Aerogels – A kind of ceramic? Properties and applications

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Aerogels are nanostructured materials, containing until 99 wt.-% air. They are manufactured by a sol-gel process [1]. After formation of a 3D network of colloidal particles, the wet gel has to be dried without shrinkage to avoid destruction of the network by cappilary forces. The drying process can be supercritical or subcritical, depending on the kind of aerogel. Because of their very special properties (extremely low density, extremely low thermal conductivity,...), aerogels are very interesting for different applications [2]. Aerogels can be classified into organic and inorganic aerogels.

The first aerogels (inorganic, silica aerogels) were manufactured already in 1931/32 by Kistler [3]. Inorganic aerogels are inert against metal liquids and cannot be wetted by them. We use them as crucible material for solidification of metal alloys. It is possible to watch the solidification process directly or by CCD-camera, because these kinds of aerogels are often transparent in a wide range of 350-2700 nm.

In the past few years, there has been a great deal of interest in the synthesis of hybrid materials with nonlinear optical properties, especially second harmonic generation (SHG). We prepare ferroelectric aerogels, like $LiTaO_3$ and $LiNbO_3$, and silica/titania aerogels loaded with ferroelectric nano -and microparticles, like $BaTiO_3$ or $KNbO_3$ [4]. Whenever an infrared laser light wave (e.g. 1064nm) penetrates these materials, the aerogel generates green light (532nm).

In recent years, organic aerogels were presented as a new, nanostructured material with possible applications like binding material for sand cores and moulds in the foundry industry [5] or in its pyrolized carbon form as a material for supercapacitors. The well investigated Resorcin-Formaldehyde (RF) aerogels [6,7] are typically catalyzed with weak bases like sodiumcabronate. Instead of base catalysis it was recently considered to use acid catalysts, especially organic acids [8].

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Opal records of abrupt changes in the Southern Ocean over Termination II

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Diatoms sequester CO_2 and other nutrients into their organic matter, as well as forming biogenic silica (opal), and can account for over half of the world's primary productivity in the surface oceans. Silicon (Si) is an important oceanic nutrient for their growth and primary production in surface waters, especially at high-latitudes. Opal bio-mineralization leads to a mass-dependent Si isotope fractionation, such that the Si isotope composition (expressed as $\delta^{30}Si$) of seawater and biogenic opal reflect the degree of Si utilization in ocean surface waters by siliceous algae, analogous to variation in carbon isotopes, but linked only to diatom productivity.

An unprecedented high temporal-resolution Si-isotope record has been measured from the South Atlantic from ODP site 1094 over the penultimate deglaciation. The qualitative trends observe a very large shift from low glacial values to high interglacial values over Termination II. These large changes are in accordance with a record from the Antarctic zone of the South Atlantic (Core RC13-259, [1]). The high temporal-resolution of this study allows us to ascertain two important features which have hitherto not been demonstrated: firstly, we can compare the time of changes in $\delta^{30}Si_{opal}$ to change in the other stable isotope opal based proxies, namely $\delta^{15}N$ and $\delta^{13}C$ [2], secondly, we can demonstrate that $\delta^{30}Si_{opal}$ changed by 1‰ in less than 2 kyrs.

The changes in diatom productivity estimated from both diatom-bound $\delta^{15}N$ and $\delta^{13}C$ records, actually occur significantly prior to the change in $\delta^{30}Si_{opal}$, (~1 kyr). This also suggests that change in the N utilization do not occur at the same time as change in Si utilization. Overall, the degree of change (1.3‰) is greater than the isotope enrichment factor during the utilization of Si by diatoms (~1.1‰), so cannot be explained as only changes in the degree of utilization (this cannot be more than 100%). Secondly, the rate of change is similar to the mixing time of the oceans (~1500 years) and many times less than the residence time of Si in the oceans (~15 kyrs), so cannot be related to changes in marine inputs to the oceans. The observed shift in $\delta^{30}Si_{opal}$ must be caused by a dramatic switch in provenance of waters coming into the Antarctic Sector of the Southern ocean with distinctly different Si isotope compositions as well as any potential change in diatom productivity.

References

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