, declining to one-tenth that value near 1000 nm. Such material limitations also manifest themselves in a peak in the responsivity of silicon-based solar cells[1]. Upconversion is employed here as a possible step toward enhancing the absorption. As a spin-off benefit, silicon detectors can indirectly detect infrared photons [2].

Materials and Methods

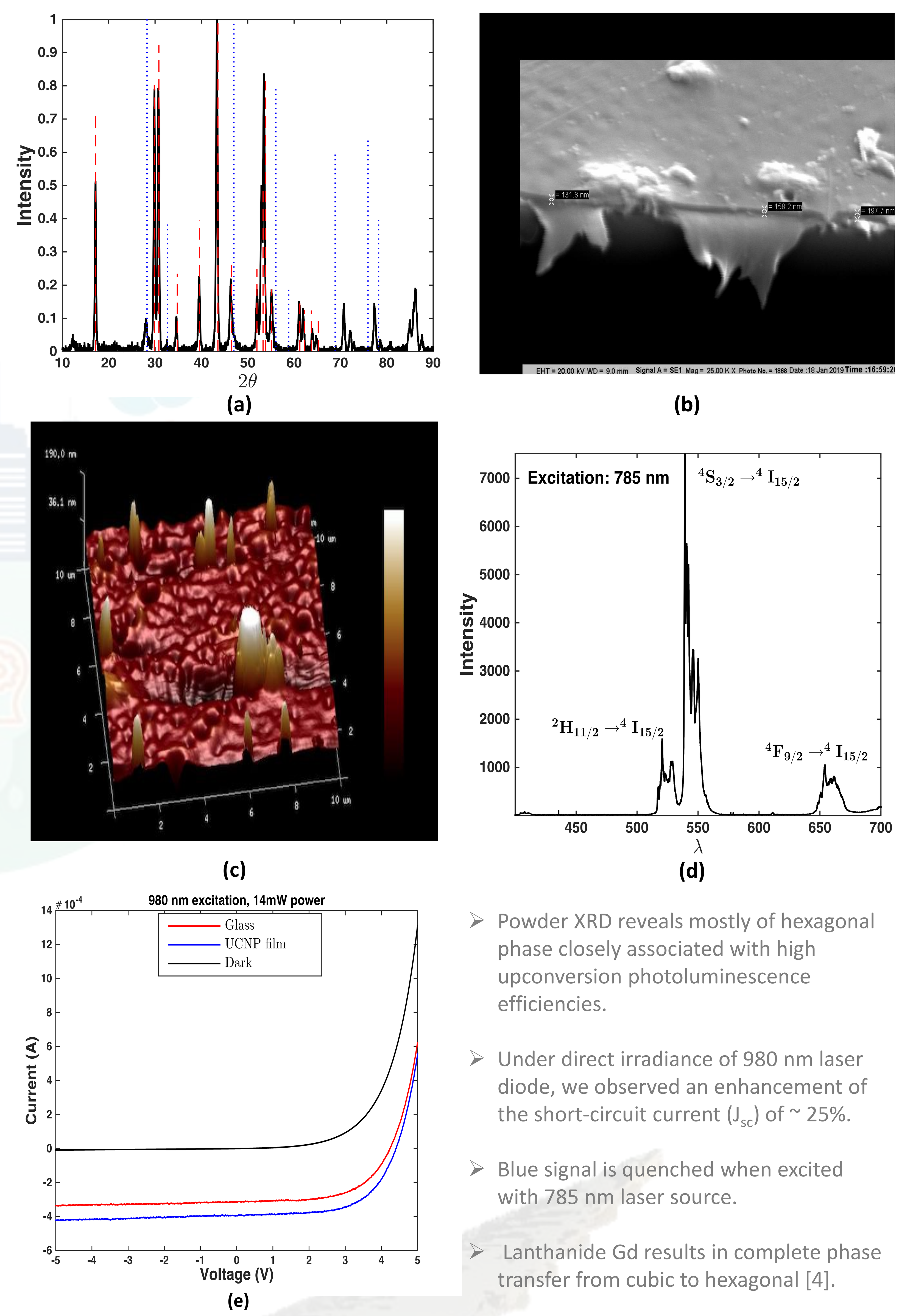
Process steps for material synthesis [3],



Film formation process,



Results



- Powder XRD reveals mostly of hexagonal phase closely associated with high upconversion photoluminescence efficiencies.
- Under direct irradiance of 980 nm laser diode, we observed an enhancement of the short-circuit current (J_{sc}) of ~ 25%.
- Blue signal is quenched when excited with 785 nm laser source.
- Lanthanide Gd results in complete phase transfer from cubic to hexagonal [4].

Provisional patent issued.

Figure 1: (a) Powder XRD of the upconversion absorber, (NaYF$_4$: Yb(18%), Er(2%), Gd(15%)). Red (blue) lines indicate hexagonal (cubic) phase of nanoparticles.
(b) Scanning electron microscopy (SEM) scans of the deposited reveal a thickness of ~158±33 nm.
(c) Atomic force microscopy (AFM) scans reveal that the roughness of the films is approximately 31 nm.
(d) Photoluminescence measurement of UCNP film under direct irradiance of 785 nm laser source.
(e) Current (A) versus voltage (V) curve for a commercial solar cell with UCNP film on top of it.

Conclusions

1. Low temperature synthesis pathway for upconversion nanoparticles which is suitable under normal environmental conditions.
2. Optimizing the film thickness for the fixed dopant concentration is desired for maximum light generation from the sample for given excitation.
3. Synthesizing an efficient material with high quantum efficiency is still a challenge at present.

Industrial Significance

Once fully developed, using upconversion ad on films in solar cells utilizing near IR will extend the detectability window of ordinary Si-based detectors, and efficiency of Si-based solar cells. For detectors, current ongoing work on other wavelengths (~ 1300-1550 nm) can reduce its cost to \$7-\$8/wafer compared to \$3000/wafer at present for InGaAs. Integrating solar cells/detectors with this layer will enhance their operating range thus making it a more industry oriented product suitable for applications such as solar energy harvesting, remote sensing, surveillance, hyperspectral imaging etc.

Technology Readiness Level: TRL 3-4

References

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[2] M Haase et al., Angewandte Chemie **50**, 5808 (2011).
[3] Z. Li et al., Nanotechnology **19**, 345606 (2008).
[4] F. Wang et al., Nature **463**, 1061 (2010).

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