A review by Hani Henein, University of Alberta, of

Principles of Metal Refining and Recycling
by
Thorvald Abel Engh, Geoffrey K. Sigworth and Anne Kvithyld

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We live at a time when the teaching of extractive metallurgy has been in decline in many University Materials Science and Engineering Programs across North America. However, we also see a growing demand in society for increased stewardship of our natural resources and the demand of a circular economy. This requires new societal demands for increased recycling. We also live during a period in history that is unprecedented in terms of advancement in technology and in the variety of sophisticated consumer electronic products. For example, mobile phones in 1997 had 11 elements compared to 24 in 2008; and presently as much as 75 elements are used in making a smartphone. The average lifespan of a smartphone is two to three years. Few are collected and recycled. Yet smartphones contain many critical materials. This book is an essential compendium of the many metals used in society and how they are processed and recycled. A critical feature in recycling is the control of impurities in metals and alloys. These impurities are of two types. Those that improve properties and those that degrade them.

This compendium of knowledge deals with wanted and unwanted impurities in metals and alloys. It is a very welcome addition to our literature. It is divided into three parts. The first provides the metallurgical basis for controlling impurities in metals and alloys. It addresses the implications on properties (tensile, ductility, yield strength, electrical conductivity, magnetic properties, fatigue, toughness, fracture, and corrosion) of dissolved elements, precipitates and inclusions. The second part of the book covers in six chapters the fundamentals of molten metal treatment for removal of such impurities. The molten state of any metal processing operation is the last, easiest and cheapest operation to control the chemistry, purity or alloying content of a metal or alloy. These operations are characterized by a score of fundamentals, such as thermodynamics, mass transfer and modeling. The basics of each of these topics is outlined and applied to address impurity control, formation and removal of inclusions, solidification and the addition of alloying elements. Each of these chapters is so comprehensive, they could each form a graduate level course in a university program.

The third part of the book is a descriptive overview of the processes and applications of the principles described in the earlier chapters to 37 elements and a detailed discussion of recycling methodologies.

The book is also self-contained providing tables of important thermodynamic properties, such as standard Gibbs Free Energies for solution of elements to a 1% mass solution in liquid aluminum, iron, copper, silicon and cobalt. Interaction coefficients for ternary alloys for aluminum, iron, copper, silicon and cobalt are also provided. Transport properties of gases and liquid metals are

presented along with a detailed description of the theory in predicting the viscosity and surface tension of liquid metals.

With over 800 references, this book will require some very careful and intense study. The one critique of the book is that it is missing any reference to hydro and electro processing of refining and recycling of metals and alloys. But given that all co-authors have experience in the pyro field, it is understandable. However, this could be a thoughtful addition for a 2nd editions. The book is well written and clearly provides a comprehensive up-to-date summary of our knowledge base in controlling impurities in molten metal processing and recycling. It will hopefully initiate a renaissance of research and training of a new generation of materials scientists and engineers in metal refining and recycling.