The effect of ultra-fine alloying elements on high-temperature strength and fracture toughness of Ti–Si–X composites

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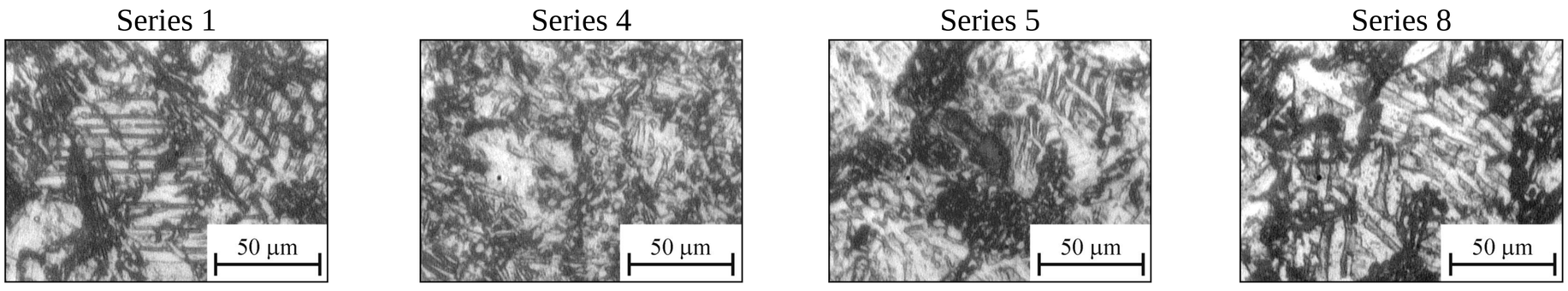
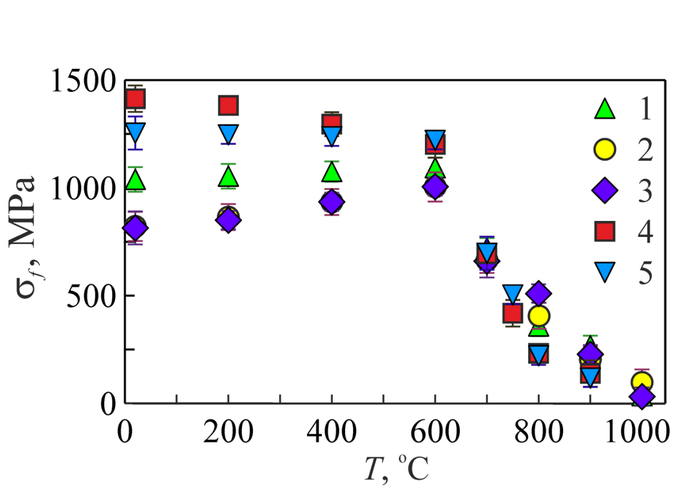
Introduction. In contrast to conventional titanium alloys, an operating temperature of which is limited by 300–500°C, advanced Ti-based composites possess high fracture toughness and strength under bend and tensile loading in the temperature range of 20°C to 650°C. Owing to their high strength-to-weight ratio, these composites are promising for applications in components of modern engines (aircraft, rocket, and internal combustion ones) as well as other power equipment (compressors, gas turbines, etc.). However, there is a need to increase their operating temperature range up to 700−800°C.

Experimental. In this work, mechanical behavior of Ti–Si–X composites (X=Al and/or Zr) have been studied in a temperature range of 20°C to 800°C. The content of alloying elements varied in a wide range (2–5 wt% Al, 2–5 wt% Zr). The composites were manufactured with electron arc smelting. Beam specimens were cut of blanks, grinded, and polished to reach a good surface quality. Strength tests of specimen series were performed under three-point bending in a temperature range of 20°C to 1000°C. Fracture toughness tests of specimen series were performed at a temperature of 20°C using an indentation method. After that, single-edge notch beam (SENB) tests under three-point bending of specimen series were carried out in a temperature range of 20°C to 900°C.

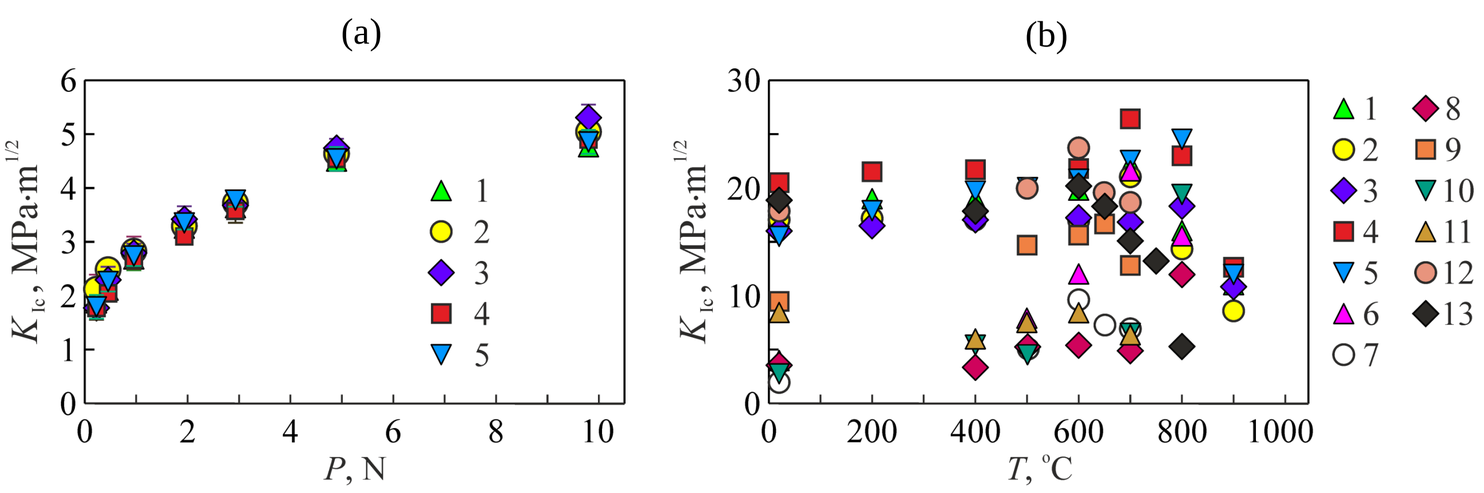


SEM microstructures of specimen series 1, 4, 5, and 8

Results and Discussion. Based on the constructed dependences of fracture toughness and strength on testing temperature for the specimen series as well as the microstructure and failure micromechanism analyses, the role of ultra-fine alloying elements in achieving good high-temperature strength and fracture toughness of Ti–Si–X composites was substantiated.



Temperature dependences of strength (under three-point bending) of separate variants of Ti-Si-X composites



Fracture toughness of Ti-Si-X composites under study: (a) Vickers indentation method; (b) temperature dependences of fracture toughness (SENB method under three-point bending; the average values)