Chapter 6
Conclusions

There can be no doubt that NMs with their unique properties will remain a major focus of interest for the material science investigations and effective innovation activities in the twenty-first century. This interest is conditioned not only by such materials with their very high mechanical, physical, chemical, and operational parameters, but also by these parameters stability under performance conditions, and the authors tried to consider and analyze this problem in their monograph. The data presented give many evidences of NMs stability under the extreme conditions including high temperatures and pressures, as well as irradiation and mechanical/corrosion actions. A high general potential of using NMs under these conditions due to the presence of numerous low-energy interfaces, nanotwinned and gradient surface structures, etc. is considered. Great perspectives of these structures and, above all, gradient objects are also highlighted in many recent publications (e.g., [1–5]). It should also be noted the continuous increasing accumulation of general nano-information that the authors sought to consider adding references to the latest publications at the end of each of the Chaps. 2–5.

To our regret, many nano-objects and materials (such as nanosemiconductors, quantum dots, nanoclusters, nanoparticles and nanotubes, fullerites, graphenes, polymers, hybrid and amorphous nanocomposites, etc.) remain mainly beyond consideration or are analyzed very fluently.

Discussing the stability problems, the authors tended to mark the poorly understood questions, and it seems useful to itemize them in short:

1. The experimental studies of NMs behavior under extreme conditions still remain short as well as insufficient, and therefore, they must be prolonged, widened, and deepened.
2. The theoretical approaches and modeling of the NMs stability mechanisms under extreme conditions must be developed, especially for the synergy effects during possible combined actions.
3. At last, it is necessary to optimize the technological processing regimes of some universal NMs capable to withstand various extreme loadings.

Alas, today the nanostructured approach application to heat-resistant materials, nuclear ones, and other advanced objects remains obviously insufficient. The

R.A. Andrievski and A.V. Khatchoyan, *Nanomaterials in Extreme Environments*,
Springer Series in Materials Science 230, DOI 10.1007/978-3-319-25331-2_6

authors hope that their modest book will be useful and provide some additional insights into NMs opportunities.

In his well-known lecture (1959) titled "There is a plenty room at the bottom", Richard Feynman invited scientists to a new physical world. Now, this "plenty room at the bottom" is gradually filling in by new mechanical objects, materials, and systems, creating new opportunities, challenges, and problems. The deep understanding of new fundamental features of the nanoworld allows us to create fantastic new materials for new giant projects. Much work to the realization of these plans lies ahead!

Acknowledgments The authors are very grateful to the Professor Dr. Herbert Gleiter for kind and inspiring attention as well as to the many colleagues and friends for sending their interesting papers. Supports from the Russian Basic Research Foundation and the Russian Academy of Sciences are also appreciated.

References

1. Zheng Sh, Beyerlein IJ, Carpenter JS et al (2013) High-strength and thermally stable bulk nanolayered composites due to twin-induced interfaces. Nature Commun 4:1696 (1–8)
2. Lu K (2014) Making strong nanomaterials ductile with gradients. Science 345:1455–1456
3. Wu XL, Jang P, Chen L et al (2014) Synergetic strengthening by gradient structure. Mater Res Lett 2:185–191
4. Wu XL, Jang P, Chen L et al (2014) Extraordinary strain hardening by gradient structure. Proc NAS 111:7197–7201
5. Andrievski RA (2015) The role of interfaces in nanomaterials behavior at extremes. Diffusion Found 5:147–170