

Flexible, Scalable, Transparent Conductors for Solar Photovoltaics: Laser Processed Silver Nanonetworks

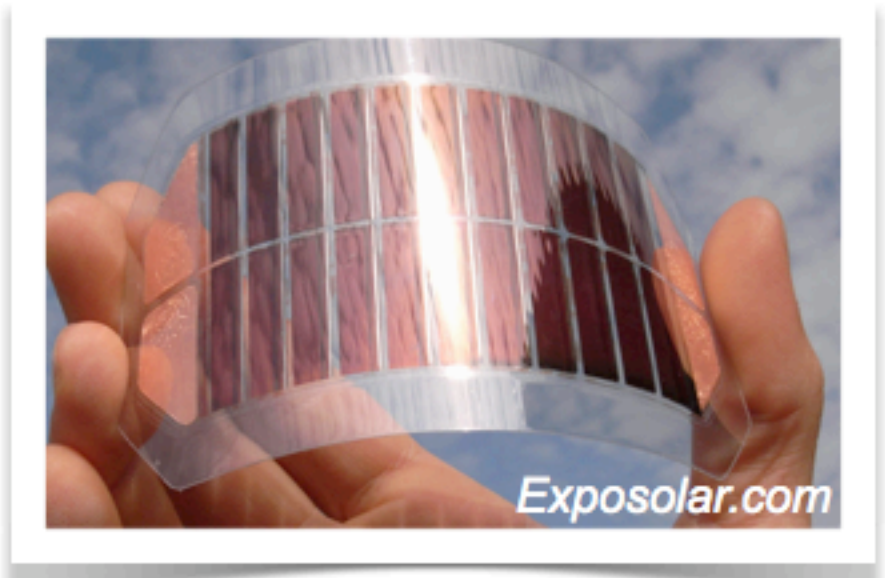
Joshua A. Spechler

Nanotechnology for clean energy IGERT: Department of Mechanical and Aerospace Engineering Princeton University



Motivation:

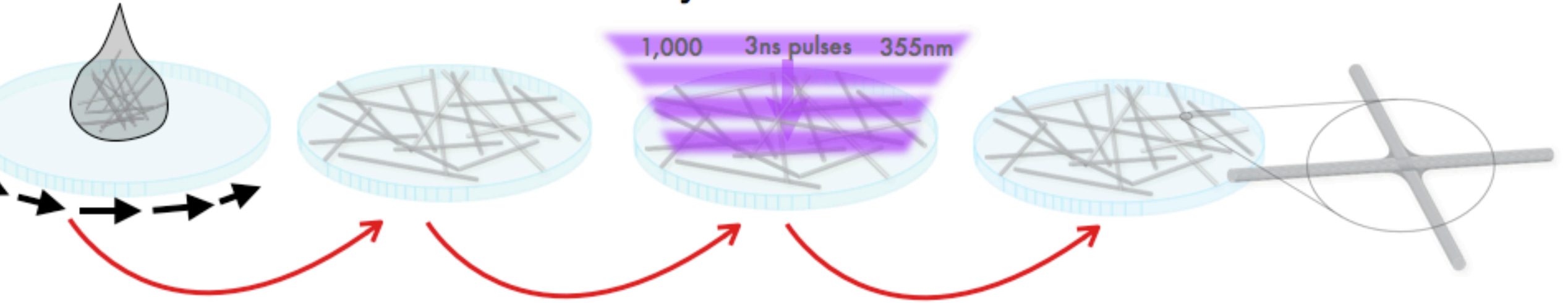
- Transparent conductors in solar cells are traditionally metal oxides which are made in an energy intensive manner, with rare earth materials.
- Flexible photovoltaic devices are desired but current metal oxide TCs degrade when mechanically stressed
- Silver nanowire electrodes are a promising, flexible alternative but they suffer from high sheet resistance from narrow nanowire-to-nanowire junctions



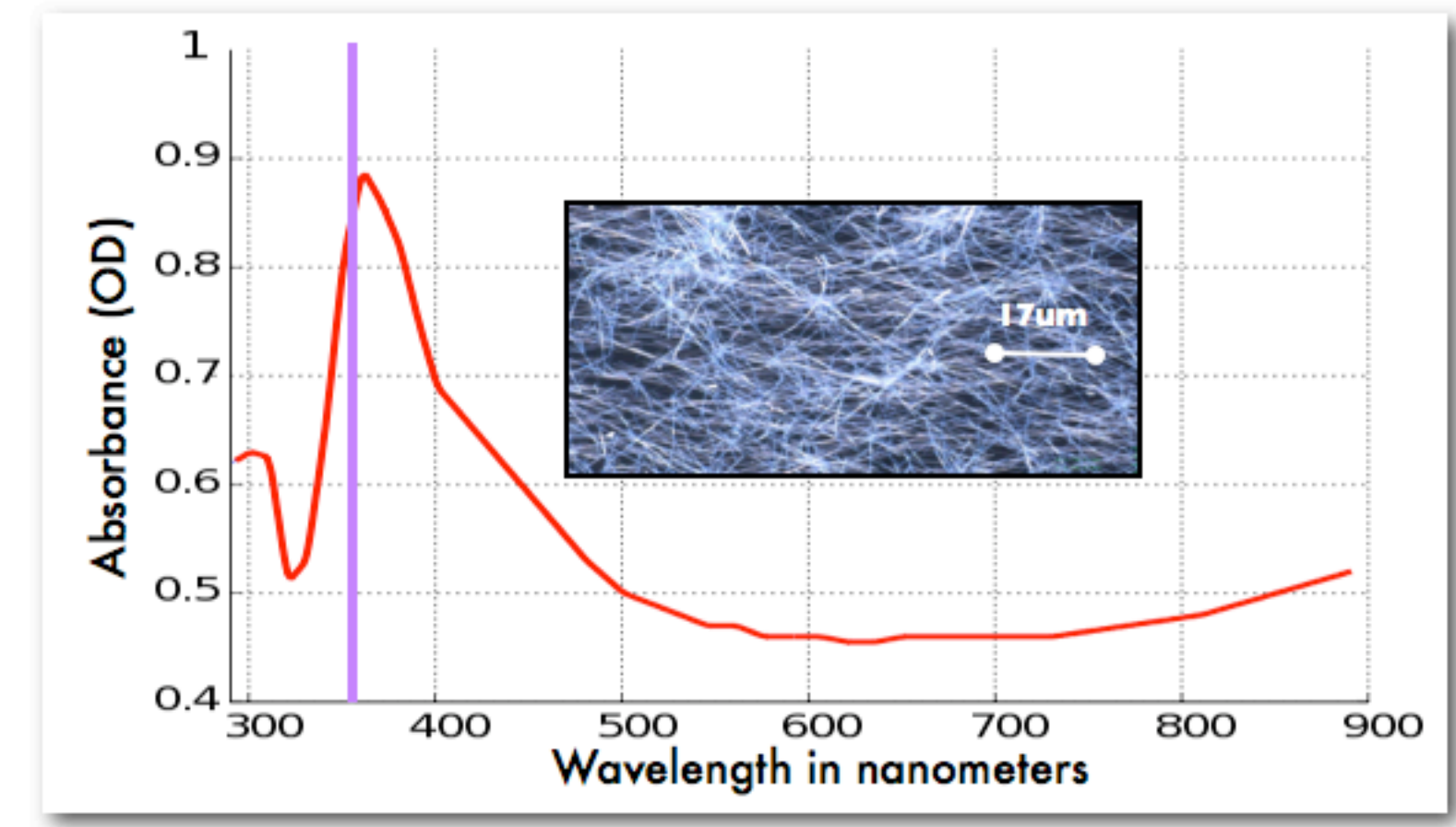
A direct-write pulsed laser processing technique can produce lower resistance and higher transparency silver nanowire networks via welding of nanowire-to-nanowire junctions

Process:

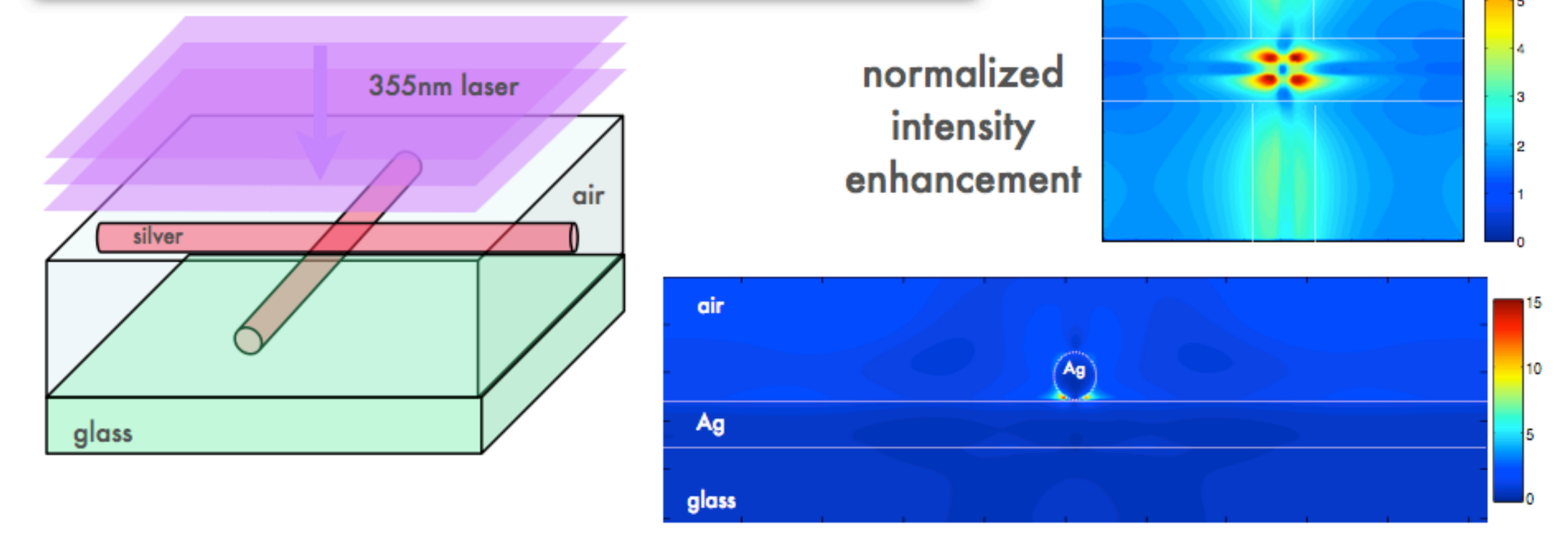
Silver nanowires in suspension are synthesized in a solvothermal manner, they can be deposited onto a substrate in a variety of 'in atmosphere' techniques (spin coating shown) the laser processing then welds the junctions in the nanowire network resulting in a more conductive layer.



Physical Mechanism/ FDTD Simulation:

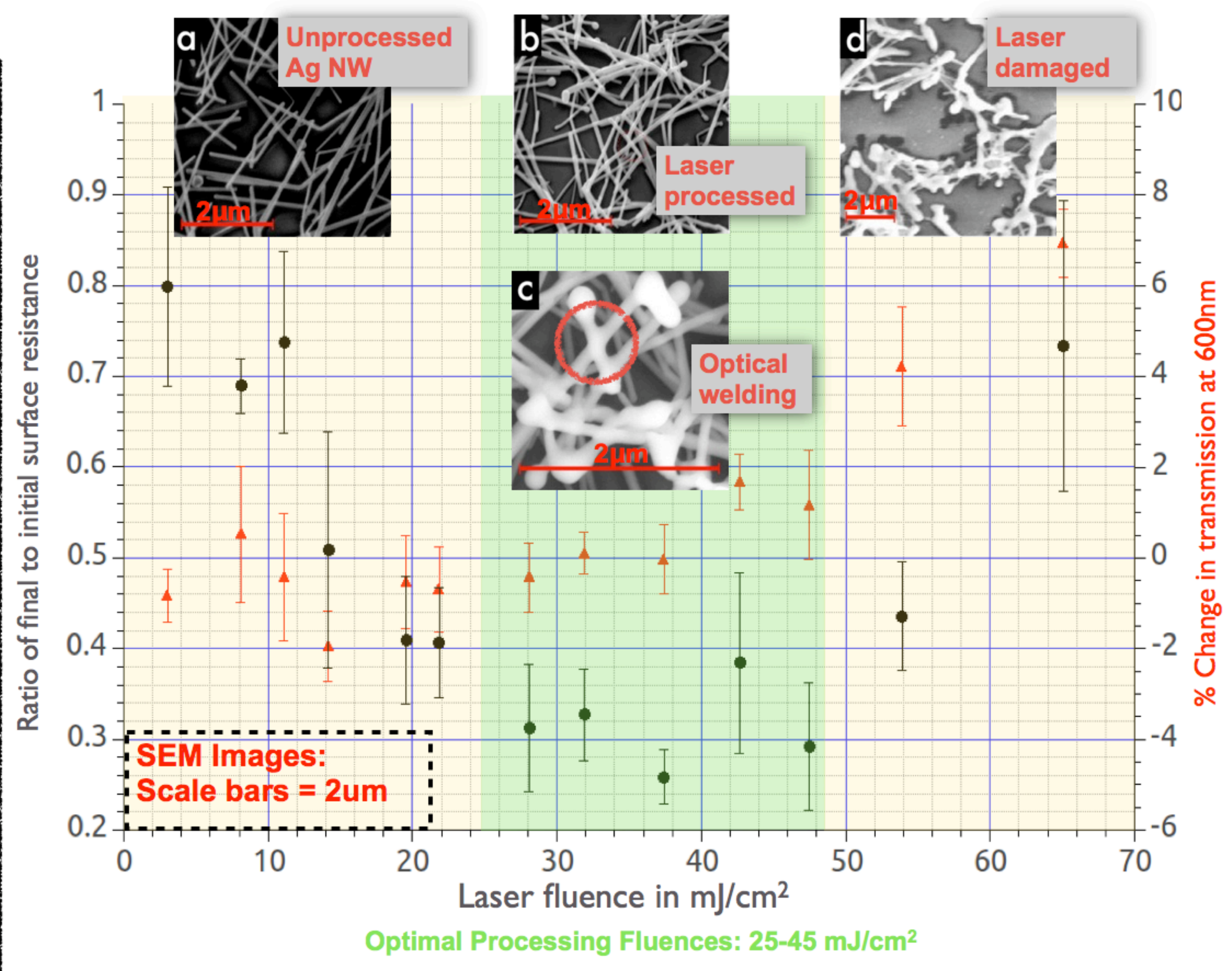


Surface plasmon resonance at the nanowire-nanowire junction concentrates the lasers power

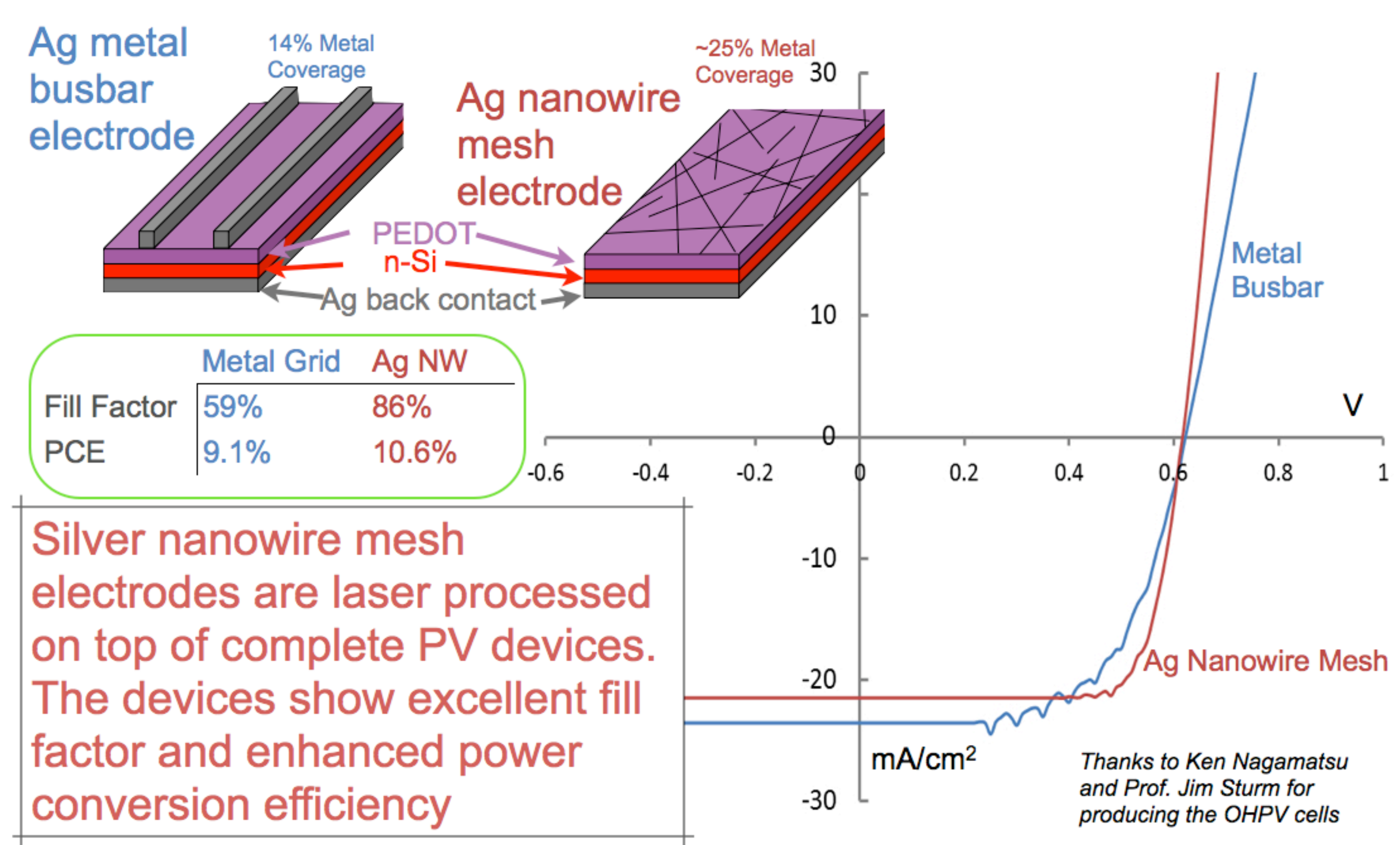


Transparency and Sheet Resistance Measurements:

With inset SEM micrographs



Laser Processing of Nanowire electrodes:



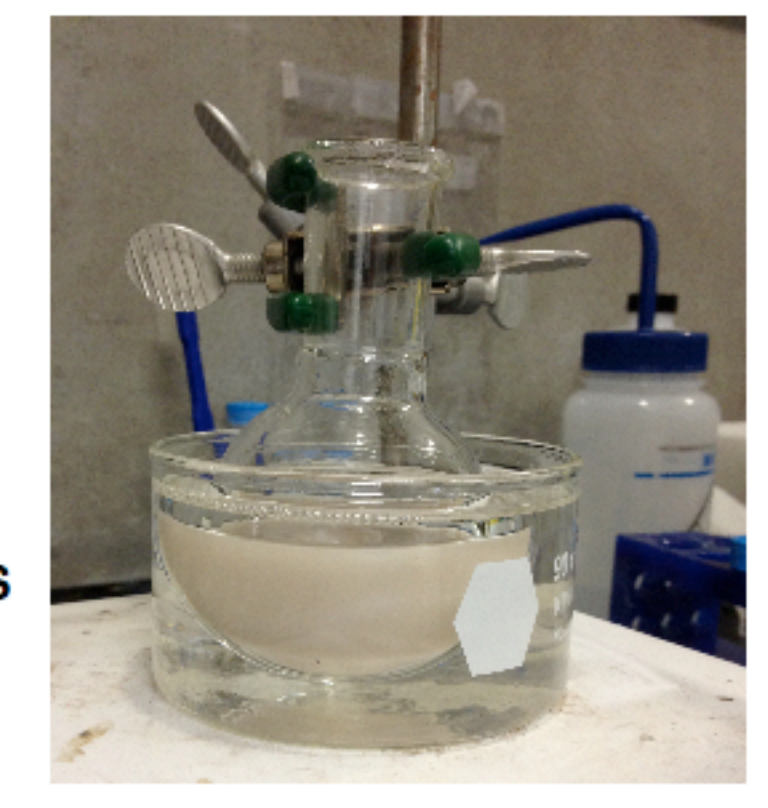
Nanotechnology for clean energy implications:

- Silver nanowire networks are made in laboratory environment with no high vacuum or high temperature steps:



ITO Magnetron sputtering: **170MJ/m²** (N. Espinosa et al. *Solar Energy Materials & solar Cells* 97 (2012) 3-13)

Ag nanowire synthesis: 2 hours of hot plate use- **8MJ/(m² equivalent)**
 Laser Processing: 15A/120V laser 1mm² spot size, rastering at 0.1m/s **18MJ/(m² equivalent)**



- Mobile communities can have lightweight and storable electricity conversion materials



Tents with solar generation fabric can provide electricity to mobile communities who live far from any electricity grid.

Conclusions

- The direct-write pulsed laser technique can significantly improve (~%80 improvement in sheet resistance) the performance of silver nanowire network electrodes.
- Optimal condition for laser processing: 30-50mJ/cm²
- Laser processing on top of complete PV devices is possible and beneficial
- Silver nanowire networks are produced in an environmentally conscious way, in contrast to ITO.

