

# Supplementary Materials: An Overview of Nano Multilayers as Model Systems for Developing Nanoscale Microstructures

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**Table S1.** Supplementary data for Figure 6 summarizing geometry parameters, surface energy parameters, and experimentally observed layer breakdown temperatures. All referenced data sets are nonequimolar binary NMM structures with experimentally observed microstructural transformations under heat treatment.

System	Alternating Layer Structure	Lattice Mismatch (%)	Geometry Parameter ( $r = b/a$ )	Surface Energy Mismatch	Layer Breakdown Temp (°C)	Norm. Average layer Breakdown Temp
Mo-Au [1]	BCC/FCC	-22.58	0.95	0.56	550	0.24
W-Cr [2]	BCC/BCC	-13.15	1.10	0.51	1000	0.34
Hf-Ti [3]	HCP/FCC	7.68	1.53	0.02	800	0.38
Ta-Hf [4]	BCC/HCP	3.40	0.96	0.22	1000	0.35
Ti-Ni [5]	FCC/FCC	18.10	1.18	0.15	600	0.38
W-Cu [6]	BCC/FCC	-14.01	1.07	0.57	800	0.28
Cu-W [6]	FCC/BCC	12.29	0.93	0.57	700	0.43
Nb-Al [7]	BCC/FCC	-22.59	0.78	0.93	600	0.29
Mo-Cu [8]	BCC/FCC	-14.30	1.07	0.39	800	0.32
Cu-Mo [8]	FCC/BCC	12.51	0.94	0.39	725	0.46
Cu-Nb [9]	FCC/BCC	8.25	0.89	0.43	607	0.45
Ta-Cu [10]	BCC/FCC	-8.81	1.12	0.44	700	0.29
Cu-Ta [11]	FCC/BCC	8.10	0.89	0.44	800	0.43

## References

1. Bahena, J.A.; Riano, J.S.; Chellali, M.R.; Boll, T.; Hodge, A.M. Thermally activated microstructural evolution of sputtered nanostructured Mo–Au. *Materialia* **2018**, *4*, 157–165.
2. Riano, J.S.; Hodge, A.M. Phase transformations in the W–Cr system at the nanoscale. *Materialia* **2018**, *2*, 190–195.
3. Riano, J.S.; Hodge, A.M. Exploring the microstructural evolution of Hf–Ti: From nanometallic multilayers to nanostructures. *Scr. Mater.* **2018**, *142*, 55–60.
4. Riano, J.S.; Hodge, A.M. Exploring the thermal stability of a bimodal nanoscale multilayered system. *Scr. Mater.* **2019**, *166*, 19–23.
5. Shi, J.; Cao, Z.; Liu, Y.; Zhao, Z. Size dependent alloying and plastic deformation behaviors of Ti/Ni nano-multilayers. *J. Alloys Compd.* **2017**, *727*, 691–695.
6. Druzhinin, A.; Ariosa, D.; Siol, S.; Ott, N.; Straumal, B.; Janczak-Rusch, J.; Jeurgens, L.; Cancellieri, C. Effect of the individual layer thickness on the transformation of Cu/W nano-multilayers into nanocomposites. *Materialia* **2019**, *7*, 100400.
7. Im, Y.; Johnson, P.; McKnelly Jr, L.; Morris Jr, J. Nb<sub>3</sub>Al formation in sputter-deposited Nb/Al multilayer samples. *Journal of the Less Common Metals* **1988**, *139*, 87–95.
8. Srinivasan, D.; Sanyal, S.; Corderman, R.; Subramanian, P. Thermally stable nanomultilayer films of Cu/Mo. *Metall. Mater. Trans. A* **2006**, *37*, 995–1003.
9. Troche, P.; Hoffmann, J.; Heinemann, K.; Hartung, F.; Schmitz, G.; Freyhardt, H.C.; Rudolph, D.; Thieme, J.; Guttmann, P. Thermally driven shape instabilities of Nb/Cu multilayer structures: Instability of Nb/Cu multilayers. *Thin Solid Films* **1999**, *353*, 33–39.
10. Zhang, Y.; Fu, L.; Zhu, J.; Yang, W.; Li, D.; Zhou, L. Thermal stability of co-sputtered TaCu amorphous nano-multilayers. *Thin Solid Films* **2021**, *138766*.
11. Lee, H.-J.; Kwon, K.-W.; Ryu, C.; Sinclair, R. Thermal stability of a Cu/Ta multilayer: An intriguing interfacial reaction. *Acta Mater.* **1999**, *47*, 3965–3975.