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# Ternary Alloy Systems

## Phase Diagrams, Crystallographic and Thermodynamic Data

**critically evaluated by MSIT®**

Subvolume C

Non-Ferrous Metal Systems

Part 2

Selected Copper Systems

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# Preface

The sub-series *Ternary Alloy Systems of the Landolt-Börnstein New Series* provides reliable and comprehensive descriptions of the materials constitution, based on critical intellectual evaluations of all data available at the time, and critically weights the different findings, also with respect to their compatibility with today's edge binary phase diagrams. Selected are ternary systems of importance to industrial alloy development and systems which gained scientific interest in the recent years otherwise. In a ternary materials system, however, one may find alloys for various applications, depending on the chosen composition.

Reliable phase diagrams provide scientists and engineers with basic information of eminent importance for fundamental research and for the development and optimization of materials. So collections of such diagrams are extremely useful, if the data on which they are based have been subjected to critical evaluation, like in these volumes. Critical evaluation means: where contradictory information is published data and conclusions are being analyzed, broken down to the firm facts and re-interpreted in the light of all present knowledge. Depending on the information available this can be a very difficult task to achieve. Critical evaluations establish descriptions of reliably known phase configurations and related data.

The evaluations are performed by MSIT®, Materials Science International Team, a group which has been working together for 20 years now. Within this team skilled expertise is available for a broad range of methods, materials and applications. This joint competence is employed in the critical evaluation of the often conflicting literature data. Particularly helpful in this are targeted thermodynamic calculations for individual equilibria, driving forces or complete phase diagram sections.

Insight in materials constitution and phase reactions is gained from many distinctly different types of experiments, calculation and observations. Intellectual evaluations which interpret all data simultaneously reveal the chemistry of a materials system best. The conclusions on the phase equilibria may be drawn from direct observations e.g. by microscope, from monitoring caloric or thermal effects or measuring properties such as electric resistivity, electro-magnetic or mechanical properties. Other examples of useful methods in materials chemistry are mass-spectrometry, thermo-gravimetry, measurement of electro-motive forces, X-ray and microprobe analyses. In each published case the applicability of the chosen method has to be validated, the way of actually performing the experiment or computer modeling has to be validated and the interpretation of the results with regard to the material's chemistry has to be verified.

An additional degree of complexity is introduced by the material itself, as the state of the material under test depends heavily on its history, in particular on the way of homogenization, thermal and mechanical treatments. All this is taken into account in an MSIT® expert evaluation.

To include binary data in the ternary evaluation is mandatory. Each of the three-dimensional ternary phase diagrams has edge binary systems as boundary planes; their data have to match the ternary data smoothly. At the same time each of the edge binary systems A-B is a boundary plane for many ternary A-B-X systems. Therefore combining systematically binary and ternary evaluations can lead to a new level of confidence and reliability in both ternary and binary phase diagrams. This has started systematically for the first time here, by the MSIT® Evaluation Programs applied to the Landolt-Börnstein New Series.

The multitude of correlated or inter-dependant data requires special care. Within MSIT® an evaluation routine has been established that proceeds knowledge driven and applies both human based expertise and electronically formatted data and software tools. MSIT® internal discussions take place in almost all evaluations and on many different specific questions, adding the competence of a team to the work of individual authors. In some cases the authors of earlier published work contributed to the knowledge base by making their original data records available for re-interpretation. All evaluation reports published here have undergone a thorough review process in which the reviewers had access to all the original data.

In publishing we have adopted a standard format that provides the reader with the data for each ternary system in a concise and consistent manner, as applied in the MSIT® Workplace: Phase Diagrams Online. The standard format and special features of the Landolt-Börnstein compendium are explained in the Introduction to the volume.

In spite of the skill and labor that have been put into this volume, it will not be faultless. All criticisms and suggestions that can help us to improve our work are very welcome. Please contact us via effenberg@msiwp.com. We hope that this volume will prove to be an as useful tool for the materials scientist and engineer as the other volumes of Landolt-Börnstein New Series and the previous works of MSIT® have been. We hope that the Landolt-Börnstein Sub-series Ternary Alloy Systems will be well received by our colleagues in research and industry.

On behalf of the participating authors we want to thank all those who contributed their comments and insight during the evaluation process. In particular we thank the reviewers – Andy Watson, Pierre Perrot, Rainer Schmid-Fetzer, Peter Rogl, Olga Fabrichnaya, Lazar Rokhlin, Nataliya Bochvar, Nathalie Lebrun, Hari Kumar, Tamara Velikanova, Anatoliy Bondar, Gabriele Cacciamani, Matvei Zinkevich, Artem Kozlov, Ludmila Tretyachenko, Joachim Gröbner, Marina Bulanova, Volodymyr Ivanchenko, Paola Riani.

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