DESCRIPTION FOR THE GENERAL PUBLIC

The current knowledge indicates that despite the many advantages of ceramic composites for use in cutting tools, progress in this specific area, requiring from the developed materials resistance to extremely difficult working conditions, is very slow. The most important properties of the ceramic materials are: high hardness, wear resistance as well as abrasion resistance to dynamic loads and fracture toughness. In recent years, due to rapid development of dry machining and machining at high speed an additional requirement for tool material is resistant to chemical and diffusion wear, especially intensified by heat treatment. Low resistance to fracture toughness, low thermal conductivity and anisotropy in coefficients of thermal expansion result in the presence of a gradient of the temperature distribution and the formation of microcracks in the blade of the cutting tool. Therefore, in recent times, novel composite systems and new methods of production of ceramic composites for use in cutting tools are investigated. The promising method of consolidation limiting the influence of thermal effects is Spark Plasma Sintering method (SPS). There are also analyzed new types of strengthening phases for application as cutting tools, including nanomaterials and materials with 2D structure. Advances in the technology of nanomaterials enable a number of opportunities to develop more efficient and environmentally friendly manufacturing methods. Due to the introduced innovations, the development of new materials with a two-dimensional structure characterized by unique functional properties is currently one of the fastest growing fields in science and technology. Since the discovery of the unique properties of graphene, the interest in two-dimensional materials (2D crystals) greatly increased.

The properties of 2D materials are significantly different from their 3D counterparts. As a result, there are required new methods of transformation of known layered three-dimensional structures to two-dimensional ones with unique properties. The such known for many years 3D structures are those of $M_{n+1}AX_n$ stoichiometry of alternately arranged layers of metal and nonmetal, called MAX phases. Our preliminary studies, confirmed by the literature data, showed the possibility of MAX phases expanding to MXenes of $M_{n+1}X_n$ stoichiometry by removing one layer of the A element from the crystal structure. Furthermore, we can delaminate MXenes to 2D structures using liquid sonication and modify them with metal oxides.

The scientific aim of the project, realized by the interdisciplinary research team from the Warsaw University of Technology (Faculty of Materials Science and Engineering and Faculty of Chemistry) as well as AGH University of Science and Technology, is to create new knowledge on the preparation and physico-mechanical properties of ceramic composites with the addition of novel two dimensional structures of early transition metal carbides/nitrides, the development of the chemical methods of surface modification with ceramic and/or metallic coating as well as investigations on mechanisms responsible for the changes of microstructure and physico-mechanical properties of the consolidated materials in the aspect of physico-chemical interactions between the surface of non-modified and modified 2D structures and the matrix material. The anisotropy of the microstructure of the composites and the crystal structure of developed 2D crystals in the chosen matrix will be also investigated.

Our first attempts to produce Si_3N_4 matrix composites reinforced with Ti_2C indicate the possibility of obtaining material with improved Young's modulus, good strength properties, bending toughness, K_{IC} , low fracture energy. The expected outcome of the project is therefore a fulfillment of a significant knowledge gap on ceramic composites added with the new family of two-dimensional structures - early transition metal carbides/nitrides. The project results will be characterized by high scientific value and high potential for scientific discoveries which will allow for preparation of over 10 publications in high-impact factor JCR journals. The project achievements will create the opportunity for breakthrough in the development of composite materials for use as cutting tools, requiring from the developed materials resistance to extremely difficult working conditions.