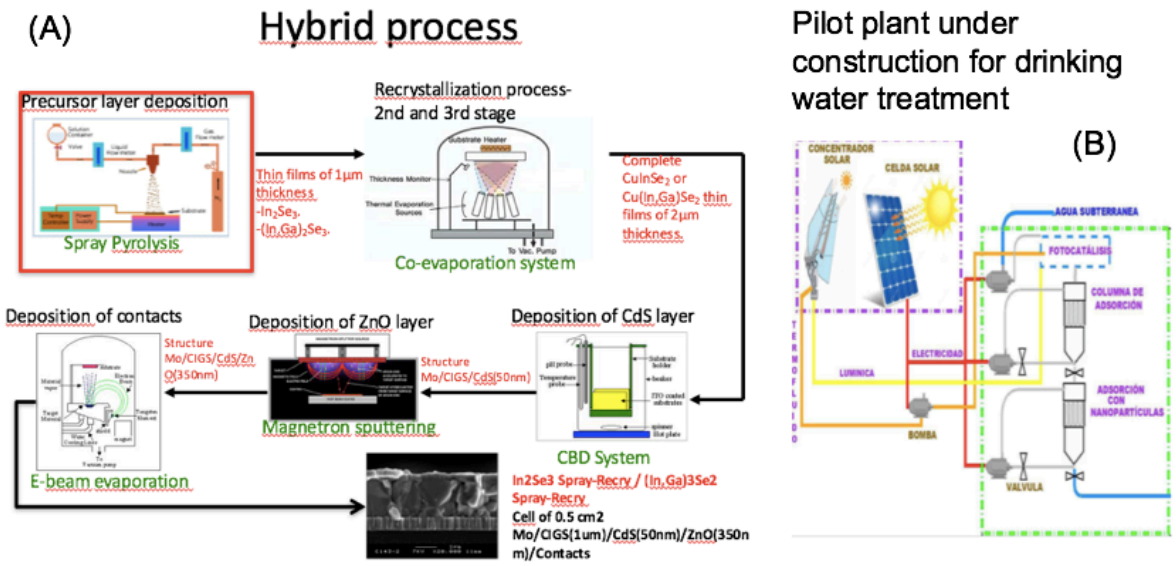
Research Plan - Professor Velumani Subramaniam PhD

One of the most gratifying aspects of an academic/research position is the opportunity to teach and interact with students, which I am enjoying since, my first teaching appointment from 1986. Whether or not they realize it, students have the freedom to explore and to think about problems in new dimensions that we never think. As teachers, we have the opportunity to guide student's discoveries and learn a great deal in the process. Unquestionably my favorite aspect of teaching/research is to work with students individually as an advisor, because i) it represents an opportunity to push forward research that I may not have time or mind to explore, and ii) of the fresh/innovative ideas that the students will bring.

Expertise and ongoing work: Photovoltaic materials: Main aim (heart & Soul) is to develop cutting-edge novel functional nanomaterials with very high absorption coefficient and increase the efficiency of the present **solar cells** in order to make it available for poor and common people. In pursuit of this, I am exploring various alternative materials for silicon, like CuInSe, CIGSe, CZTS, Perovskites etc. With a big boost in the renewable energy market in USA and around the world and a lot of sunshine @ Texas, ***I feel it is the future.*** I want to engage students of Department of Physics in collaboration with local industries for the installation of PV devices in remote places at small scale as a social activity. Presently a very strong collaboration between French Scientist and my group is going on and we have obtained about 11% efficiency for a new hybrid based fabrication technique developed in my lab (fig A below is the schematic of the process – a patent is in process) to reduce the cost of the CIS Solar cells. Also I am using the microscopic techniques at junctions to identify reasons for plundering the efficiency and wish to move forward. Majority of my publications are in novel functional semiconducting materials and graduated already about 8 Ph.D.´s, two Masters, and 4 undergraduate theses; and presently about five Ph.D. students are working on this. Currently, I have a mega project running to fabricate large area (10 x 10 cm^2) CIGSe based Solar cells using the newly developed hybrid technique in my lab.



Photocatalytic Materials: Water pollution and tackling is a complicated process, I am sure with advancement in nanotechnology, we can find a solution for it and on this line, I am working with my research students to explore new alternative materials based on $BiVO_4$-TiO_2, Fe_3O_4-TiO_2 nanocomposites for ***visible light photocatalysis*** – already published about eight papers in peer-reviewed international journals on this topic and graduated two Ph.D. students ($BiVO_4$ and doped $BiVO_4$). This is a multidisciplinary research work involving the Biotechnology and Chemistry Departments along with the Electrical Engineering. This will lead to conditional collaboration with Biotechnology, Biology, Chemistry and Mechanical Engineering to design & fabricate a portable pilot plant for water treatment (Fig. B, above). An ongoing project funded by Mexican Energy Ministry with CONACyT in Mexico. Also, I am planning for minimum of two patents from this project.

Fuel cell (past work) electric vehicles are flooding the market with one of the costliest charged catalyst, platinum. It is imminent that we should find an alternative for Platinum, even though I am not a chemist, I wish to contribute myself in the search for an alternative to Platinum with tri-metallic nanocomposites and also working on the design of PEM bipolar plates; already published about 4 paper on this and graduated five undergraduates, one Master

and one PhD thesis. This will pave a way to explore collaboration with other departments like Chemistry and Electrical & Electronics Engineering.

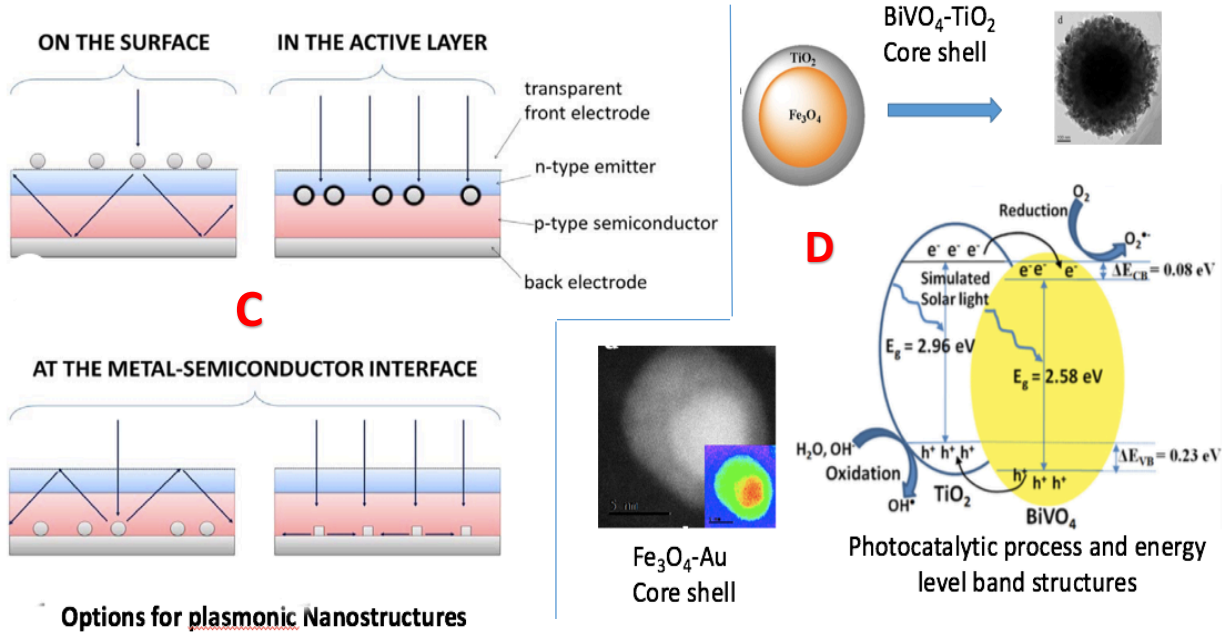
Bio-Materials (past work): During 2012 to 2017 I was developing cutting-edge novel materials, nanocomposite materials and core-shell structures for biomedical applications and biosensors. Along with a postdoc and, one Ph.D. and a Masters student we explored a plethora of nanostructures for virus and cancer detection, biosensors as well as theranostic nano flotillas for imaging and drug delivery in cancer animal models, where I must collaborate with biological and bioelectronics departments. Due to my huge commitments on other two projects and lack of human resources, personal concentration in this area is bit low.

Even though I have listed four areas of research (which gives a wide knowledge to teach various topics), if you want to me choose one, as a physicist, I will go for the PV materials and engineering the materials to capture maximum photons & avoiding recombination´s and use it for energy conversion applications in PV or PC.

Current tasks and goals: Given a chance and facilities, wish to continue my research on the **energy harvesting materials** especially, the Chalcopyrites for PV and Bismuth-based composite nanostructures for visible light photocatalysis.

PV materials: Having been achieved about 11 % efficiency in the new hybrid deposition techniques, my task is to explore the possibilities to improve the efficiency by bandgap engineering, introducing plasmonic nanostructures (as in below fig C), manipulating charge recombination, and exploring the Na incorporation. The present plan is i) to vary In & Ga contents and engineer the band-gap ii) to incorporate suitable metal nanostructures for CISe and CIGSe based absorbers, which can give a significant boost to improve the efficiencies in two ways, namely by adopting light trapping schemes to manipulate the light at sub-wavelength and by exploiting spectral modification processes to shift

frequencies of the solar spectrum, which are initially not absorbed, into the region of maximum absorption of the cell. Plasmonic nanoparticles (NPs) can give a significant boost to both these aspects, by scattering and concentrate the electromagnetic field into the active region of the device, and by doing that within specific spectral regions, which can be properly tuned by optimizing the size, shape, distribution of the plasmonic NPs, and by choosing the right surrounding medium. Last but not least manipulate with Na contents also.



Collaboration, future connections to industry and opportunities for entrepreneurship: TTU located in the sunshine area having proximity to Dallas where there are more than 40 colleges, university and institutions are located. And Houston, which is home to about 20 of the fortune 500 companies and hosting more than 5,000 energy-related firms, is considered by many as the Energy Capital of the world, there is every possibility to achieve my dreams or even to promote a spin-off with interested entrepreneurs on above materials.

PC Materials: At present, I am working on two heterogeneous nanostructures, $BiVO_4$-TiO_2 and Fe_3O_4-TiO_2 (structures shown in above fig D) for the visible light photocatalysis (process depicted in above fig D) and adsorption of heavy metals respectively. Presently my task is to Engineer the complex nanoparticle

composites and probe into the emergent interfacial energetic alignment, kinetic processes and its role for understanding the mechanisms of photon harvesting (in $BiVO_4$-TiO_2) and the heavy metal adsorption (in Fe_3O_4-TiO_2). Also, our group is analyzing various Mesoporous structures to embed the nanocomposites and to strike BOP.

Collaboration, future connections to industry and opportunities for entrepreneurship: If offered an opportunity I will join hands with Professors from various departments at TTU to explore the opportunities to present it to various entrepreneurs for a spin-off company with the planned patents; since water treatment is a persisting problem throughout the world.

As everybody knows, no one person will embody all of them, research should be a **multidisciplinary and collaborative nature**. In the above-mentioned areas of research interest, I am already collaborating with Biotechnology, computational theoretical Chemists, and other engineering departments for the design of biosensors, molecular simulations, and fabrication & installation of solar cells, and water treatment plants respectively. So I will definitely (it`s obligatory) to collaborate with other faculties within the Department and other Centers/Departments at the TTU in order to achieve my research goals as well. Apart from that, I will plan to submit new proposals to various funding agencies like DOE, US Army Labs, U.S. Naval Research Laboratory, NASA, NSF, DARPA, bilateral projects with various countries, etc to set up my lab for Materials Science.

As per my knowledge, I am confident that with the existing facilities @ TTU, I can continue to work on my areas of research interest and I am sure that with my expertise along with the existing expertise @ TTU, we can move forward and have a great impact on the energy harvesting materials sooner.

I WISH TO MOTIVATE YOUNGER GENERATION THRO TEACHING TO ACHIEVE LAURELS IN RESEARCH AND DEVELOPMENT

15 Oct 2018, Mexico