The need for clean, renewable and sustainable source of energy is a growing concern for present and future society. To meet this challenge, the new technological advances are necessary to replace the existing fuel infrastructure since current supplies of fossil fuels are steadily declining and produce toxic by-products. Therefore, it is clear from an economic, energetic and environmental standpoint, that the only solution which can meet these demands, is conversion of solar energy into clean fuels. However, it cannot happen without fabrication of the carefully designed micro/nanostructures incorporated in powerful heterojunction governing the overall efficiency of the device. Use of such high efficiency heterojunction is welcome to a number of fields including solar cells, photovoltaics, sensors, capacitors, artificial photosynthesis, biomimetics etc. Therefore, such studies should be directed towards deep understanding of the charge carrier behavior in single and complex semiconductor based systems. The investigations envisaged in this project, will be done with use of transient absorption spectroscopy and certainly reveal a dependence of the photoelectrode architecture on the charge carriers' origin, separation, collection, trapping, lifetime and thus its effectiveness in the desired photelectrochemical processes. Prior to the transient absorption measurements intended to establish the correlation between the structural properties and the charge carrier dynamics, the photoelectrodes will be carefully designed and manufactured. This step will consist of identification of promising semiconductor systems based on earth abounding materials, and developing facile and inexpensive synthesis route to produce these materials as photoelectrodes to precisely evaluate their potential and address their limitations based on in-depth understanding of their photoelectrochemical properties. This initial step is critical for making a true impact on solar fuel production relaying on to quality of the construction, optimization and photoelectrochemical performance of the heterojunction made of the elaborated single systems. Presentation and comparison of the charge carrier dynamics occurring in single systems: bare & modified as well as in mixed metal oxides under irradiation are particularly useful in clarifying the observed differences in their photoelectrochemical performance. Going further, the obtained transient absorption spectra recorded under a number of excitation energy density and excitation wavelengths followed by the interpretation of the transient phenomena occurring upon absorption and its decay, will enable a construction of a powerful junctions to boost exciton generation and to fine tune the band energetics. Deep understanding of the charge transport at the junction will enable a creation of a kind of road map to the powerful heterojunction which can be used further in any solar device to boost its performance. Therefore, these results will surely provide a valuable contribution to the ongoing search of the efficient materials and devices for sustainable energy source.