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Phase Stability and Microstructural Evolution in Vanadium-Titanium Alloys with Oxygen Dissolution and Varying Titanium-content

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Continuously diminishing fossil fuel resources, environmental concerns and changing geo-political scenario have incentivised the search of alternative energy resources and technologies. In this changing scenario, hydrogen may evolve as a new energy currency. It has been realised that single point solution to this energy problem is not quite achievable due to the limitation arising out of resources, climatic conditions etc. Judicious selection of energy technologies and its exploitation in its most efficient form is the way forward. Vanadium alloys have attracted attention in the recent past due to its high-temperature strength, low activation, fast decay characteristics, non-magnetic properties. In addition to that vanadium alloys may be used in metal hydride batteries due to its ability to absorb hydrogen. However, the kinetics of hydrogen absorption-desorption is strongly dependent on the alloying elements present in the alloy. Last decade has observed an upsurge in research activities in development, processing and characterisation of vanadium alloys with a view to apply this material in fusion reactors and in metal-hydride batteries. In course of this development, mostly two alloys have received most attention and those are V-4Ti-4Cr and V-4Ti-4W. Both the alloys are in the vanadium rich corner of the phase diagram. As cast alloys are single phase BCC in structure. It has been observed that the alloys possess high strength up to high temperature. However, processing ability of these alloys are limited. Additionally, the alloys have strong affinity to oxygen, carbon, nitrogen etc. When the above elements are absorbed in minute quantities they are dissolved in the BCC solid solution and incorporation beyond a certain limit leads to the precipitation of oxide or carbide phases in the matrix. In order to study the effect of oxygen dissolution, pure vanadium was heated by pulsed laser in a controlled oxygen atmosphere. Post heating experiment, the sample was thinned from the back and was made electron transparent to study the effect of oxygen incorporation. It has been observed through electron energy loss spectroscopy that oxygen dissolution gradually decreases from the surface. Due to oxygen incorporation a new phase is nucleated at the surface which is plate like in morphology. The diffraction pattern from the plate like phase indicates that it is related to the cubic phase. However, there is elongation along the c-axis and contraction along the a- and b-axes. First principles DFT calculation also indicates that oxygen incorporation introduces strain in the lattice and in order to accommodate the strain the BCC structure transforms to tetragonal structure. The tetragonal phase has been observed in high resolution phase-contrast imaging. In high resolution imaging individual atomic columns could be observed. However, in certain localised regions intensity delocalisation could be observed. Through multislice simulation it has been observed that the intensity delocalisation is mainly due to the presence of atomic scale strain fields in the oxygen incorporated alloy. Similar tetragonal phases are observed in V-Ti binary alloys also which has been synthesized by vacuum-arc melting in an argon back-filled chamber. The morphology of the phase also remains the same. It is believed that the nucleation of the tetragonal phase in V-Ti alloy is also related to the oxygen incorporation effect. The stability of this phase over temperature is currently being studied by in-situ electron microscopy. The as-melted alloys have been characterized by X-Ray diffraction studies in a high-resolution Diffractometer using Cu-target. The I vs. 2θ plots hence generated from the cast alloys, when stacked vertically above the plot of pure vanadium revealed a consistent left-ward shift of the fundamental peaks coming from the bcc alloy. This implies that upon alloying vanadium with increasing Ti-content, lattice parameter of the disordered bcc unit cell also went up by small fractions of an angstrom unit to accommodate it. But as it turns out from extensive TEM investigations, such straight forward interpretation is perhaps not true and the leftward shift in the peak positions arise due to convolution of several effects at the sub-microstructural level.

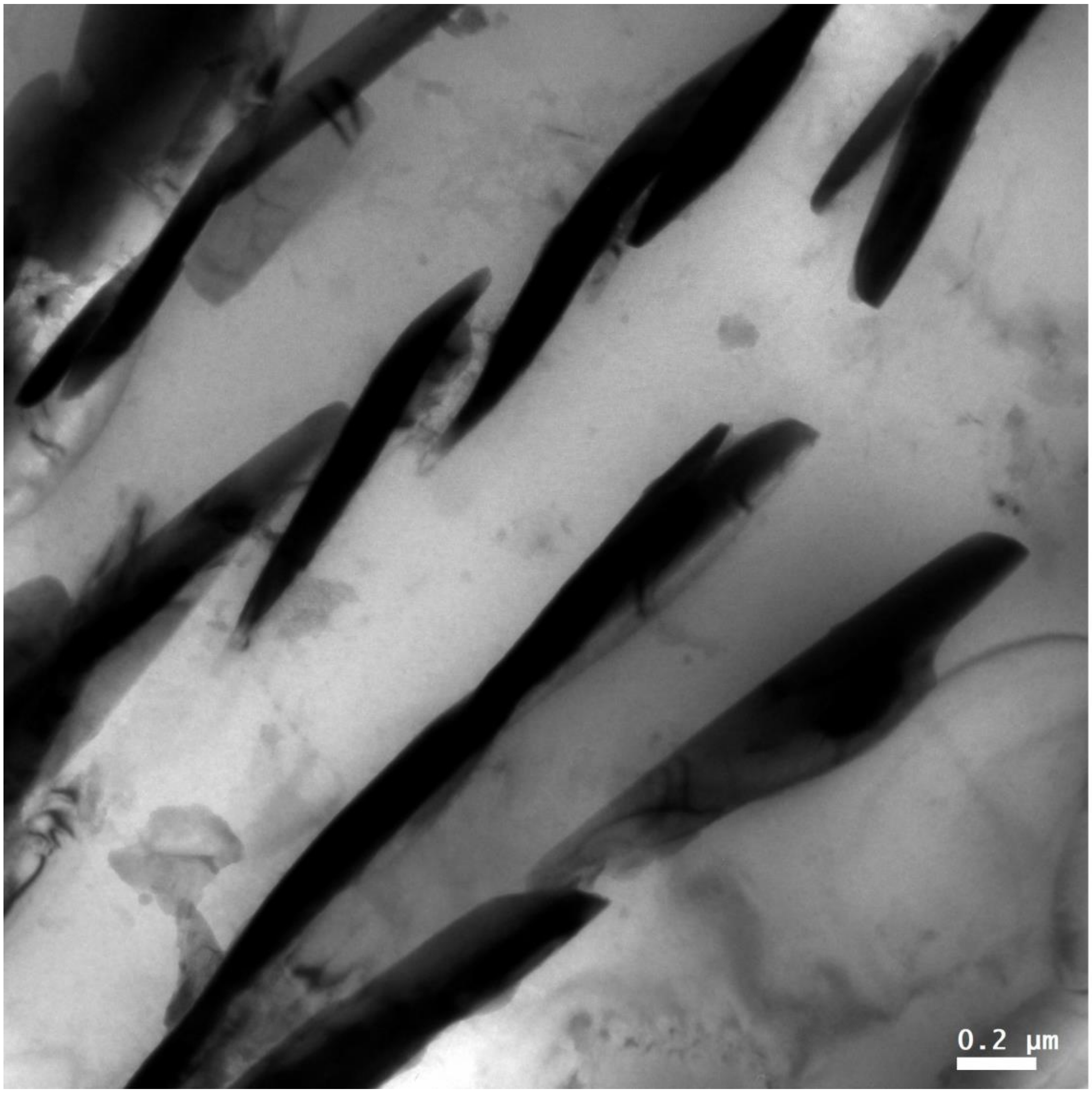

Figure 1. Whisker like morphology found in the cubic matrix phase of V-15wt%Ti alloy. Associated diffraction pattern reveals spot-splitting and extensive diffuse scattering.

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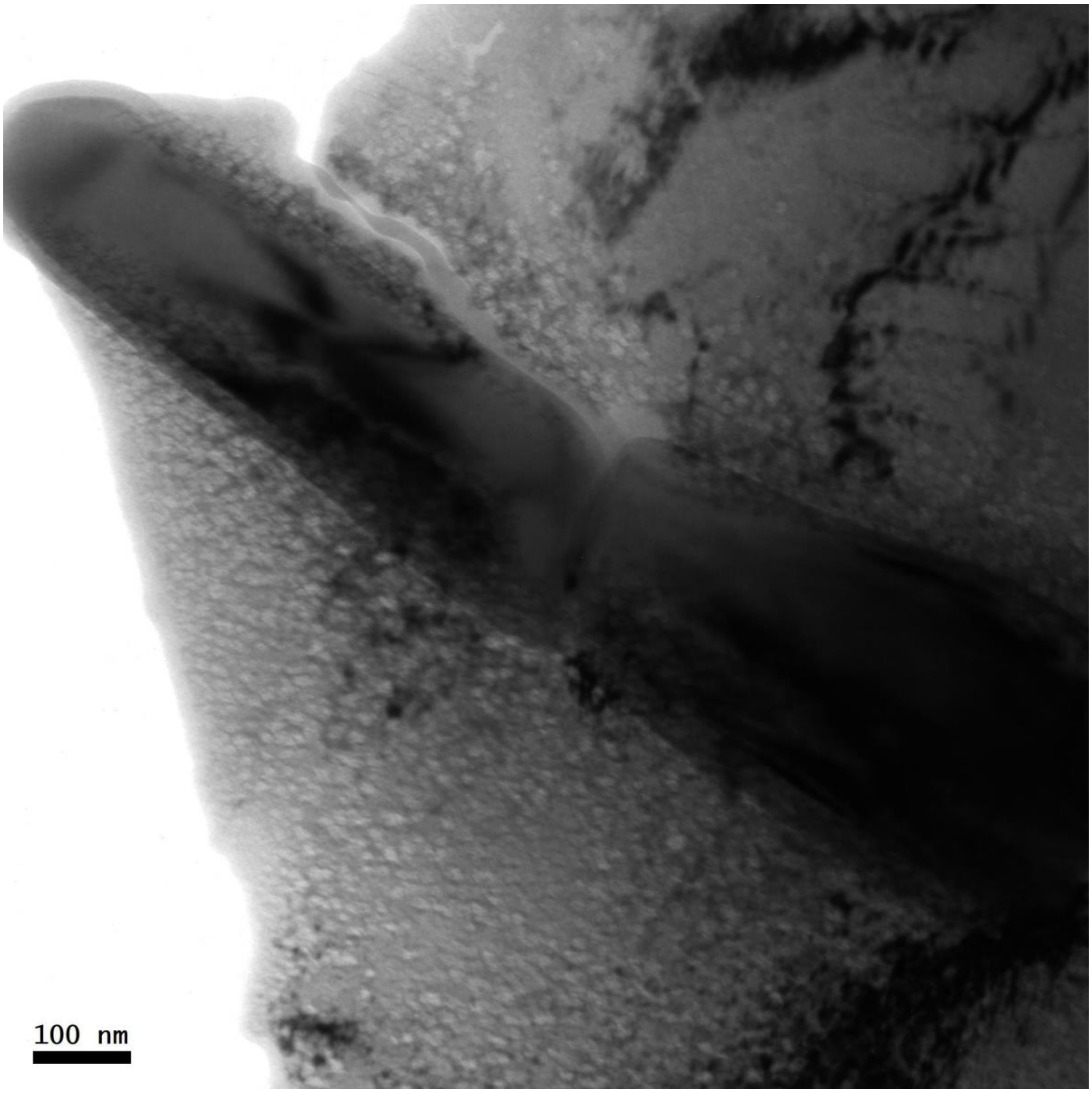

Figure 2. Highly anisotropic growth behaviour of the lath/whisker like feature in V-30wt%Ti alloy, which is believed to be assisted by dissolved oxygen and initial stages of phase separation.

References

[1] S.J. Zinkle, H. Matsui, D.L. Smith, A.F. Rowcliffe, E. van Osch, K. Abe, V.A. Kazakov, Research and development on vanadium alloys for fusion applications, J. Nucl. Mater. 258–263 (1998) 205–214
[2] Chanchal Ghosh, Akash Singh, Joysurya Basu, Divakar Ramachandran, E. Mohandas, Microstructural and microchemical studies of phase stability in V-O solid solution, Materials Characterization 124 (2017) 129–135
[3] Chanchal Ghosh, Joysurya Basu, Divakar Ramachandran, E. Mohandas, "Phase separation and ω-transformation in binary V-Ti and ternary V-Ti-Cr alloys" Acta Materialia 121, 2016, 310-324.
[4] Li-JiangGui, Yue-LinLiu, First-principles studying the properties of oxygen in vanadium: Thermodynamics and tensile/shear behavior, Computational Condensed Matter 7 (2016) 7-13.