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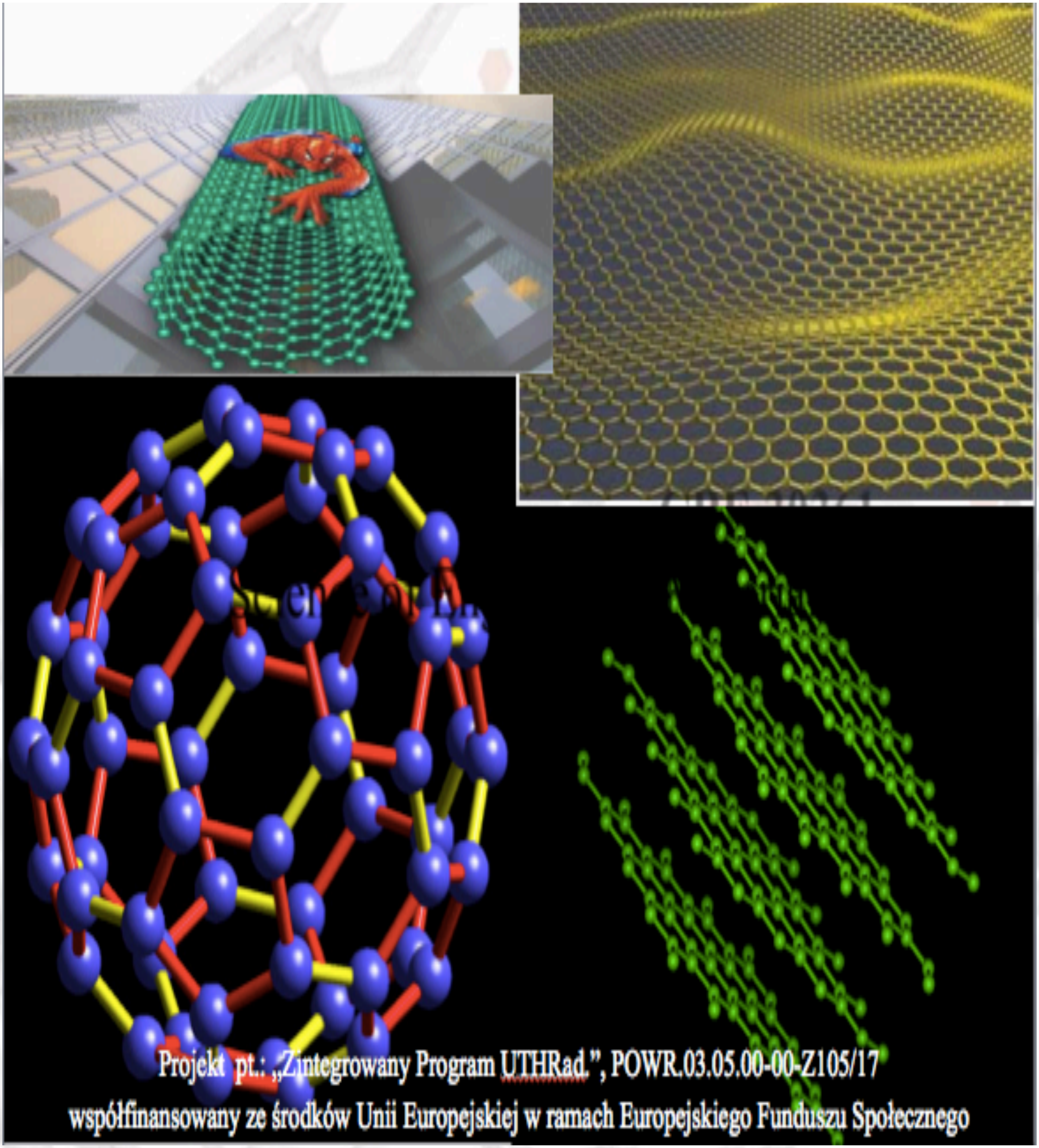

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Course Number:1
Course Title: Science of Engineering Materials
Lecture №01

Composite materials and prospects for their application

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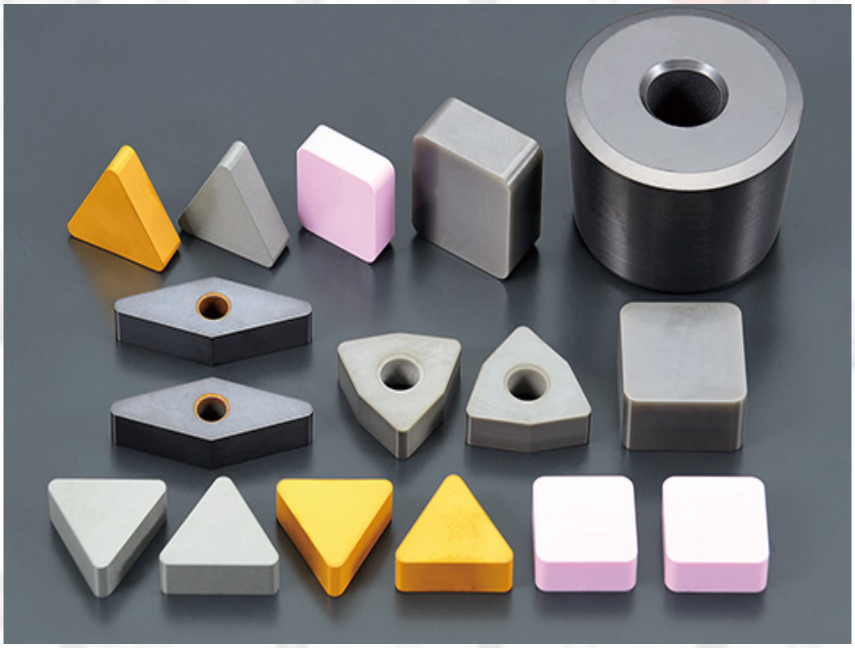
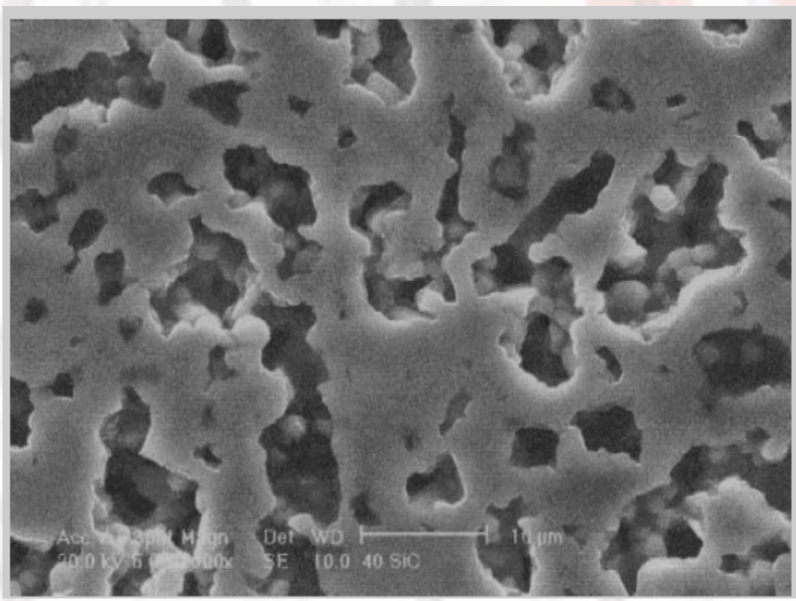
WHY STUDY MATERIALS SCIENCE AND ENGINEERING?

Many an applied scientist or engineer, whether mechanical,civil, chemical, or electrical, will at one ime or another be exposed to a design problem involving materials. Examples might include a ransmission gear,the superstructure for a building, an oil refinery component, or an integrated circuitchip. Of course, materials scientists and engineers are specialists who are totally nvolved in the investigation and design of materials. Many times, a materials problem is one of selecting the right material from the many thousands that are available. There are several criteria on which the final decision is normally based. First of all, the in-service conditions must be characterized, for these will dictate the properties required of the material. On only rare occasions loes a material possess the maximum or ideal combination of properties.
Thus, it may be necessary to trade off one characteristic for another. The classic example involves strength and ductility; normally, a material having a high
Strength will have only a limited ductility. In such cases a reasonable compromise between wo or more properties may be necessary. A second selection consideration is any deterioration of material properties that may occur during service operation. For example, significant reductions in mechanical strength may esult from exposure to elevated temperatures or corrosive environments.
Finally, probably the overriding consideration is that of economics: What will he finished product cost? A material may be found that has the ideal set of properties but is prohibitively expensive. Here again, some compromise is inevitable.
The cost of a finished piece also includes any expense incurred during fabrication o produce the desired shape. The more familiar an engineer or scientist is with the various characteristics and structure–property relationships, as well as processing techniques of materials he more proficient and confident he or she will be to make judicious materials choices based on these criteria.

A recently, most binary composite systems were made based on ZrO_2 such as ZrO_2-TiB_2, ZrO_2-TiCN, ZrO_2-SiC, ZrO_2-TiN, and ZrO_2-TiC. Consequently, high mechanical properties of the material can be expected when ZrO_2 is hardened by nanoparticles of the second phase (tungsten carbide). It will allow extensive use of obtained ceramics.

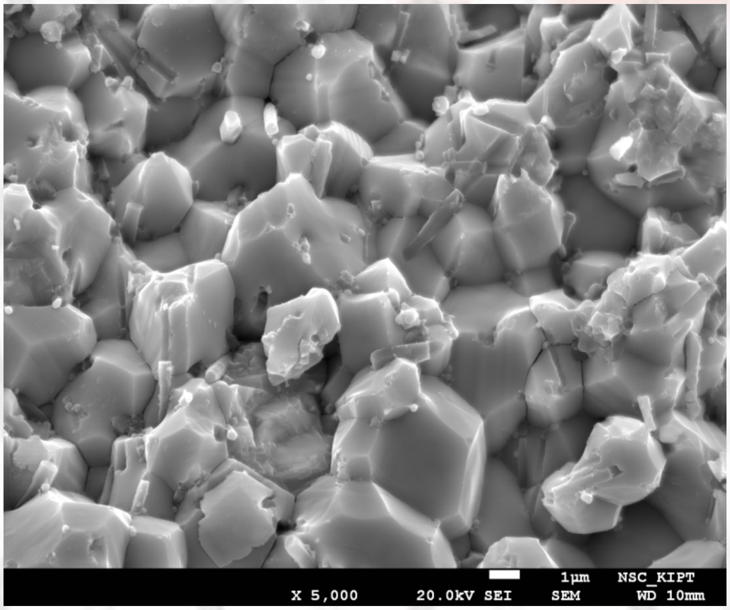


Oxide ceramic, in particular, nanostructured and composite materials as instrumental is of great demand, because of their high physical and mechanical properties. But along with high hardness and temperature resistance, the use of such materials is limited by their low strength and crack resistance. It is not possible to solve this problem by traditional hot sintering. The reason for this is the rapid growth of grain, competing with the compaction of particles .



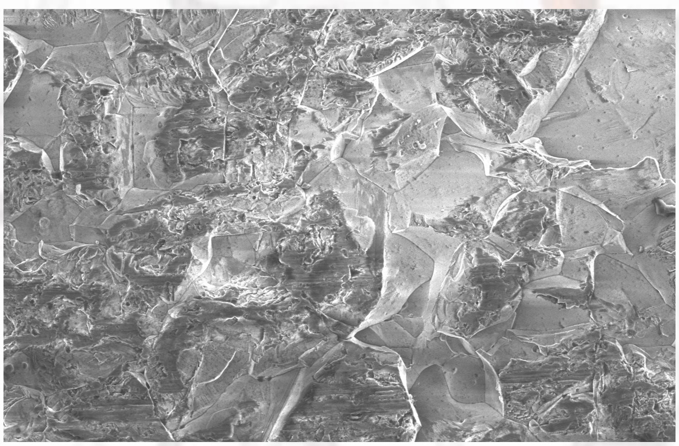
Microstructure of Al2O3 ceramic sintered in argon atmosphere
without activating additives

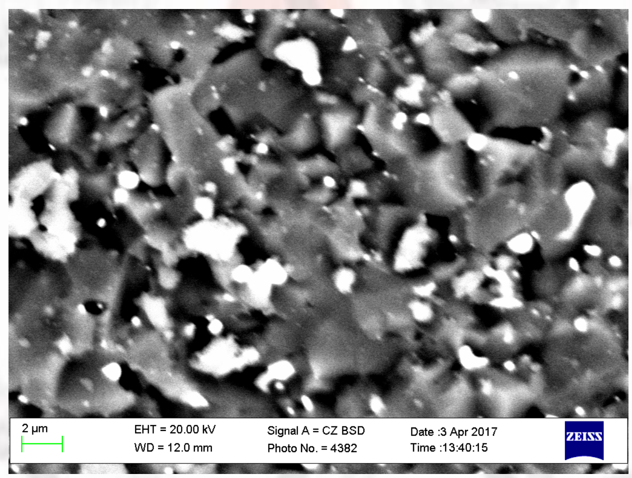
Grain size of the sintered ceramics determines its mechanical and operational properties and increases with increasing sintering temperature and holding time. The ceramics consists of pure Al_2O_3 without any additives sintered at T=1600-1700 ° C have the average grain size about 20 µm (Fig. 7a), which is quite a lot. The growth of grain can be restrained by lowering the sintering temperature and holding time, but this entails poor sintering of the particles due to incomplete grain diffusion. As the content of SiC particles increases, the grain size decreases. The presence of additive particles (SiC) prevents grain growth, without requiring a reduction in the sintering temperature and holding time for this. In Fig. 7b, it can be seen that the addition of SiC to Al_2O_3preserves the microsurface of the composite.



Microstructure of Al_2O_3-SiC ceramics sintered by electroconsolidation at a temperature T = 1400˚C pressure P = 30 MPa.

The growth of grain can be restrained by lowering the sintering temperature and holding time, but this entails poor sintering of the particles due to incomplete grain diffusion. As the content of SiC particles increases, the grain size decreases. The presence of additive particles (SiC) prevents grain growth, without requiring a reduction in the sintering temperature and holding time for this. In Fig. b, it can be seen that the addition of SiC to Al_2O_3 preserves the microsurface of the composite. When using micro-SiC, the grain size was about 3 μm at a sintering temperature of 1400 ° C. To effectively control grain growth a large number of reinforcing particles are needed. This can be achieved either by increasing the mass content of SiC in the composite (which adversely affects the mechanical properties) or by using finely dispersed SiC powders. As can be seen from Fig using nano-SiC, the composite retains its microstructure even at temperatures of 1700 ° C and has a grain size smaller than that of the composite sintered at 1400 ° C with the addition of micro-SiC.

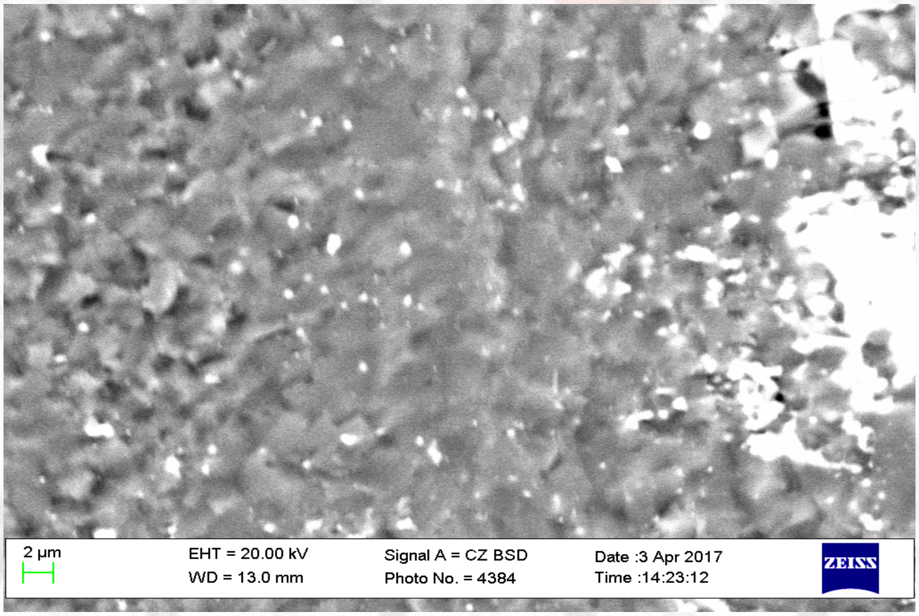




a) Al_2O_3; T=1600 ˚C

b) Al_2O_3+15% μ-SiC; T=1400 ˚C

The combination of high strength of the material with its high toughness is difficult to achieve because of competing mechanisms during consolidation. The application of electroconsolidation technologies and mathematical modeling allowed to optimize the parameters of consolidation for obtaining a composite material with high mechanical properties. When using powder Al_2O_3 with the addition of nanodispersed nano-SiC powder as a raw material, it was possible to obtain a composite for instrumental use having hardness H_V = 25 GPa and crack resistance K_{IC} = 6.5 MPa·m$^{1/2}$,



Al_2O_3+15% nano-SiC; T=1400 °C

Processes of formation of materials with fine and dense structure during sintering

a - grain boundaries are fixed, pores turn into vacancies and disappear at grain boundaries; b - due to the occurrence of anomalous grain growth, the movement of the boundaries is large and the pores remain inside the material. The arrows in the diagram indicate the direction of movement of the substance.