Acoustical properties of TEOS based granular silica aerogels

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Currently available data suggests that granulated aerogels can be of interest in terms of their sound absorption performance in the audio frequency range. However, there is still no thorough understanding of the complex physical phenomena which are responsible for their observed acoustical properties.

This paper makes use of advanced material characterization methods and a mathematical model to explain and predict the acoustical properties of granular silica aerogels. The samples are produced through a two-step, acid-base sol-gel process, with sol silica concentration and density being the main variables. The pore structure is carefully characterised by nitrogen sorption analysis and scanning electron microscopy, and the acoustical properties of hard-backed granular silica aerogels are measured in a bespoke acoustic impedance tube and the results predicted accurately with the adopted theoretical model. Although silica aerogels have over 90% porosity, this was not reflected in the parameter values predicted with the model. Results found that only a proportion of the micro and mesopores in the direct vicinity of the grain surface influenced the acoustical properties of aerogel. Further work in the hierarchical pore structure of aerogels is required to understand better the roles of different pore scales on the measured acoustical properties of granulated aerogel.

In this extended abstract we focus on one type of silica aerogel prepared with variable $PEDS_{P750}$ content in the sol to produce an aerogel named PEDS E30. Fig.1 shows that the particles are not spherical but angular with sharp edges. The complex reflection coefficient of these materials was measured in a specially developed impedance tube with 10 mm diameter in the frequency range of 300 – 3000 Hz.
Granular aerogels consist of highly porous particles with a large internal pore surface area. Modelling of their acoustical properties requires accounting for its multiscale nature and physical processes that occur at different scales. In this work, the model proposed by Venegas et al. [1] was applied. This upscaled analytical model has been developed for an array of spherical porous grains in which two inner-particle scales of porosity are considered. The model accounts for the viscosity and heat transfer effects in the voids formed between the particles, rarefied gas flow and heat transfer in the inner-particle transport pores, interscale (voids to/from inner-particle pores) pressure diffusion, interscale (transport- to/from mesopores) mass diffusion, and sorption in the micro- and mesopores.

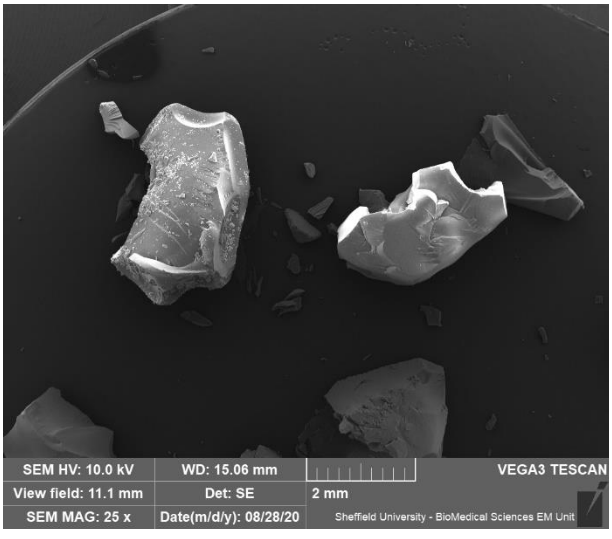
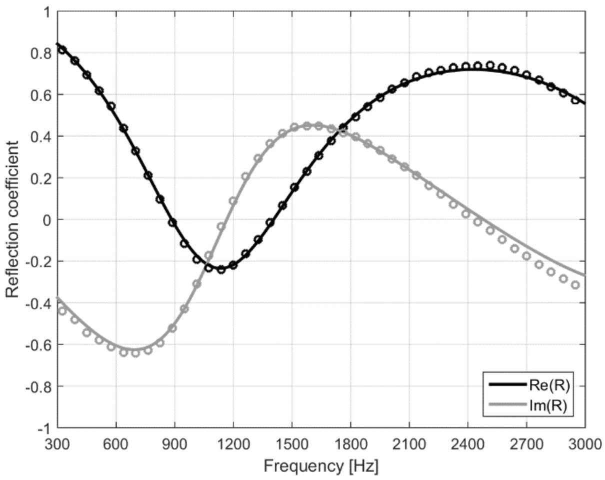


Figure. 1. SEM image of PEDS E30 showing micrometric grains of the 2-3 mm fraction.

After inserting the key experimental parameters obtained from this study into the model, Fig. 2 shows there is agreement between the measured and predicted acoustical surface impedance spectra. The relative mean error between the data and predictions was generally less than 3.1%, this suggests that the model captures the acoustical behaviour of aerogel PEDS E30 accurately.

Figure 2. Measured and predicted reflection coefficient for a hard-backed layer of aerogel granulate PEDS E30.



The results found the values of the inverted parameters to make physical sense. Silica aerogels have close to 100% open porosity, however this is not reflected in the parameter values inverted using the proposed mathematical model. Our findings indicate that not all the aerogel's mesopores appear to contribute to the observed acoustical performance.

Table 1. Measured properties and inverted parameters of PEDS E30.

Properties of PEDS E30	Measured	Inverted
r_p [mm]	1.50	0.85
d [mm]	50	52.9
ϕ [%]	93.5	57.7
mesopore radius [nm]	22.7	17.7

The radius, r_p of the macropores is in the order of 1 µm, which is a typical value for this type of transport pores (see ref. [2] for the case of activated carbon). The mesopore radius, measured from the SEM images, for PEDS E30 was 22.7 nm. Making use of the Knudsen diffusion coefficient, D_e the model inverts the nanopore radius parameter as 17.7 nm for PEDS E30. This value is close to those measured from the SEM images. The overall porosity, ϕ estimated from the porosity data is 57.7 whereas from the measured BET data was 93.5.

Aerogels usually consist of fully interconnected pores and this is not reflected in the pore parameter values inverted using the acoustical data and adopted sound propagation model. It is likely that only a proportion of the mesopore length which is in the direct vicinity of the transport pores or grain surface may influence the acoustical properties of the produced aerogels. This remains an open question and naturally suggests that more research is needed to understand better the relative roles of macro-, meso- and micropores on the acoustical properties of aerogels.

References

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