Author: Mr. Gaurav Shantaram Biraris
Email: gauravbiraris@live.com

Nanoscaled composites based on skeleton of aerogels or xerogels.

Aerogel is a synthetic porous ultra light material derived from a gel, in which the liquid component of the gel has been replaced with a gas. The result is a solid with extremely low density. The aerogel is monolith and hence it can be exploited for role of skeleton or scaffold. It is extremely porous consisting uncountable capillaries.

Aerogels are prepared by sol-gel chemistry. It is possible to make composite aerogels by using two different precursors those follow gel formation. A characteristic of extreme porosity of aerogels makes them least dense. They are stable upto many hundreds of ^{o}C. My program is to dip the aerogel in another molten solid. Due to surface tension the molten material will get filled in the pores of aerogels. It depends on surface tension of molten material that whether it will rise up of get down. Upon cooling, the molten material gets solidified and will form the composite. The porosity of aerogel can be manipulated by manipulating the drying conditions.

Aerogels can be made of variety of materials including metal oxides, polymers, semiconductors etc. And molten material can be metals or polymers or any material which melts. Aerogels are stable at higher temperature so that many of the *to be molten* materials melt without disturbing the aerogel structure. For example, one can find evidences for high temperature stability of aerogels in publications like [1], [2], [3] etc. In fact the major application of aerogels is insulation from high temperature volumes, thus it is evident those are stable at such temperatures.

The solution

The solution is very simple. Select two (or more) materials from which nanocomposite is to be made. One of them necessarily needed to be formed by sol-gel route. Obtain aerogel of that component. The component which can’t be synthesized by sol-gel chemistry is needed to be melt. Then put the aerogel in contact with the molten material in heated environment. In certain time, the pores of aerogel will be filled by the molten component. The aerogel can be dipped inside the molten component if required. Upon cooling, we will get a nanocomposite of aerogel material and molten material.

The component to be used is needed either to be molten or it has to amenable to be synthesized by sol-gel route. Further, it is necessary that at least one component should be melt and at least one should be made by sol-gel.

In case where a composite of more than two components is desired, multicomponent aerogel or molten mixture (alloy) can be used. While synthesizing aerogel, if same types of precursors of different elements are used, one can get a composite aerogel. For example, by using metal chlorides of different metals, aerogels of two (or more) metal oxides can be made. Further, there are reports of novel aerogel composites [4],[5],[6],[7]. (Electrospinning also result in porous like materials which can be composited with aerogels [8]) Further, instead of using pure melt, a mixture of melts can be adopted.

There is scope to alter the cooling conditions to get different properties of the composite. As this is ideation challenge, only concept should be needed.

Rationale

Let's address the technical requirements of the challenge one by one.

1. *Macroscopic:* Macroscopic composites of the seekers desire can be formed as aerogels and melts can be got at desired larger extent.
2. *Nanoscale*: the crosslinking of gel and pore size of gel can be obtained of nanoscale. Thus aerogel is referred as a nanomaterial. In case of composite aerogel or molten mixtures, the distribution is ideally of molecular size. Size of pores of aerogels and size of crosslinked matrix can be obtained of about 5 nm.
3. *Composition:* The composite can be made with two or more components. Normally aerogels are 90% to 99% porous. Thus with this porosity, volume proportion of component composing aerogel would be only 1% to 10%. As seeker wishes the contribution at least 5%, drying conditions of aerogel are to be changed. If normal drying is done instead of supercritical drying, then xerogel will be obtained with composition about 30% (this is good as it reduces cost of aerogel). Partial supercritical drying can result in 5% to 30% proportion of lesser component.
4. *Materials-agnostic:* The solution is materials-agnostic. The composite can be made with the components which follow sol-gel route and the components which liquefy at temperature keeping aerogel or xerogel stable. Thus the class of components for this method is much wider containing most of the applied materials.

5. *Near fully dense*: The composite would be of density more than 90% of theoretical maximum as there is no surfactant or binding agent. The pores of aerogel or xerogel gets filled by the molted component. There would be some trapped bubbles like voids (may be of solution from sol-gel) which have no opening for molten material to get in; but their contribution to the volume would be much less than 10%.
6. *Stability:* The method proposed has stage of processing at temperatures more than 600°C. Hence it is believable that the composites constructed so are stable at 300°C.
7. *Orientation/Anisotropy*: Such control is possible upto some extent. Aerogel monolith isn't isotropic as distribution of pores isn't uniform. Orientation to the molecules of some molten components can be given by magnetic or electric fields' manipulation.

References

[1] Lijie Zhang, Jinghua Gu, Hongying Yao, Yue Zhang; *Preparation of porous SiO_2 monoliths with high porosity and high temperature stability*, Rare Metals, March 2011, Volume 30, Issue 1 Supplement, pp 552-556

[2] J.F Poco, J.H Satcher Jr., L.W Hrubesh, *Synthesis of high porosity, monolithic alumina aerogels*, Journal of Non-Crystalline Solids, Volume 285, Issues 1–3, June 2001, pp 57–63

[3] Aegerter, Michel Andre, Leventis, Nicholas, Koebel, Matthias M., *Aerogels Handbook*, Springer 2011

[4] Michele L. Anderson, Rhonda M. Stroud,Catherine A. Morris, Celia I. Merzbacher and Debra R. Rolison, *Tailoring Advanced NanoscaleMaterials Through Synthesis ofComposite Aerogel Architectures*, Advanced Engineering Materials, 2000, 2, No. 8

[5] Li Ye, Zhi-Hong Ji, Wei-Jian Han, Ji-Dong Hu and Tong Zhao, *Synthesis and Characterization of Silica/Carbon Composite Aerogels*, Journal of the American Ceramic Society Volume 93, Issue 4, pp 1156–1163, April 2010

[6] GuiAn Li, TingLiang Zhu, ZhongXun Deng, YaJuan Zhang, Fei Jiao, HaiRong Zheng; *Preparation of Cu-SiO_2 composite aerogel by ambient drying and the influence of synthesizing conditions on the structure of the aerogel*, Chinese Science Bulletin, March 2011, Volume 56, Issue 7, pp 685-690,

[7] Shibing Ye, Jiachun Feng and Peiyi Wu, *Highly elastic graphene oxide–epoxy composite aerogels* via *simplefreeze-drying and subsequent routine curing*, Journal of Materials Chemistry A volume 1, Issue 10, 2013 pp 3495-3502

[8] Huijun Wu, Yantao Chen, Qiliang Chen, Yunfei Ding, Xiaoqing Zhou, and Haitao Gao, *Synthesis of Flexible Aerogel Composites Reinforced with Electrospun Nanofibers and Microparticles for Thermal Insulation*, Journal of Nanomaterials, Volume 2013 (2013), Article ID 375093, 8 pages