IMPROVING HIGH TEMPERATURE PERFORMANCE OF TITANIUM MATRIX COMPOSITES WITH TAILORED MULTISCALE ARCHITECTURE

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ABSTRACT

Discontinuously reinforced titanium matrix composites (DRTMCs), as one of the most important metal matrix composites (MMCs), are expected to exhibit high strength, elastic modulus, high-temperature endurability, wear resistance, isotropic property , and formability.. Recent innovative research shows that tailoring the reinforcement network distribution totally differently from the conventional homogeneous distribution can not only improve the strengthening effect but also resolve the dilemma of DRTMCs with poor tensile ductility. Based on the network architecture, multiscale architecture, for example, two-scale network and laminate-network microstructure can further inspire superior strength, creep, and oxidation resistance at elevated temperatures. Herein, the most recent developments, which include the design, fabrication, microstructure, high-temperature performance, strengthening mechanisms, and future research opportunities for DRTMCs with multiscale architecture, are captured. In this regard, the service temperature can be increased by 200ºC, and the creep rupture time by 59-fold compared with those of conventional titanium alloys, which can meet the urgent demands of lightweight nickel-based structural materials and potentially replace nickel base superalloys at 600-800 ºC to reduce weight by 45%. In fact, multiscale architecture design strategy will also favorably open a new era in the research of extensive metallic materials for improved performance.

INTRODUCTION

Figure 1. Applications of DRTMCs.

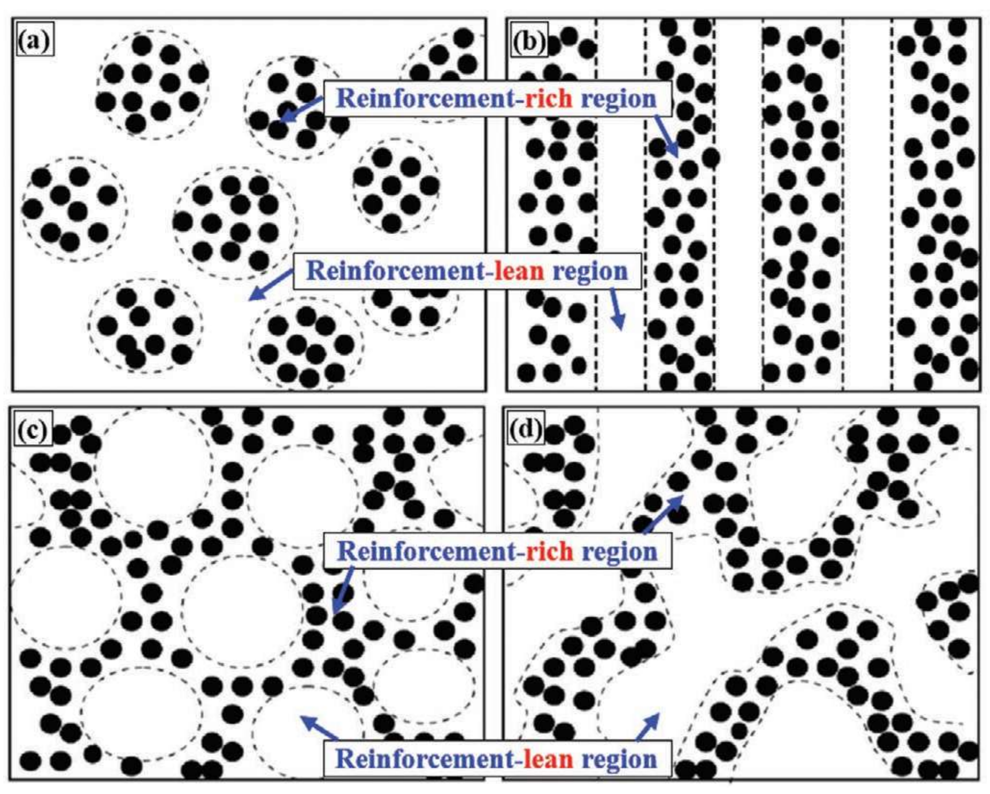

Figure 2. Schematic illustrations tailoring reinforcement-rich and reinforcement-lean regions with four different patterns.

RESULTS AND DISCUSSION

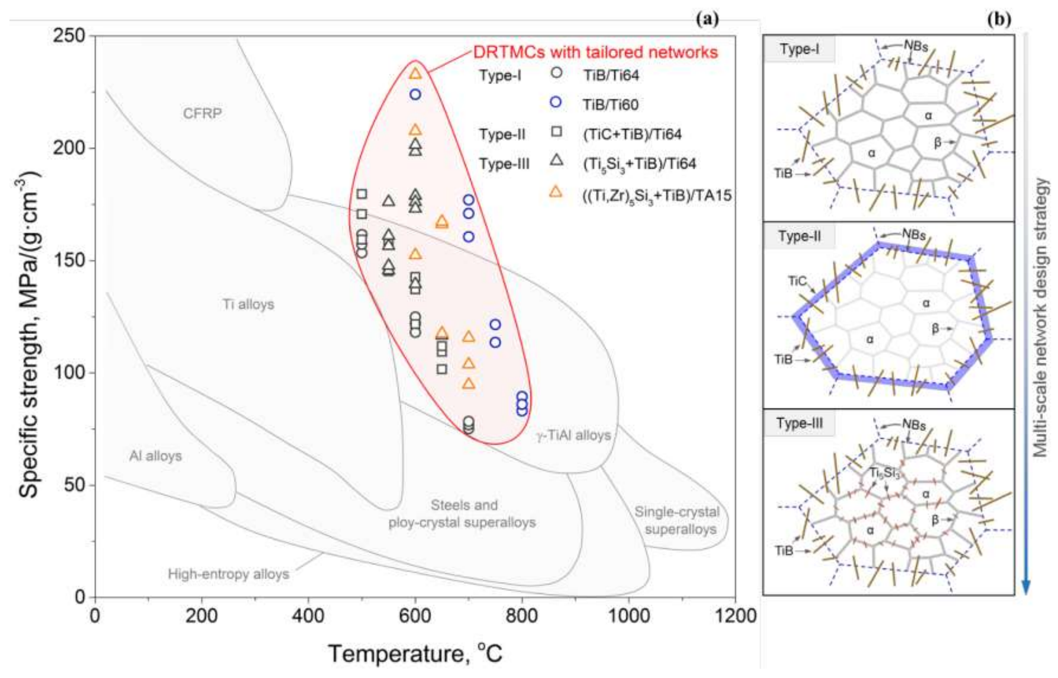

Figure 3. Tensile property comparison and schematic for network design strategy.

Type-I: prototypical network with TiB whiskers distributing at the prior margins of the matrix powders

Type-II: hybrid network consisting of both TiB whiskers and TiC particles

Type-III: two-scale network with TiB whiskers forming the first-scale network and nanoscale (Ti, Zr)$_5$Si$_3$ precipitates developing the secondary-scale network.

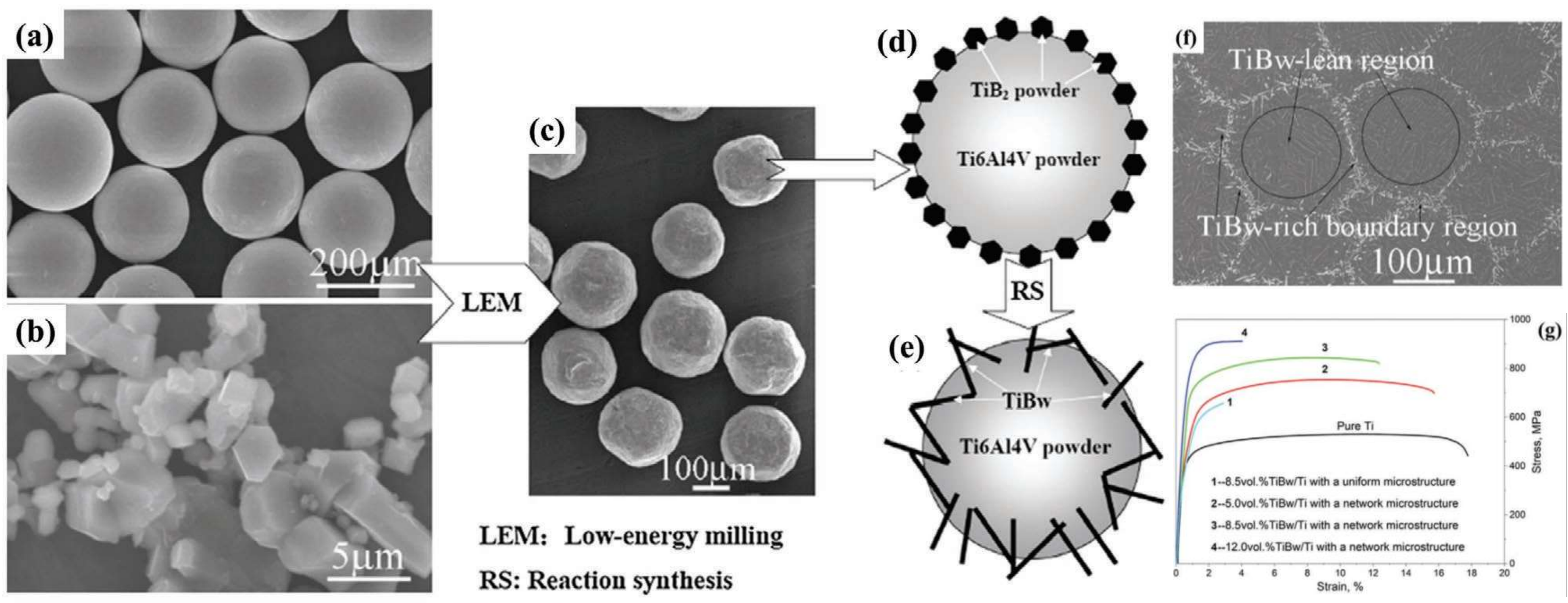

Figure 4. The fabrication process, microstructure, and room tensile properties of DRTMCs with type-I network.

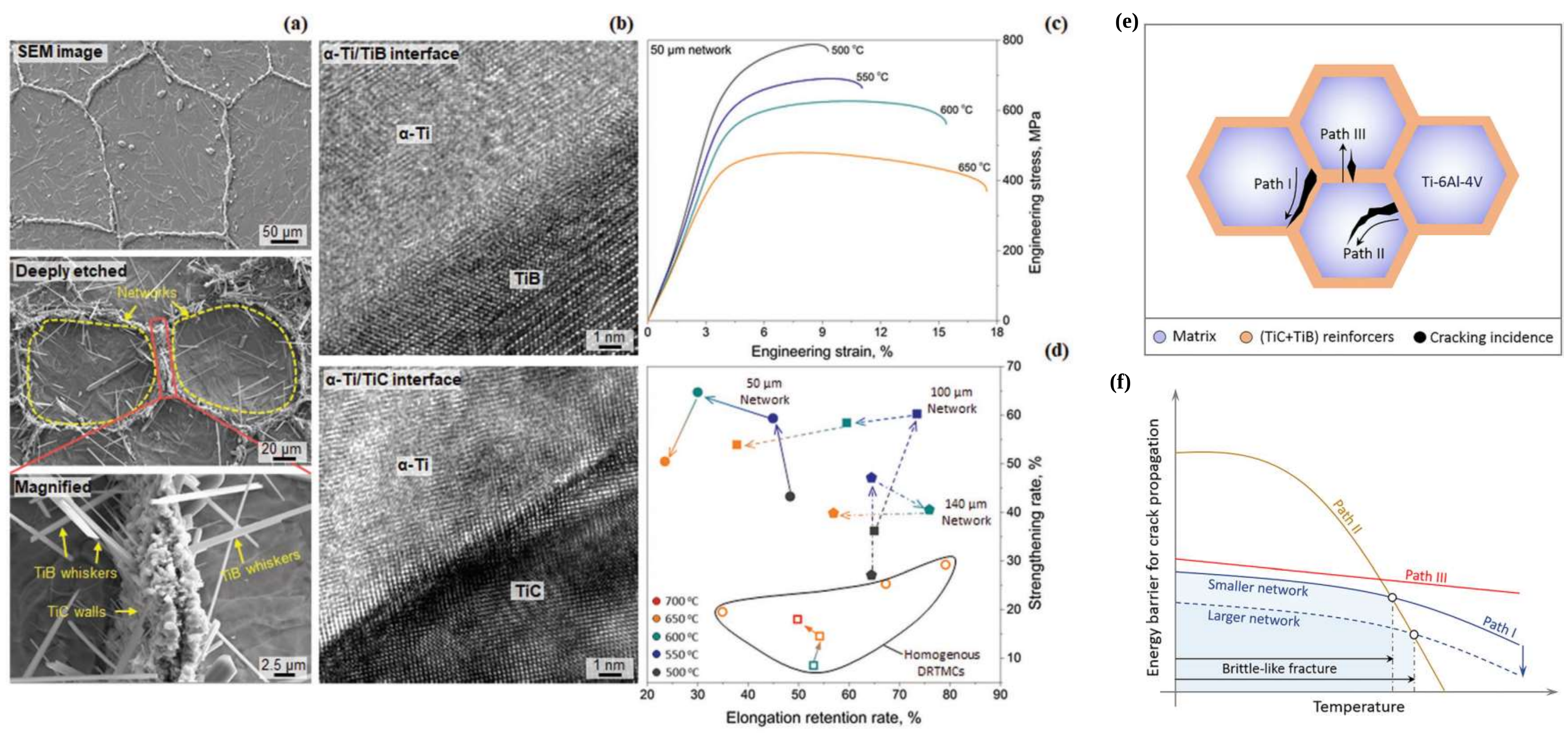

Figure 5. Design and tensile properties of (TiC+TiB)/Ti64 DRTMCs with Type-II network.

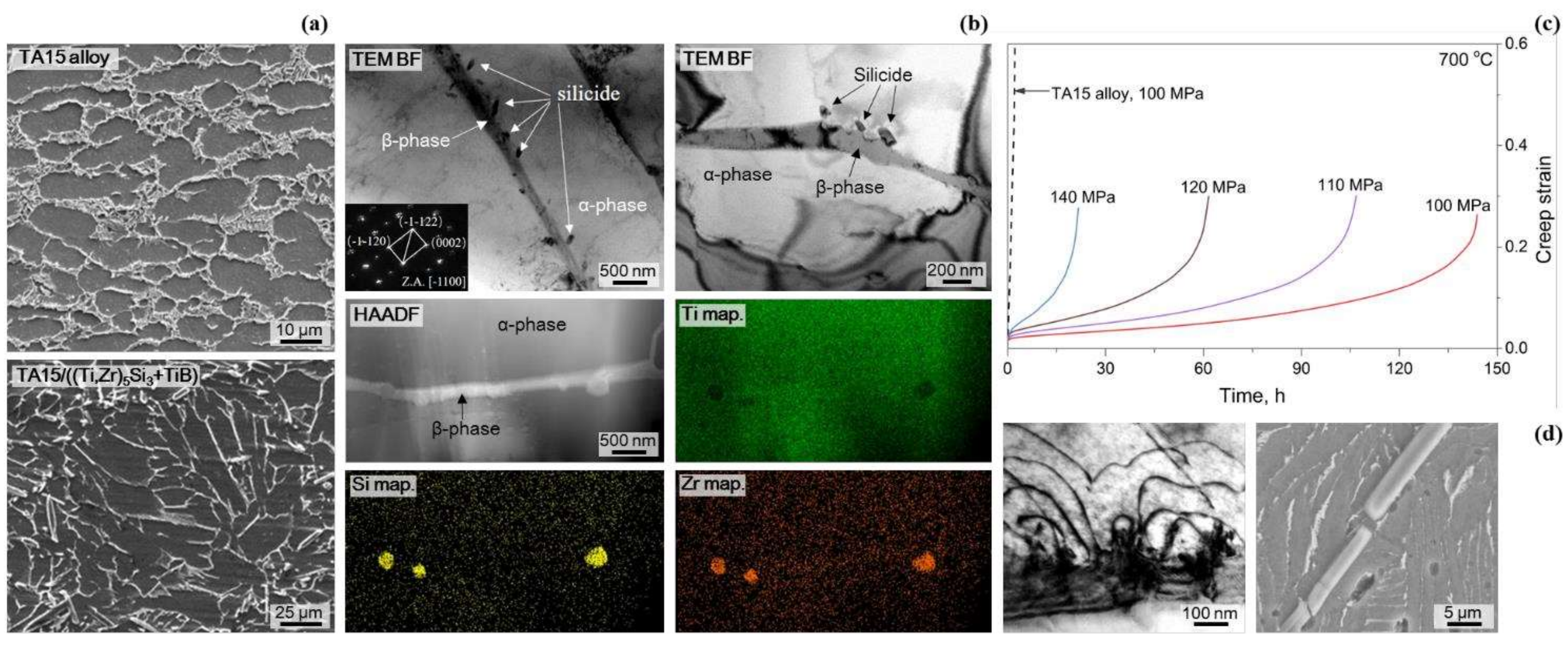

Figure 6. Microstructure and creep response of the ((Ti, Zr)$_5$Si$_3$+TiB)/TA15 DRTMCs with Type-III network

CONCLUSIONS

1. Tailoring the reinforcement distribution to a network microstructure can increase the ductility of TiB/Ti composites by 5-fold than that with a homogenous microstructure.
2. The significant specific strength deterioration temperature was extended up to ≈ 700ºC.
3. The creep rupture time of DRTMCs can be increased by 59-fold compared with conventional due to the presence of both dislocation pinning at the (Ti, Zr)$_5$Si$_3$ site and load transfer at the network boundary.