Laser probe mass spectrometric study of nitrogen and noble gases in individual chondrules from different classes of chondrites

## **A THESIS**

submitted for the Award of Ph.D. degree of

## MOHANLAL SUKHADIA UNIVERSITY

in the

Faculty of Science

6у

JP Das



Under the Supervision of

Prof. S. V. S. Murty

PLANETARY AND GEOSCIENCE DIVISION
PHYSICAL RESEARCH LABORATORY, AHMEDABAD

## **MOHANLAL SUKHADIA UNIVERSITY**

**UDAIPUR** 

Year of submission: 2007

## **Contents**

Acknowledgements		i iii
Abstract List of Tables		
		iv
List of	rigures	•
Chapte		
Introdu		
1.1	What are chondrules?	3
1.2	Chondrule classification	5
1.3	Thermal histories of chondrules	9
1.4	Type-I and Type-II chondrules: genetically related?	11
1.5	Chemical and isotopic studies of chondrules	11
1.6	The setting for chondrule formation: Nebular or Planetary origin	15
1.7	Noble gases in chondrites	16
1.8	Noble gases in chondrules	16
1.9	In-situ produced noble gas components	17
1.10	Trapped noble gas components	18
1.11	Nitrogen in Meteorites	21
1.12	Objective of the present study	25
1.13	Earlier studies of noble gases and nitrogen related to present work	27
1.13.1	Noble gas studies on chondrules	27
1.13.2	Nitrogen studies on chondrules	29
Chapte	r 2	
	mental details	
2.1	Introduction	31
2.2	Selection of chondrites	31
2.3	Separation of chondrules	32
2.4	The VG Micromass 1200	34
2.5	Gas extraction units	34
2.5.1	Laser microprobe (used for chondrule analyses)	35
2.5.2	The glass extraction system (used for bulk chondrite analysis)	41
2.6	Standard procedures	46
2.6.1	Gas extraction from chondrules	46
2.6.2	Gas extraction from bulk chondrite samples	47
2.6.3	Cleaning and separation (Laser microprobe)	48
2.6.4	Cleaning and separation (Glass extraction system)	49
2.6.5	Mass analysis	50
2.6.6	Data acquisition and reduction	50
2.6.7	Calibration of the mass spectrometer	53
2.7	Chemical characterization of chondrules	55
2.7.1	Method to determine the chemical composition of chondrule	55
2.7.2	Limitations of EPMA method	56
2.7.3	Petrographic and Mineralogical descriptions of chondrules	57

Chan		
Chap	gases in chondrules -in situ produced components	
3.1	Introduction	72
3.2	Calculations of cosmogenic and radiogenic noble gases	73
3.3	Results	75
3.3.1	Cosmogenic noble gases ( <sup>3</sup> He, <sup>21</sup> Ne and <sup>38</sup> Ar)	75
3.3.2	Production rates ( <sup>3</sup> He, <sup>21</sup> Ne and <sup>38</sup> Ar) and cosmic ray exposure age of chondrules	95
3.3.3	Radiogenic noble gases ( <sup>4</sup> He, <sup>40</sup> Ar and <sup>129</sup> Xe)	110
3.3.4	Gas retention ages (T <sub>4</sub> , T <sub>40</sub> ) of chondrules	119
3.4	Discussion	121
3.4.1	Loss of cosmogenic and radiogenic noble gases from chondrules	121
3.4.2	Precompaction exposure of chondrules and duration of their formation	122
3.4.3	Precompaction irradiation and exposure to solar cosmic rays	125
3.5	Summary	
	2 WALLAND Y	127
Chap	ter 4	
Noble	gases in chondrules -trapped components	
4.1	Introduction	130
4.2	Calculations of trapped noble gases	131
4.3	Results	133
4.3.1	Trapped <sup>20</sup> Ne	133
4.3.2	Trapped <sup>36</sup> Ar	142
4.3.3	The elemental ratio <sup>36</sup> Ar/ <sup>20</sup> Ne in chondrules	142
4.4	Discussion	145
4.4.1	Presence of different noble gas components in chondrules	145
4.4.2	Solar type noble gases in chondrules	150
4.5	Summary	154
Chan	4	
Chap	ped nitrogen in chondrules	
5.1	Introduction	157
5.2	Corrections of the measured δ <sup>15</sup> N for cosmogenic contribution	157
5.3	Results	159
5.4	Discussion	171
5.4.1	Did the chondrule-forming event affect the N-compositions?	173
5.4.2	Did chondrules act as open systems during their formation?	175
5.4.3	N-components in chondrules/ chondrule precursors	177
3.4.3	•	1//
5.4.4	Nature of N-component required for chondrules of ordinary and carbonaceous chondrites in addition to HL and Q components	179
5.4.5	Heterogeneity in chondrule precursors and survival of various N-components	181
5.4.6	Uniform N-composition of EC chondrules	185
5.5	Summary	186
Chap	ter 6	
	cations to the chondrule formation process and future directions	
6.1	Introduction	189
6.2	Cosmogenic noble gases and precompaction irradiation records in chondrules	189
63	Evidence of fractionation between metal and silicate phases during chondrule	100

189

191

6.3

6.4

formation

Solar type noble gases in chondrules

6.5	Trapped components of nitrogen in chondrules: presence of Insoluble organic matter in chondrules	191
6.6	Possible scenario to account for trapped N and noble gas compositions	194
6.7	Uniform N-composition of EC chondrules: are chondrules formed in planetary environment?	195
6.8	Future Directions	197
Appe	ndix	198
Refer	References	