Alternative energy sources have become one of the main directions of research and innovation in this area. Polymer electrolyte membrane fuel cells (PEMFCs), ecologically friendly devices that directly convert chemical energy into electricity with high efficiency without the combustion process, are considered to be one of the most promising energy-conversion technologies available. In a fuel cell, the fuel (such as hydrogen, methanol, and formic acid) is oxidized at the anode, and the released electrons are transferred to cathode where oxygen is reduced. Advantages of fuel cells include high conversion efficiency (up to two-three times higher with respect to conventional combustion engines), continuous operation as long as the fuel is provided, with no need of recharging as in secondary batteries. Despite significant progresses in the field in terms of both performance and durability at reduced costs, low-temperature fuel cells still require the adoption of suitable and typically expensive catalysts based on platinum. In order to reduce costs and increase the efficiency of the fuel cells are necessary to develop the new electrode materials that have a higher activity for both the process of oxygen reduction at the cathode and electrochemical oxidation of the fuel at the anode. The primary purpose of the proposed research is to develop, characterize and demonstrate new highly-active platinum-group-metal-free graphene-supported nanostructured materials for electroreduction of oxygen. This research is of importance to the technology of low-temperature fuel cells, and our efforts will concentrate (but they will not be limited) to the development of catalytic systems for anion-exchange systems operating in both acidic and alkaline medium. Moreover, this proposal is focused on finding a correlation between the type and the composition of metals or metal alloys and a system of coordinating them in nano-platelets of graphene and related materials structure and their electrocatalytic activity towards oxygen reduction. Finding this correlation will contribute to design and develop the better cathode materials which will be characterized higher activity towards the reduction of oxygen and also take place at higher potential (closer to thermodynamic potential). To understand better the mechanism of the oxygen reduction reaction and influence of composition on catalytic center properties it is important to define mutual interactions between particular components. For this purpose XPS studies, extended X-ray absorption fine structure (EXAFS), X-ray absorption near edge structure (XANES) spectroscopies and ^{57}Fe Mössbauer spectroscopy will be performed to comment on modification of electronic properties of core metals due to interaction with coordination heteroatoms existed in graphene and graphene related materials, and correlation of those modifications to electrocatalytic activity towards more efficient oxygen reduction reaction. Structure characterization will be conducted with X-ray diffraction, scanning electron microscopy, high resolution transmistion electron microscopy, as well as and correlated with catalytic properties. Special attention will be paid to the investigations of dynamics of charge transport and electrocatalytic phenomena using both modern electroanalytical methodology (chronoamperometry, chronocoulometry, rotating ring disk voltammetry) and impedance methodology.