Electronic Supplementary Material (ESI) for Nanoscale.

SUPPLEMENTARY INFORMATION

Electrodeposited High Strength, Thermally Stable Spectrally Selective Rhenium Nickel Inverse Opals

Runyu Zhang,[acd] Joseph Cohen,[a] Shanhui Fan [e] and Paul V. Braun*[abcd]

a Department of Materials Science and Engineering, University of Illinois at Urbana Champaign, Urbana, IL, 61801, USA
b Department of Chemistry, University of Illinois at Urbana Champaign, Urbana, IL, 61801, USA
c Frederick Seitz Materials Research Laboratory, University of Illinois at Urbana Champaign, Urbana, IL, 61801, USA
d Beckman Institute of Advanced Science and Technology, University of Illinois at Urbana Champaign, Urbana, IL, 61801, USA
e Department of Electrical Engineering, Stanford University, Stanford, California, 94305, USA

Corresponding Author

*Email: pbraun@illinois.edu

Estimation on the cost of Rhenium

To estimate the cost (*c*) of Rhenium needed in a sample with a practical size, a simple calculation can be made using this equation:

$$c = C\rho V = C\rho(Ah\phi)$$

where *C* is the unit cost of Rhenium: \$1050 / lb = \$ 2.315 / g (BASF, June 26, 2017), ρ is the density of Rhenium: 21.02 g/cm^3, *A* is the area of the sample, *h* is the material thickness and Φ is the solid filling fraction of porous material.

Assuming the sample is pure Re, with A equals 10 cm $\times$ 10 cm, thickness *h* equals 5 µm, and Φ is ~20%, the total cost of Re in this sample is \$0.48.

Comparison of Thermal Stability and Mechanical Properties

Material	Bulk Material $T_{melting}$(°C)	Processing Method	Processing Temperature (°C)	Thermal Stability (°C)	Duration (h)	Reference
Fe	1538	Pyrolysis	~400	Unknown	Unknown	1
Co	1495	Pyrolysis	~400	500-700	~1	2
Ni	1455	Electroplating (Aqueous)	RT	550-600	~1	3
W/Mo	3422/2623	Pyrolysis	500-1000	800-1000	~0.5	4
W	3422	Electroplating (Molten Salt)	425	<1000	<0.5	5
W	3422	ALD	>200	>1000	>10	6
$Re_{88}Ni_{12}$	3182/1455	Electroplating (Aqueous)	near RT	1000	~5	This work

Table S1. Summary of available results on the thermal stability of 3D refractory metallic inverse opals.

Material	E (GPa)	H (GPa)	Reference
SiC	25	0.56	7
TiO2 @ Silica	1.7-8.3	0.04 - 0.4	8
Al_2O_3	2.5-7.5	0.15-0.3	9
Cu	20	NA	10
Ni	~28	~0.3	This work
$Re_{88}Ni_{12}$	~35	~0.8	This work

Table S2. List of results on the elastic modulus (E) and hardness (H) of available ceramic and metallic 3D inverse opals.

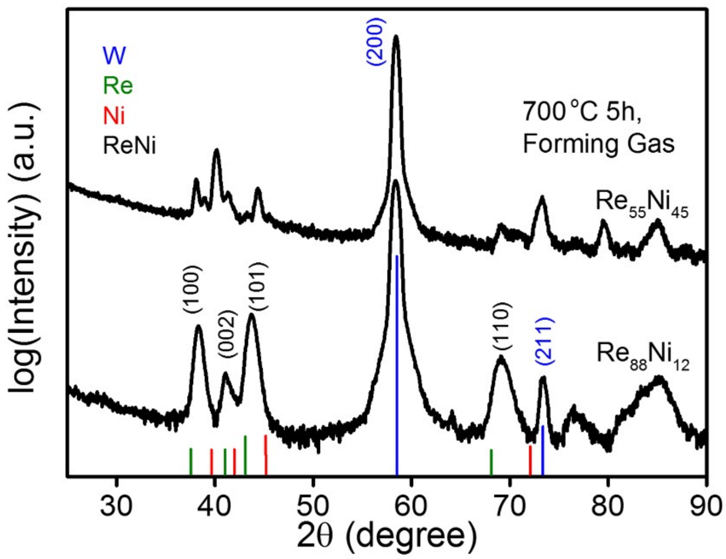

Figure S1. The XRD spectra collected from $Re_{55}Ni_{45}$ and $Re_{88}Ni_{12}$ sample after annealing under 700^{o}c for 5h.

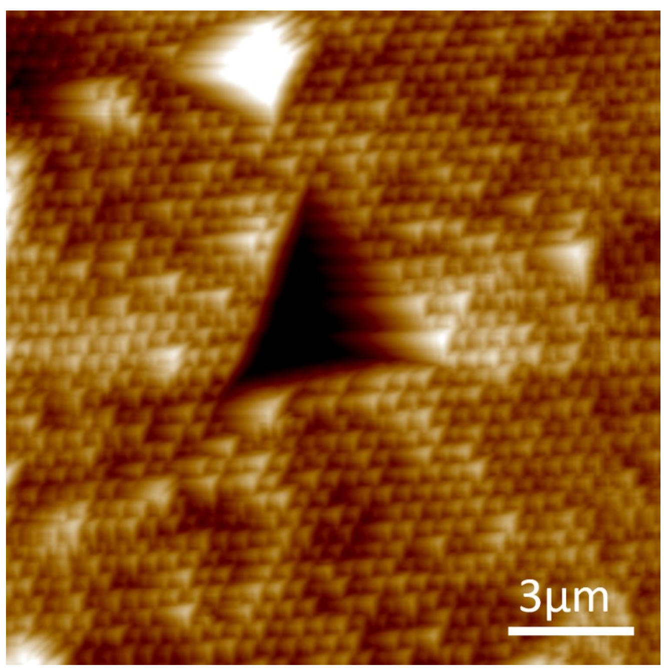

Figure S2. The morphology of the sample after nanoindentation where the dark triangular region reflects the shape of the Berkovich tip and the surrounding regions are the inverse opal without indentation. As can be seen from the image the material is plastically deformed after the indentation.

Reference

1 H. Yan, C. F. Blanford, J. C. Lytle, C. B. Carter, W. H. Smyrl and A. Stein, *Chem. Mater.*, 2001, **13**, 4314–4321.
2 C. F. Blanford, C. B. Carter and A. Stein, *J. Mater. Sci.*, 2008, **43**, 3539–3552.
3 X. Yu, Y.-J. Lee, R. Furstenberg, J. O. White and P. V. Braun, *Adv. Mater.*, 2007, **19**, 1689–1692.
4 N. R. Denny, F. Li, D. J. Norris and A. Stein, *J. Mater. Chem.*, 2010, **20**, 1538–1545.
5 K. A. Arpin, M. D. Losego and P. V. Braun, *Chem. Mater.*, 2011, **23**, 4783–4788.
6 K. A. Arpin, M. D. Losego, A. N. Cloud, H. Ning, J. Mallek, N. P. Sergeant, L. Zhu, Z. Yu, B. Kalanyan, G. N. Parsons, G. S. Girolami, J. R. Abelson, S. Fan and P. V. Braun, *Nat. Commun.*, 2013, 4, 2630.
7 J. Zhou, H. Li, L. Ye, J. Liu, J. Wang, T. Zhao, L. Jiang and Y. Song, *J. Phys. Chem. C*, 2010, **114**, 22303–22308.
8 J. J. do Rosário, J. B. Berger, E. T. Lilleodden, R. M. McMeeking and G. A. Schneider, *Extreme Mech. Lett.*, 2017, **12**, 86–96.
9 J. J. Roa, A. Coll, S. Bermejo, E. Jiménez-Piqué, R. Alcubilla, L. Castañer and L. Llanes, *J. Phys. Appl. Phys.*, 2016, **49**, 455303.
10 M. T. Barako, J. M. Weisse, S. Roy, T. Kodama, T. J. Dusseault, M. Motoyama, M. Asheghi, F. B. Prinz, X. Zheng and K. E. Goodson, in *Thermal and Thermomechanical Phenomena in Electronic Systems (ITherm), 2014 IEEE Intersociety Conference on*, IEEE, 2014, pp. 736–743.