The aim of the project is to obtain new, advanced gel materials with the desired properties. The research will focus on modification and derivatization of polymer chains in the gels to get their needed properties. Among those properties are the abilities to: self-heal, self-assembly, be degraded and undergo a volume phase transition under specified conditions. It will be important that the obtained hydrogel materials will exhibit the mentioned properties under conditions similar to those prevailing in human body. The goals of this project will be realized through the functionalization of the polymeric materials with natural compounds. An accent will be given to preparation of these gels in micro- and nano-size to allow shortening of time of volume phase transitions and achieving the balance with the environment.

The polymeric hydrogels are cross-linked hydrophilic polymer networks filled with an aqueous solution. Fluid content in the hydrogels is usually very high, often exceeds 95%; nevertheless, these materials exhibit properties of liquids and solids. In the macroscopic scale the gels behave as solid bodies. The tridimensional net is responsible for preservation of their actual shape and storage of the mechanical energy, and participates in all deformation processes. In parallel, in the microscale, the gels exhibit properties of liquids: the diffusional transport of small molecules and ions takes place in them. Such hydrogel properties as: absorption of large amount of water, three-dimensional network that gives specific mechanical properties, thermal and chemical resistance, flexibility, non-toxicity, often biocompatibility, biodegradability and sorption of heavy metal ions and organic compounds stand behind wide use of the gels in many fields.

In addition to the above-mentioned properties of polymer gels, the gels can exhibit other very interesting features. By appropriate functionalization of the polymer network, hydrogels can undergo self-healing and self-assembly process, can be degradable and may undergo volume phase transition under strictly defined conditions. The volume phase transition occurs as a response to particular changes in the environmental, either physical or chemical, conditions such as temperature, light, magnetic and electric fields, pH and presence of specific molecules and ions. When a swollen hydrogel undergoes the volume phase transition, water is ejected from the polymeric network and the shrunken state is formed. These changes originate from a shift in the balance between repulsive intermolecular forces that make the polymer network expand, and attractive forces that make it shrink.

Furthermore, an incorporation into the polymer network of bonds that can undergo breaking under relatively mild conditions, e.g. by hydrolysis, reduction or oxidation, may lead to a degradable hydrogel. Materials that are degraded due to pH changes, the presence of reductants (e.g. glutathione – a tripeptide present in human cells, whose concentration is usually significantly elevated in cancer cells) or oxidants (e.g. hydrogen peroxide that is formed in the case of inflammation which often accompanies cancer) become very interesting for medicine and pharmacy. Recently an increase in interest in the processes related to self-healing and self-assembly of gel materials has appeared. These phenomena are related to restoration of broken bonds in a mechanically damaged material or to formation of bonds between different hydrogel networks.

The preparation of new advanced gel materials with the desired properties fits well to the current trends in materials research. Biocompatible hydrogel materials with features such as self-healing, self-assembly and degradation under strictly defined conditions gain great interest in medicine, bioengineering and pharmacy as potential medical glues, medical implants and drug delivery systems. The innovative nature of planned research is related to the use of derivatives of such natural compounds as: N,N’-diacryloyl derivative of cystine and selenocystine, and N-δ-acrylic derivative of ornithine to give polymeric materials new, desired properties. Particularly, it should be emphasized that a very promising compound - N,N'-diacryloylselenacystine, which has not been described in the literature yet, is planned for use. A novelty of the proposed project is also an attempt to induce electrochemically the volume phase transition and to control electrochemically the self-healing and self-assembly processes. Especially, formation of new materials with new properties or with enhanced properties compared to those described in the literature will be desirable. A positive result in any part of the project may open new possibilities of practical applications of the newly obtained material or may be a prerequisite for further research in the direction of potential applications.