



Contents

Chapter 1. Introduction	1
Chapter 2. Theoretical background	5
2.1 Nanostructured materials	5
2.1.1 Categorization of nanostructured materials	6
2.2 Synthesis of nanostructured materials	7
- Electrodeposition	8
- Inert gas condensation	8
- Devitrification of amorphous phases	9
- Equal-channel angular pressing (ECAP)	9
- Ball milling	9
2.3. Mechanisms of nanostructure formation	12
- Electrodeposition	13
- Inert gas condensation	13
- Devitrification of amorphous phases	13
- Equal-channel angular pressing (ECAP)	14
- Ball milling	14
2.4 Structure of grain-boundaries	18
2.5 Thermal stability	21
2.6 Consolidation of nanostructured powders	23
- Ex-situ consolidation	23
- In-situ consolidation	24
2.7 Properties of nanocrystalline materials	26
2.7.1 Physical properties	26
- Diffusion	26
- Elastic properties	26
2.7.2 Mechanical properties	26
- Yield strength	27
- Ductility	27
- Work-hardening	28
- Strain rate sensitivity	28
- Inverse Hall-Petch effect	29



2.7.3 Deformation behavior	30
- Grain-boundary sliding	30
- Core and mantel	30
- Grain-boundary rotation/grain coalescence	32
Chapter 3. Sample preparation and characterization	35
3.1 Preparation of nanostructured powders	35
3.2 Microstructural characterization	36
3.2.1 X-ray diffraction	37
- X-ray analysis	37
- Classical and modified Williamson-Hall methods	38
- Whole powder pattern modeling (WPPM)	39
3.2.2 Scanning electron microscopy (SEM)	40
3.2.3 Transmission electron microscopy (TEM)	41
Chapter 4. Grain- and substructure-size evaluated by XRD, SEM and TEM	43
4.1 Classical and modified Williamson-Hall methods	45
4.2 Whole powder pattern modeling (WPPM)	49
Chapter 5. Nanostructure formation during ball milling of Cu-based alloys	53
5.1. Effect of stacking-fault energy on nanostructure formation during cryomilling	53
5.1.1 Nanostructure formation during cryomilling of Cu-Zn powder mixtures	54
5.1.2 Nanostructure formation during cryomilling of Cu-Al powder mixtures	67
5.2. Nanostructure formation during cryomilling and subsequent room temperature milling	79
Chapter 6. Thermal stability of nanostructured Cu and Cu-based alloys	87
Chapter 7. Conclusions	101
References	109
Declaration	127