3D Printing of Aerogels

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Abstract

Aerogel is an ideal thermal superinsulator with great potential for multiple mass-market applications [1]. Although aerogels can have exceptionally high strength-to-weight ratios [1], silica aerogels are generally brittle and impossible to machine by subtractive processing. The viability of aerogel additive manufacturing has been demonstrated for graphene [2], graphene oxide [3], carbon nitride [4], gold [5], resorcinol-formaldehyde [6], and cellulose [7], but is quoted as "…not feasible for silica aerogels" [8]. With excellent replication fidelity at 10-1000 µm length scale, a printing capability for silica gels will create the possibility for spatially varying compositions and functions of the aerogels and enable a breakthrough in a technological adaptation of aerogels for miniaturization applications. Here, we present a direct ink writing protocol to print silica aerogel objects based on a custom-tailored silica precursor system. Functional (nano)particles or various polymers are easily incorporated. The method enables the production of miniaturized objects with outstanding shape fidelity. The printed aerogel can be pure silica without polymer additives, or hybrids with tailored compositions and functions, with typical properties for silica aerogel (S_{BET} 751 m^2/g, λ 15.9 $mW \cdot m^{-1} \cdot K^{-1}$). Furthermore, various aerogel materials (cellulose, RF silica composites and polyimide silica composites) can be printing based on developed methodology, which show good shape fidelity and comparable aerogel performance. We demonstrate a proof of concept of additive manufacturing silica-based aerogel materials and conclude with a perspective for the potential 3D printed aerogel materials and components in the targeted markets.

Fig 1. 3D printing silica aerogel lotus flower

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