# Contents

**List of Contributors**

page vii

1. Introduction

SARA S. RUSSELL, HAROLD C. CONNOLLY JR., AND ALEXANDER N. KROT

**Part I  Observations of Chondrules**

9

2. Multiple Mechanisms of Transient Heating Events in the Protoplanetary Disk: Evidence from Precursors of Chondrules and Igneous Ca, Al-Rich Inclusions

ALEXANDER N. KROT, KAZUHIDE NAGASHIMA, GUY LIBOUREL, AND KELLY E. MILLER

3. Thermal Histories of Chondrules: Petrologic Observations and Experimental Constraints

RHIAN H. JONES, JOHAN VILLENEUVE, AND GUY LIBOUREL

4. Composition of Chondrules and Matrix and Their Complementary Relationship in Chondrites

DOMINIK C. HEZEL, PHIL A. BLAND, HERBERT PALME, EMMANUEL JACQUET, AND JOHN BIGOLSKI

5. The Chondritic Assemblage: Complementarity Is Not a Required Hypothesis

BRIGITTE ZANDA, ÉRIC LEWIN, AND MUNIR HUMAYUN

6. Vapor–Melt Exchange: Constraints on Chondrite Formation Conditions and Processes

DENTON S. EBEL, CONEL M. O’D. ALEXANDER, AND GUY LIBOUREL

7. Chondrules in Enstatite Chondrites

EMMANUEL JACQUET, LAURETTE PIANI, AND MICHAEL K. WEISBERG

8. Oxygen Isotope Characteristics of Chondrules from Recent Studies by Secondary Ion Mass Spectrometry

TRAVIS J. TENNER, TAKAYUKI USHIKUBO, DAISUKE NAKASHIMA, DEVIN L. SCHRADE, MICHAEL K. WEISBERG, MAKOTO KIMURA, AND NORIKO T. KITA
Table of Contents

9  $^{26}$Al–$^{26}$Mg Systematics of Chondrules 247
KAZUHIDE NAGASHIMA, NORIKO T. KITA, AND TU-HAN LUU

10 Tungsten Isotopes and the Origin of Chondrules and Chondrites 276
THORSTEN KLEINE, GERRIT BUDDE, JAN L. HELLMANN, THOMAS S. KRUIJER, AND CHRISTOPH BURKHARDT

11 The Absolute Pb–Pb Isotope Ages of Chondrules: Insights into the Dynamics of the Solar Protoplanetary Disk 300
JAMES N. CONNELLY AND MARTIN BIZZARRO

12 Records of Magnetic Fields in the Chondrule Formation Environment 324
ROGER R. FU, BENJAMIN P. WEISS, DEVIN L. SCHRADER, AND BRANDON C. JOHNSON

Part II Possible Chondrule-Forming Mechanisms 341

13 Formation of Chondrules by Planetesimal Collisions 343
BRANDON C. JOHNSON, FRED J. CIESLA, CORNELIS P. DULLEMOND, AND H. JAY MELOSH

14 Making Chondrules by Splashing Molten Planetesimals: The Dirty Impact Plume Model 361
IAN S. SANDERS AND EDWARD R. D. SCOTT

15 Formation of Chondrules by Shock Waves 375
MELISSA A. MORRIS AND AARON C. BOLEY

16 Evaluating Non-Shock, Non-Collisional Models for Chondrule Formation 400
ALEXANDER HUBBARD AND DENTON S. EBEL

17 Summary of Key Outcomes 428
HAROLD C. CONNOLLY JR., ALEXANDER N. KROT, AND SARA S. RUSSELL

Index 437

Colour plate section to be found between pages 246 and 247