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Effect of elastomer structure on ceramic–elastomer composite properties

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Ceramic – elastomer composites, obtained via infiltration of porous SiO_2 by urea-urethane elastomer, were made and studied. Such composites are a new class of construction and functional materials. Also the structure and properties of urea-urethane elastomers used for infiltration were investigated.

The porous ceramics is light but distinguished by low fracture toughness. Due to joining it with elastomer the composites with increased toughness are obtained. Urea-urethane elastomers with different hard and soft segments content were used for infiltration the porous SiO_2. The elastomer structure and properties change with the hard and soft segments content. Also the ceramic-elastomer composite properties are strongly depended on the elastomer structure and properties.

SEM investigation showed that the pores are fully filled by elastomer, independent on the elastomer soft and hard segment content. The infiltration leads to fabrication of composites with percolation structure. The effect of the elastomer structure, with different soft and hard segments content, on the composite compression strength was revealed.

1. INTRODUCTION

Ceramic-elastomer composites are a new class of materials with significant application opportunities. These composites exhibit high compression strength together with the ability to achieve large deformation. They combine the ceramic hardness and stiffness with the rubbery entropy-elasticity of elastomers [1, 2]. This combinations of properties suggest, that such composites could be used as shock absorbers. Moreover, these composites could retain piezoelectric properties of ceramic matrix. It makes them used for a host of sensor and actuator applications, especially for hydrostatic sonar sensors [3, 4].

Studied composites were obtained via infiltration of porous ceramics by urea-urethane elastomers [5]. Cast segmented urea-urethane elastomers have their macromolecules built from soft (S) and hard segments (H). The molar ratio of hard and soft segments can change accordingly to the molar ratio of substrates. The elastomer structure and properties depend strongly on the S/G molar ratio. Hitherto the influence of the elastomer structure and properties on the composite compression strength was not investigated.

The reported studies aims to the microstructure and properties of the elastomers with different soft and hard segments content used to obtain ceramic-elastomer composites. Also the influence of the elastomer structure and properties on the ceramic-elastomer composite compression strength was evaluated.

2. EXPERIMENTAL AND RESULTS

Ceramic – elastomer composites were obtained via infiltration of porous SiO_2 by urea-urethane elastomers. Urea-urethane elastomer was synthesized by one-shot method from the following substrates:

- 4,4'-Diphenylmethane diisocyanate (MDI) [15];
- ethylene oligoadipate (OAE), average molecular weight 2040 a.u.;
- dicyandiamide (DCDA), used in the form of concentrate with OAE.

The elastomers with mole ratio of MDI/OAE+DCDA equal to 1,25 (S/G=0,25); 2.5 (S/G=1,50) and 2,8 (S/G=1,80) were made. The mixture of the substrates was cast into special moulds with porous ceramic samples inside where the infiltration process was carried out [5]. Porous SiO_2 samples had cylindrical shape with a 20 mm diameter and 20 mm height. The average open porosity measured by the Archimedes method was equal to 40 %. The average size of pores, measured by the bubbles method [6] was 105 μm .

SEM investigations of the brittle fracture of elastomers with different S/G ratio were made using Scanning Electron Microscopy (Hitachi S-3500N). The elastomer microstructures are shown in Fig. 1 and Fig. 2.

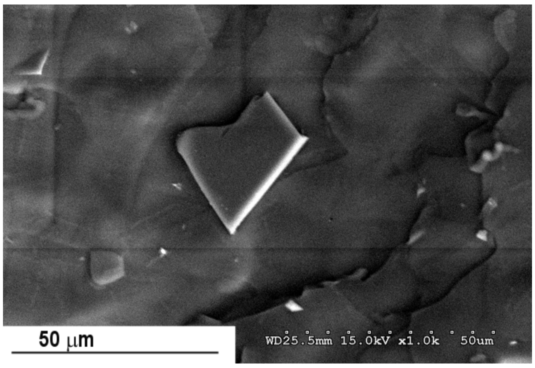

Figure 1. SEM image of the brittle fracture of the polymer with S/G equal to 0,25

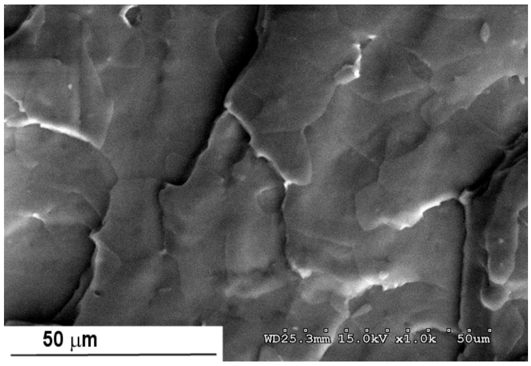

Figure 2. SEM image of the brittle fracture of the polymer with S/G equal to 1,50

Selected mechanical properties of elastomers synthesized were measured using standard methods. The results are listed in Table 1.

Table 1. Mechanical properties of urea-urethane elastomers with different S/G ratio

S/G [mol/mol]	**R_m [MPa]**	**σ_{100} [MPa]**	**σ_{300} [MPa]**	**ε_r [%]**	**ε_{rt} [%]**	**E [MPa]**	**R_{rd} [kN/m]**	**H [°ShA]**	**η [%]**
0,25	40,5	1,8	3,1	835	5	7,0	52,4	64	46
1,50	31,6	8,1	19,2	420	11	26,7	78,6	88	30
1,80	32,3	11,2	27,2	348	16	26,2	76,2	94	30

Observations of ceramic-elastomer composites microstructure were also made. As shown in Fig. 3. and Fig. 4. the elastomer with different S/G ratio infiltrated into the pores of ceramic matrix leading to the microstructure with percolation of the elastomer phase. Although the mixtures of the elastomer substrates before curing had different viscosity, it occurs that it doesn't influence on the degree of pores infiltration. All pores are filled with urea-urethane elastomers very well.

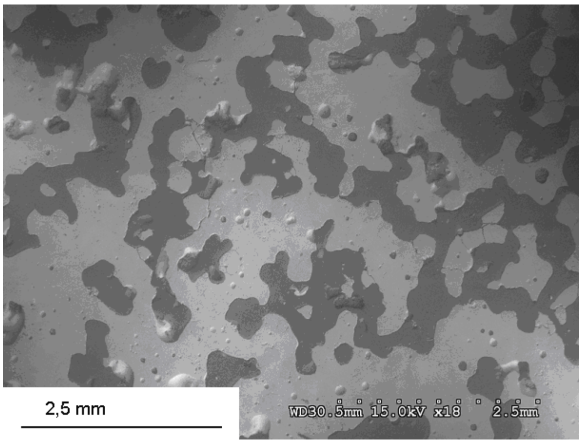

Figure 3. SEM image of surface of the ceramic-elastomer composites (S/G=0,25)

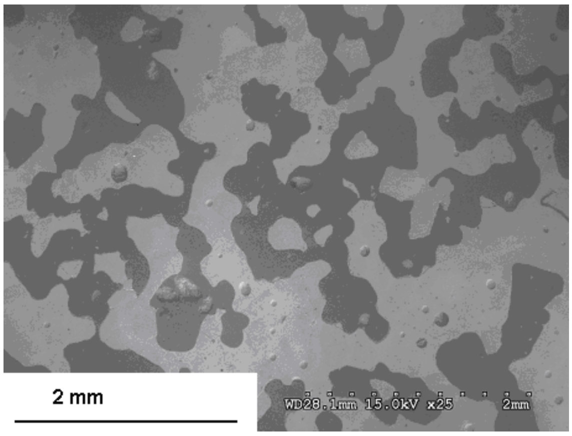

Figure 4. SEM image of surface of the ceramic-elastomer composites (S/G=1,50)

Test of the compression was carried out on tensile test machine Instron type 1115. The diagrams of stress-strain are presented in Fig. 5. These composites exhibit high compression strength together with ability to sustain large deformation due to the fact that the elastomer shows the rubber elasticity and deforms after the ceramic looses its cohesion. The high compression strength of the composite is due to the fact of the crack energy dispersed by the elastomer. Also the elastomer microstructure and properties determined by soft and hard segments content, effect on the composite compression strength.

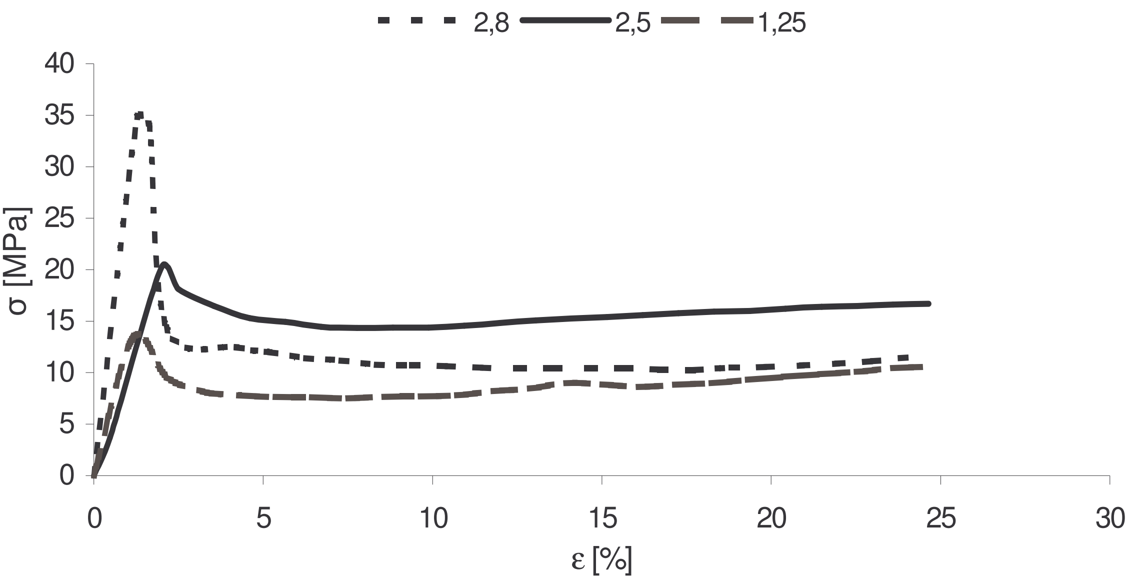

Figure 5. Diagrams of compression of composites infiltrated by elastomer with different hard segment content (S/G)

3. SUMMARY

Results of research show that infiltration method can be used to fabricate composites with percolation of ceramic and elastomeric phases. The elastomer microstructure and properties can change in a broad range. It depends on the soft and hard segments content. SEM observations of the fracture surface of the composites proved that all pores are completely filled by elastomer, independently on soft and hard segment content.

The compression strength of the composites depends on the hard segment content of elastomer used to the infiltration of porous SiO_2.

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