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Preface

Preface to the viewpoint set: Triple lines

A triple line is the site of common contact between three phases, be they solid, liquid or vapour. Triple lines are ubiquitous in everyday life but also have considerable importance in materials science. In metals and ceramics, triple lines are found where a liquid contacts a solid, where three crystals meet or where a liquid meets a grain boundary; at high temperature all these triple lines can move. In every one of these instances, the triple line is a site of complex phenomena that govern the processing, the microstructural development and the properties of many engineering materials. This complexity arises for a number of reasons: triple lines are dominated by capillarity, are thermodynamically and chemically complex, and furthermore are often sites of singularity – in elasticity, for example.

Given their importance and ubiquity, triple lines are a recurrent research theme in the materials science community. The important subject of wetting, of both metals and ceramics by high-temperature liquids, has such importance in the processing of inorganic materials that it is now the subject of dedicated conferences and publications. Dihedral angles, of importance both in processes such as liquid phase sintering and in phenomena such as liquid metal embrittlement, are another subject that has driven a number of research groups to devote significant effort leading to intriguing results and important contributions. Where three grains meet, triple lines again appear; grain boundary triple lines exert an important influence in processes such as recrystallization and grain growth, particularly of fine-grained materials; here too important and interesting contributions have recently been made. One could continue the list of venues where the subject has been a rich and important focal point of research, such as the materials science of thin films, the mechanics of joints, or our understanding of nucleation and growth, both in solidification and in solid-state transformations.

The subject is important and rich, yet it has seldom been declared or addressed per se, with the view that a triple line is, with the dislocation and the crack tip, one of the generic line defects in materials science, having laws and features of its own that go beyond the specific guise, context or angle in which it may appear. This observation formed the starting point of the present viewpoint set, which was designed to bring together a number of authors who have, in different ways and different venues, contributed to our understanding of triple lines in metals and ceramics.

In relatively refractory materials, such as metals and ceramics, interatomic bonding is dominated by chemical bonds. Triple lines in metals and ceramics therefore typically come with elevated linear forces and energies, and in that sense differ fundamentally from low-temperature aqueous or organic systems, in which triple line phenomena are typically governed by weaker physical bonding forces (these have been the subject of much recent work, in contexts such as superhydrophobicity). These differences are manifest in the higher energies, higher stresses and higher temperatures generally characteristic of metal and ceramic triple lines.

The topics addressed here include the physics and chemistry of wetting at both free surfaces and grain boundaries, the interplay between capillarity and mechanical, physical or chemical phenomena, and the relation between these phenomena and materials processing, structure and performance. The authors are from diverse backgrounds, but have all been engaged in the study of triple lines in one or a few of their many variegated manifestations. Our goal in organizing this *Scripta Materialia* viewpoint set was to compose a broad panoramic view of the state of the art on this topic, which may perhaps serve to define future directions and challenges on this interesting and important, yet in a sense relatively young and discreet, cross-cutting topic of materials science.

This viewpoint set was timed so as to appear just ahead of a two and a half day workshop at the Centre de Physique des Houches, Savoie, France, to be held on 25–28 May 2010 in honour of the retirement of Dr. Nicholas Eustathopoulos, who has performed seminal research on the physics and chemistry of triple lines that govern wetting, of both solids and grain boundaries. It is our hope that the reader will find this collection of articles, and the links that appear between these, an interesting and somewhat different window into current research in materials science and engineering.

The viewpoint set begins with a general overview article by A.H. King entitled “Triple lines in materials science and engineering”; this is followed by a second article focusing on triple lines in the general sense, by W.C. Carter, M. Baram, M. Drozdov and W.D. Kaplan and entitled “Four questions about triple lines”.

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Triple lines influence the microstructural development of crystalline materials from their very inception: "Triple lines in nucleation" are presented and discussed by A.L. Greer in the following contribution. This influence continues in solidification, in solid-state phase transformations, and in recrystallization and grain growth. These three aspects are addressed in the following three articles of the viewpoint set: "The influence of solid–liquid interfacial energy anisotropy on equilibrium shapes, nucleation, triple lines and growth morphologies" by M. Rappaz, J. Friedli, A. Mariaux and M.A. Salgado-Ordorica; "The role of triple line in solid-state microstructural evolutions: interplay with interfaces and consequences on instabilities and pattern selection" by Y.J.M. Brechet; and "Thermodynamics and kinetics of grain boundary triple junctions in metals – recent developments" by G. Gottstein, L.S. Schwindlerman and B. Zhao.

The dihedral angle is a well-known triple line that has considerable influence both in the processing and the in-service performance of materials, particularly at high temperature. The next three articles – "Strains and stresses caused by penetrative wetting of grain boundaries by the liquid phase" by L. Klinger and E. Rabkin, "Grain boundary ridges and triple lines" by B.B. Straumal, V.G. Sursaeva and B. Baretzky, and "The role of dihedral angle on the control of skeleton coordination and pore closure in aggregates driven by capillary force" by F. Delannay – are focused on this particular triple line variant.

Another well-known triple line is the wetting angle. Two articles provide a view on both experimental and theoretical approaches to the fundamentals of wetting by metals and ceramics: "Early stages of dissolutive spreading" by E. Saiz, J. De Coninck, M. Benhassine and A.P. Tomsia, and "Approaches to atomistic triple-line properties from first principles" by A. Hashibon and C. Elsaesser.

The viewpoint set then presents a series of articles that address the impact of triple lines in materials processing. Two, namely "A role of wettability in metal–ceramics joining" by K. Nogi and "Wetting in high-temperature materials processing: the case of Ni/MgO and NiW10/MgO" by N. Sobczak, R. Nowak, R. Asthana and R. Purgert, illustrate how the sessile drop experiment can be adapted for processing-oriented investigations. One article addresses the influence of triple lines in crystal growth: "On the twinning occurrence in bulk semiconductor crystal growth" by T. Duffar and A. Nadri. The viewpoint set then closes with two articles from research groups who address wetting in infiltration processing: "On the triple line in infiltration of liquid metals into porous preforms" by J.M. Molina, J. Narciso and E. Louis, and "Reactive infiltration by Si: infiltration versus wetting" by N. Eustathopoulos, R. Israel, B. Drevet and D. Camel.

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