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Acoustical Investigation of Aerogel Granules Modeled as a Layer of Poroelastic Material

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SYMPOSIUM ON THE ACOUSTICS OF
PORO-ELASTIC MATERIALS

Acoustical Investigation of Aerogel Granules * Modeled as a Layer of Poro-elastic Material *

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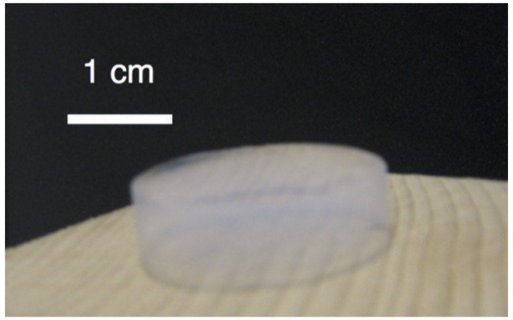
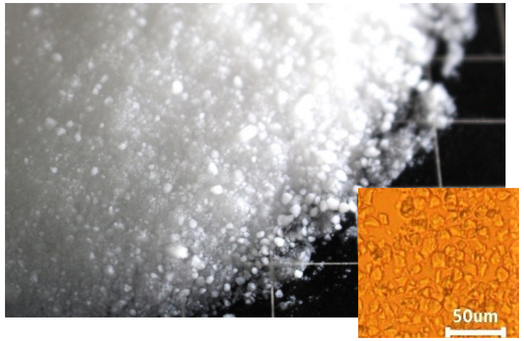
What are aerogel granules? %

Background picture source: http://www.buyaerogel.com

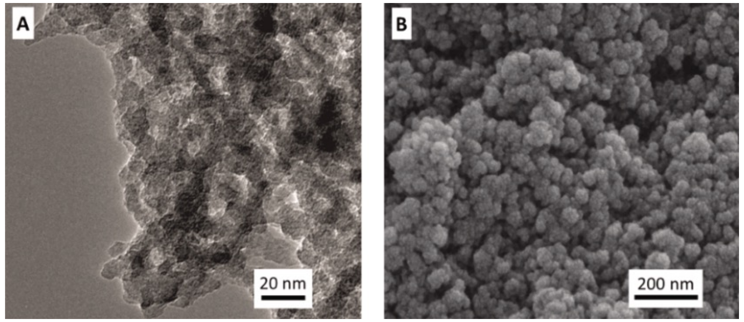
Aerogel: from Solid to Granules



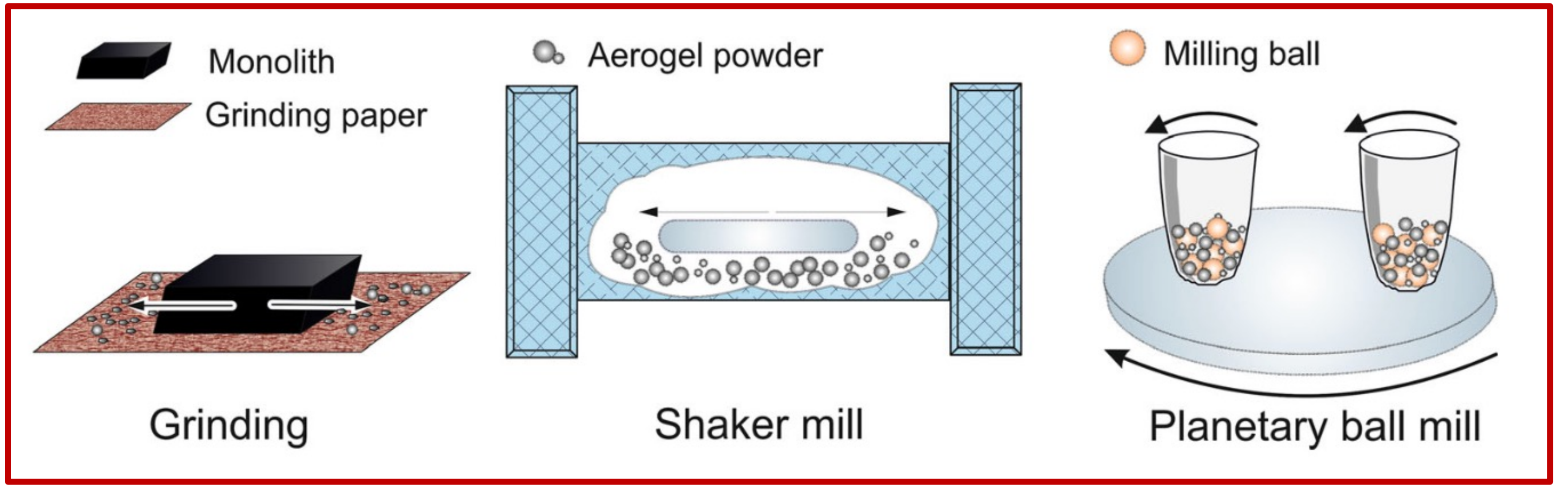
Silica aerogel solid[1]



Silica aerogel granules[2]



TEM and SEM of granules[3]



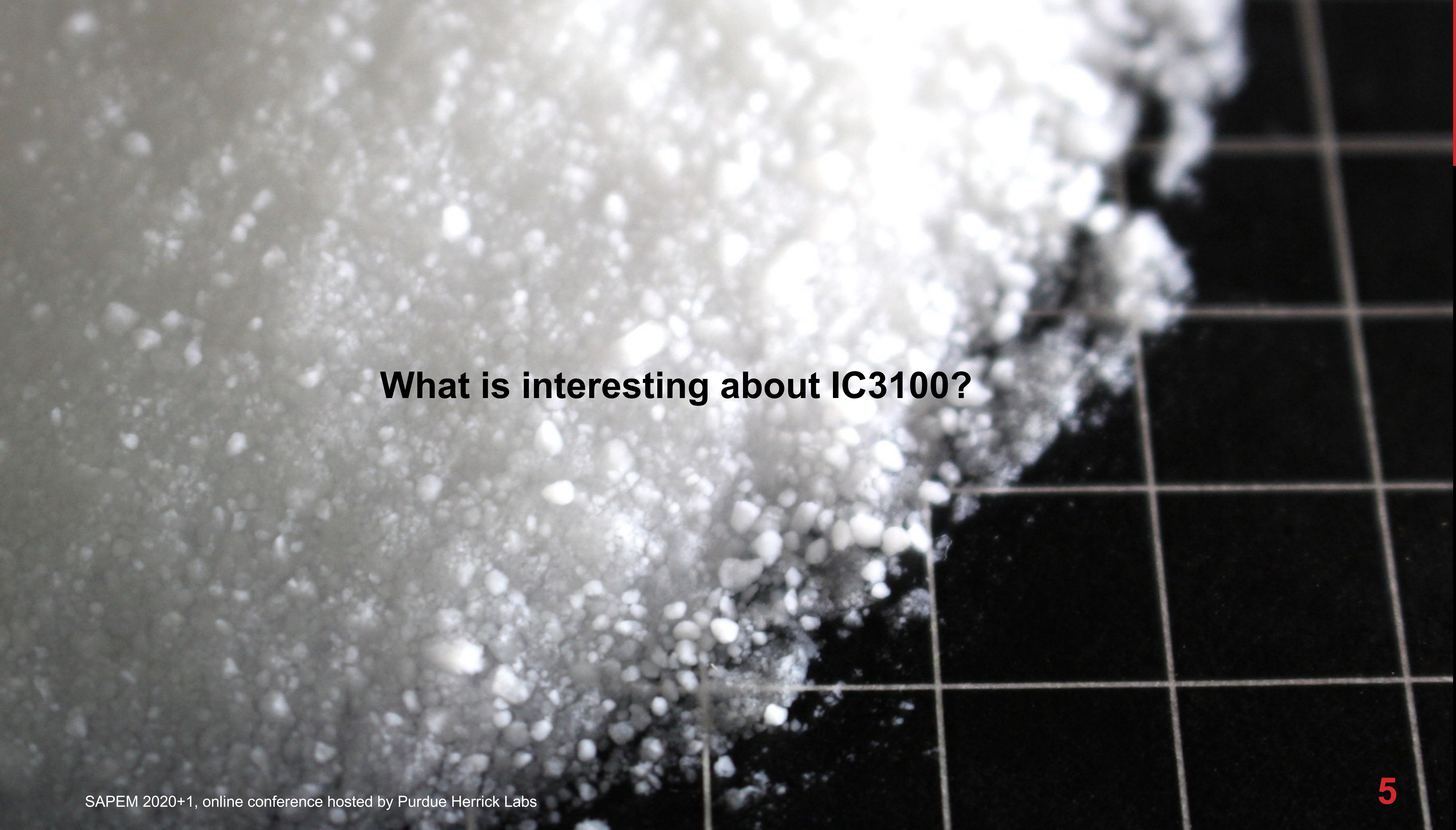
Different Pulverization Methods[4]

Acoustics of Aerogels

- Gronauer and Fricke [5] studied sound wave propagation in **silica aerogel tiles (solids)** and found that the sound speed within them was as low as 120 m/s – significantly lower than in air.

- Forest *et al*. [6] modeled aerogels using the Biot theory [7] and compared those results with experimental measurements, which showed that the observation of "the slowing down of sound speed" was qualitatively consistent with analytical predictions.

- **The current study was focused on improving our understanding of the acoustical behavior of a special type of aerogel granules (ENOVA IC3100) by using the JCA model [8,9] and the Biot theory [7].**

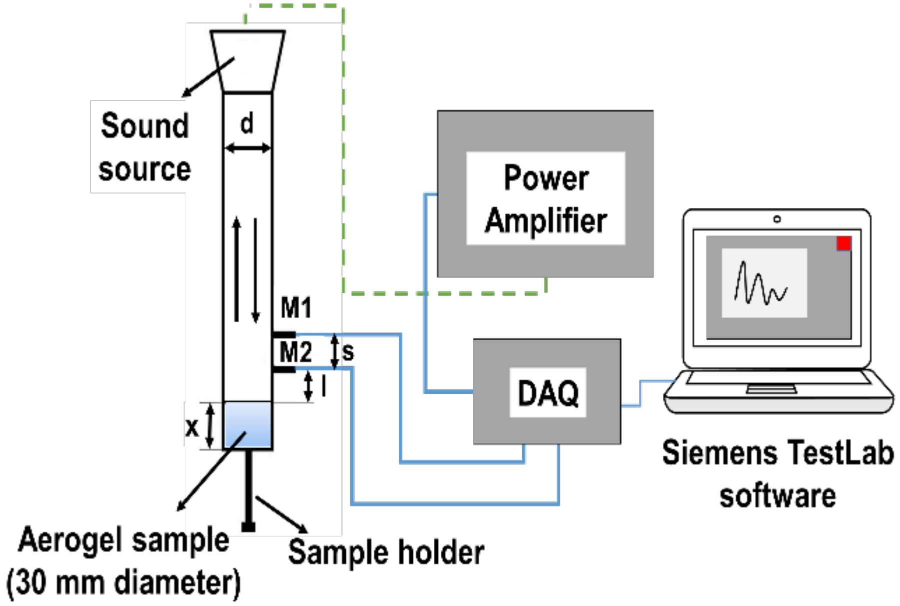


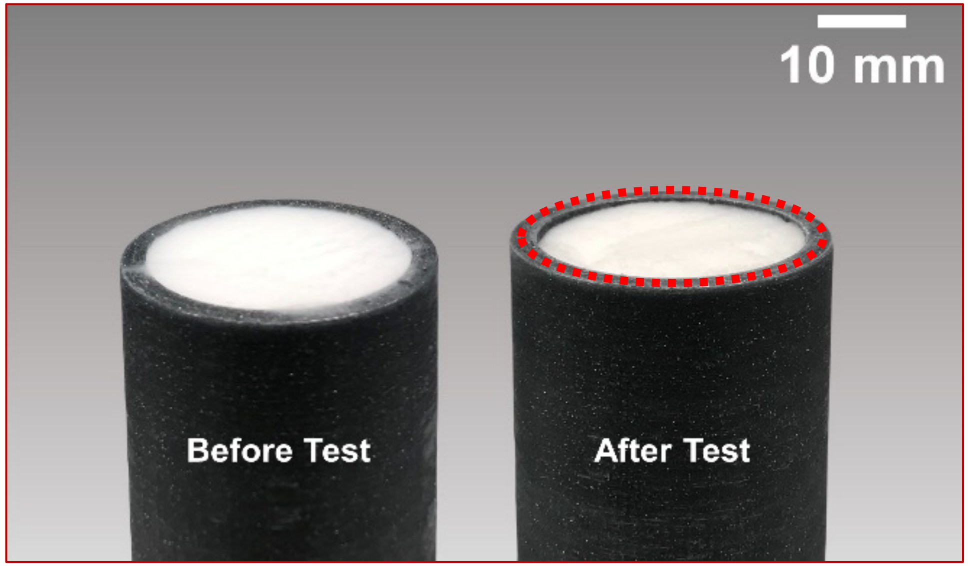
What is interesting about IC3100?

ENOVA IC3100 Viscous Jelly-like Granules

See video record of the presentation to watch this video

Acoustic Properties Characterization

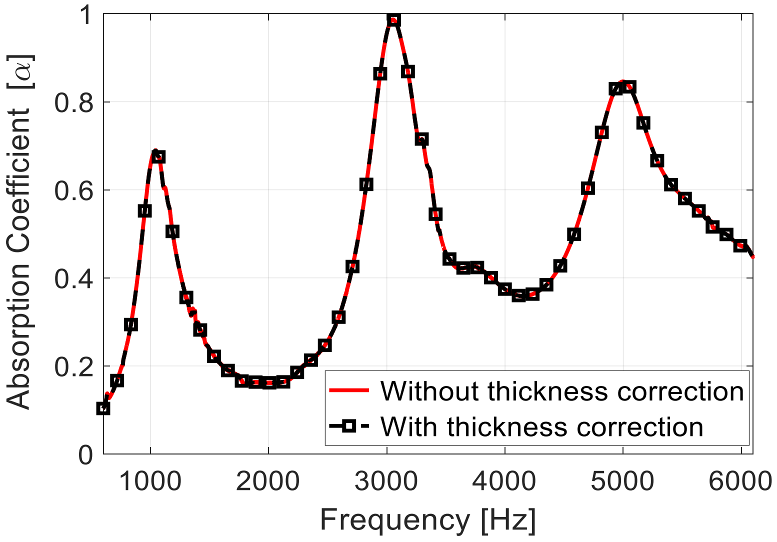


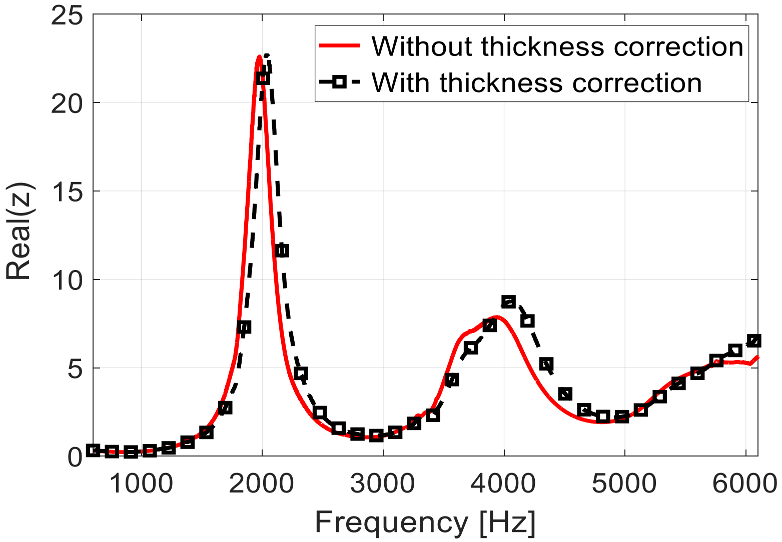


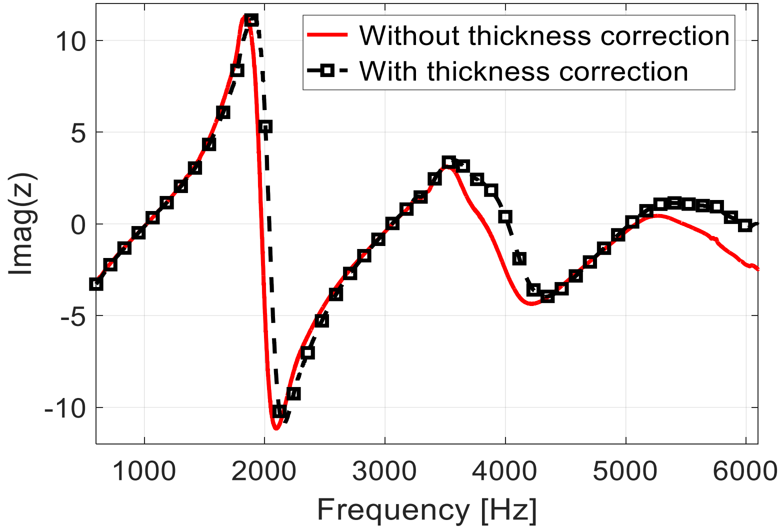
- The unconsolidated aerogel particles behave like a viscous liquid / jelly
- ENOVA IC3100 has a bulk density around 40 kg/m^3 and particle sizes range from 2 to 40 μm
- Sample shrank vertically after ASTM E1050-19 sound absorption measurements [10]

Acoustic Properties Characterization

- **IC3100 normal incidence sound absorption and impedance – 12.7 mm sample**







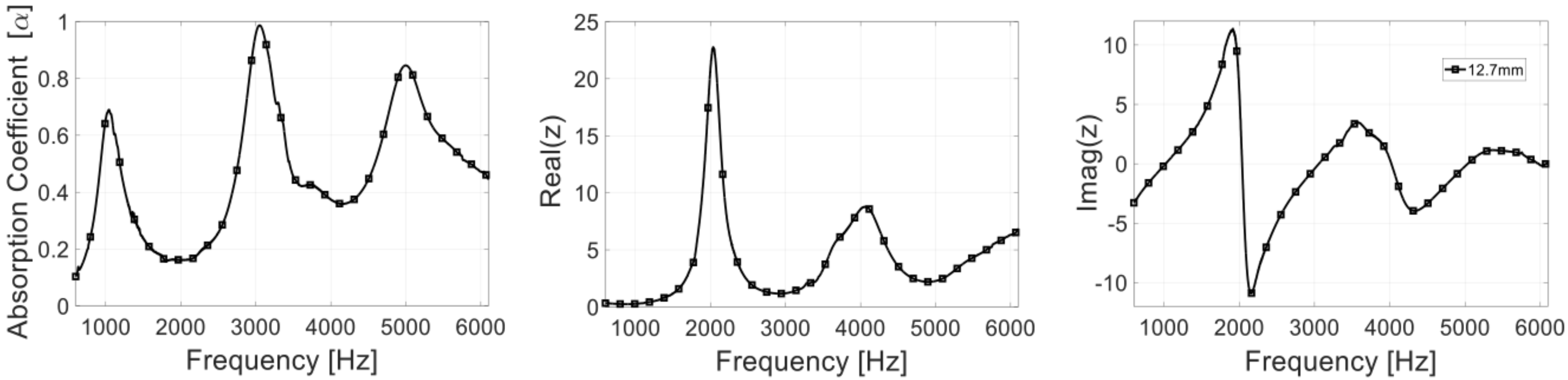
- Small change of the distance between sample surface and Mic 2 due to a sunken sample has observable impact on normalized surface impedance, especially the reactance

- Thickness correction was applied to ensure accurate characterization of sound absorption coefficient and impedance

- Location of 1st quarter wave resonance (depth resonance) is consistent with 50 m/s wave speed

Acoustic Properties Characterization

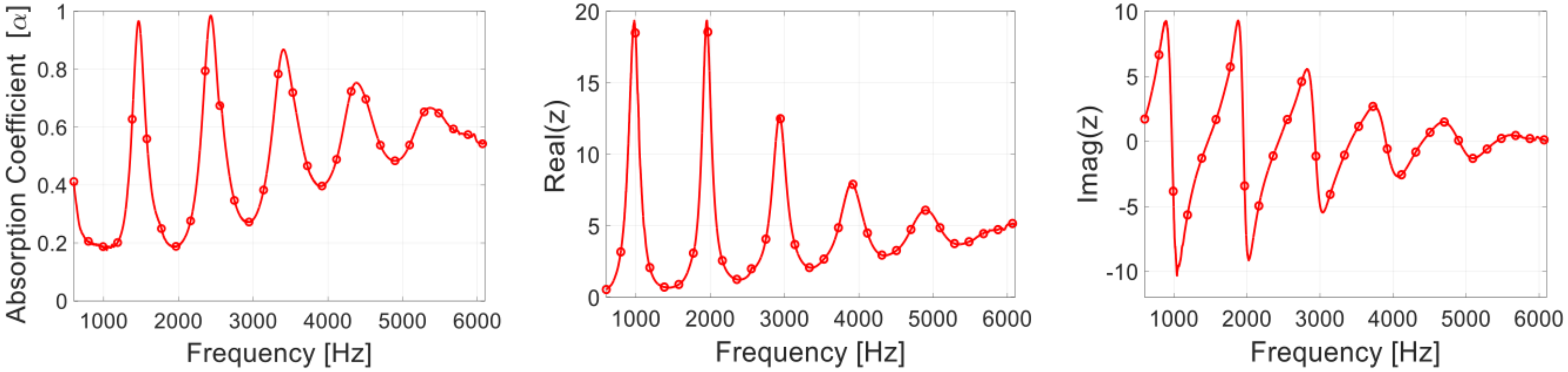
- **Corrected normal incidence sound absorption and impedance – 12.7 mm sample**



- The acoustical performance of the IC3100 aerogel granules differs from what would be expected from a conventional sound absorbent like a layer of polymeric fibers: i.e., multiple, lightly damped depth resonances of the aerogel layer, with large peak values of absorption coefficients appearing at low frequency

Acoustic Properties Characterization

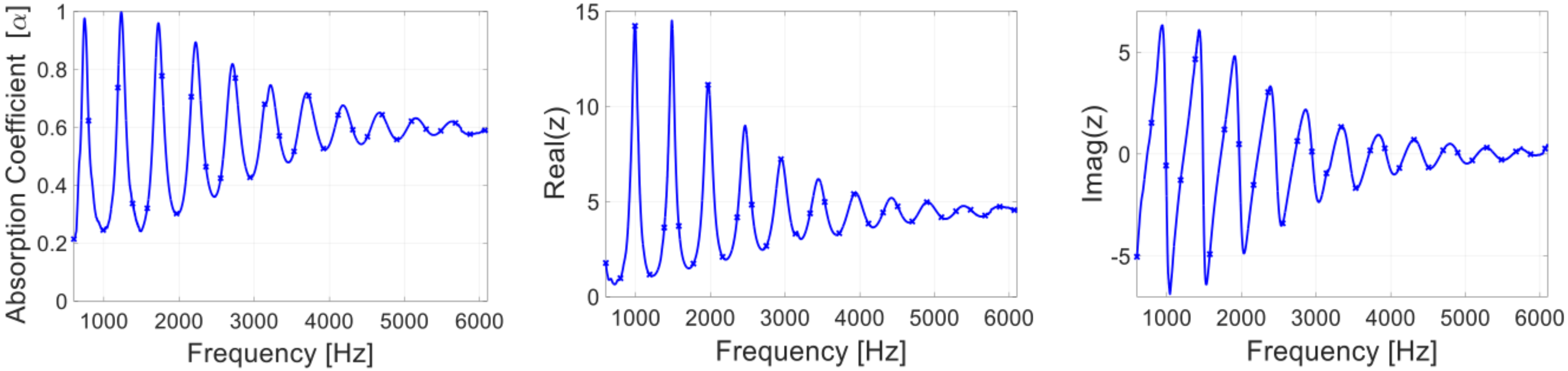
- **Corrected normal incidence sound absorption and impedance – 25.4 mm sample**



- The acoustical performance of the IC3100 aerogel granules differs from what would be expected from a conventional sound absorbent like a layer of polymeric fibers: i.e., multiple, lightly damped depth resonances of the aerogel layer, with large peak values of absorption coefficients appearing at low frequency

Acoustic Properties Characterization

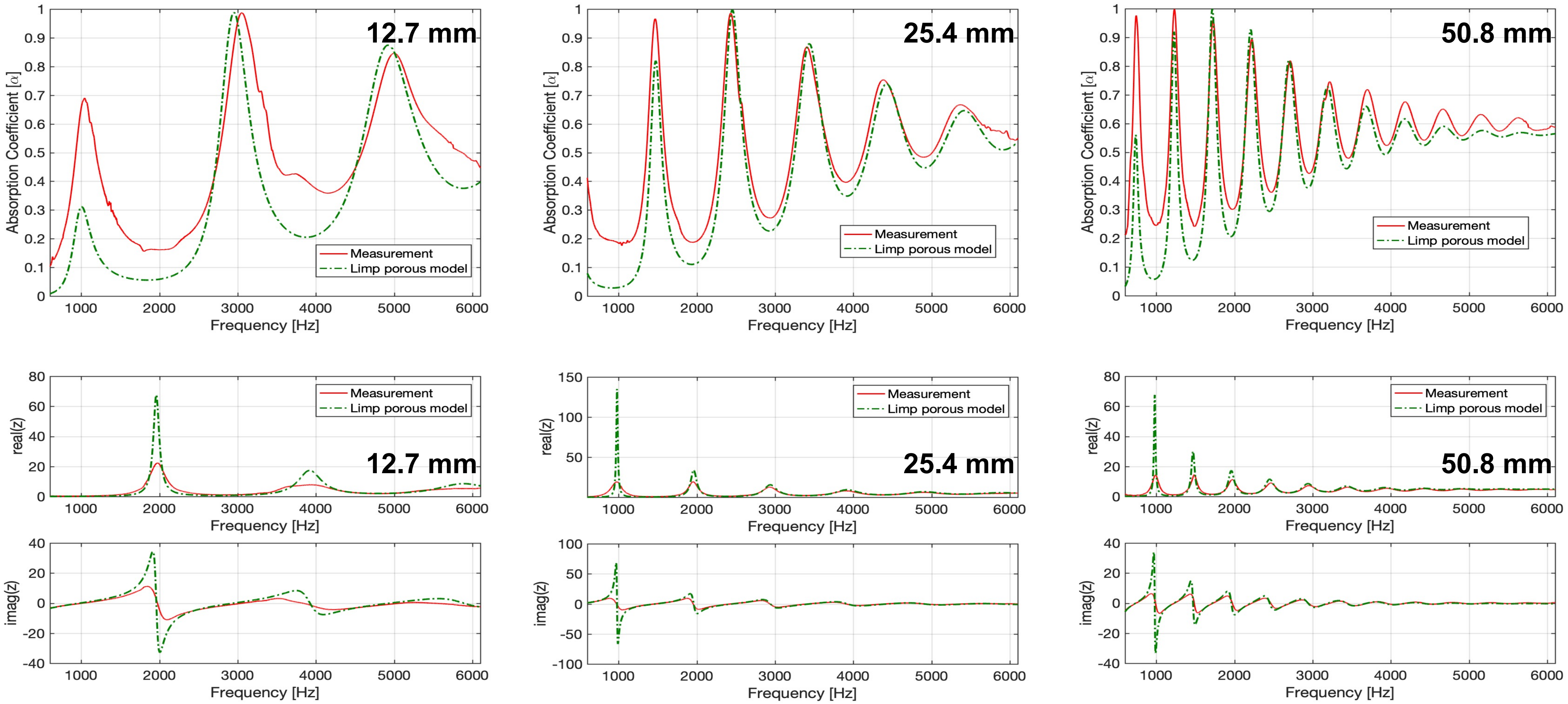
- **Corrected normal incidence sound absorption and impedance – 50.8 mm sample**



- The acoustical performance of the IC3100 aerogel granules differs from what would be expected from a conventional sound absorbent like a layer of polymeric fibers: i.e., multiple, lightly damped depth resonances of the aerogel layer, with large peak values of absorption coefficients appearing at low frequency

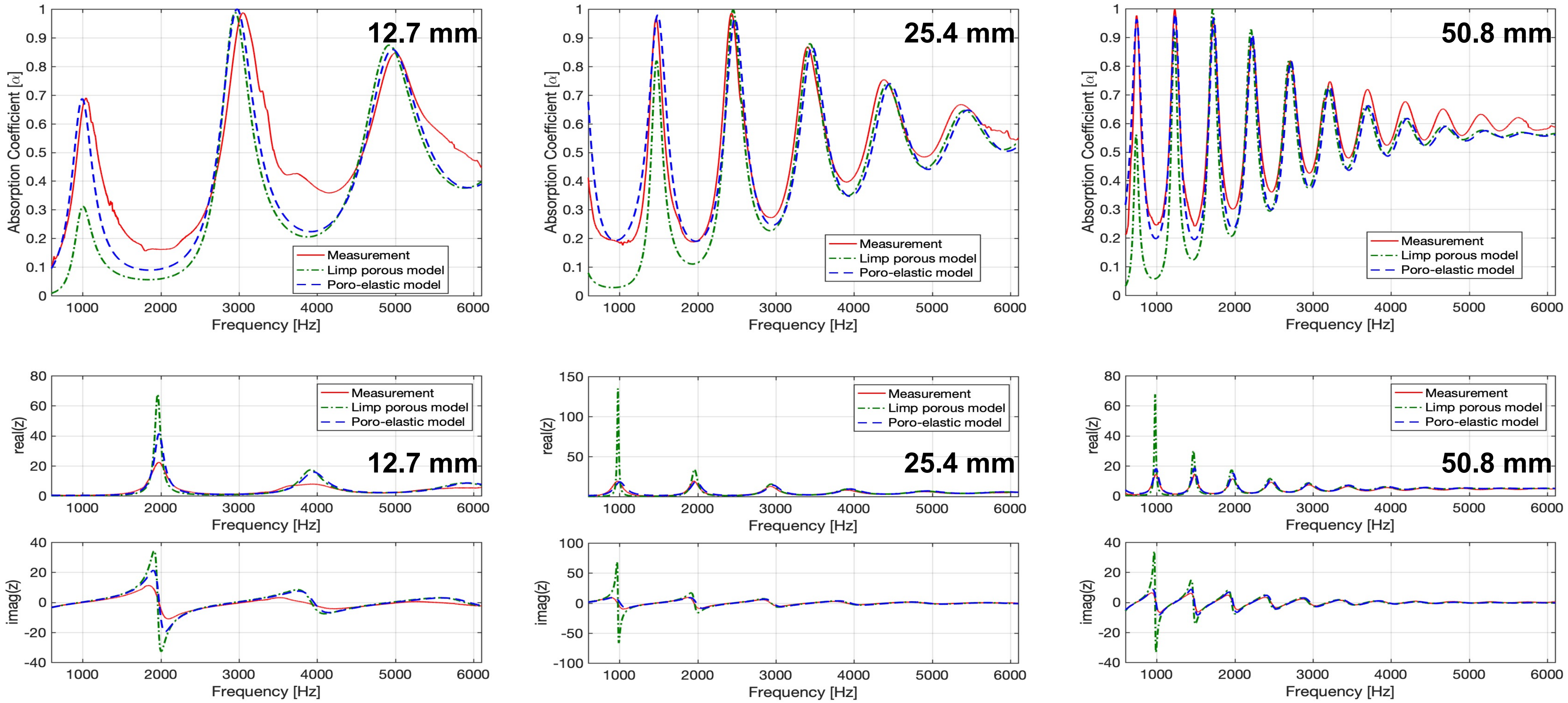
Modeling of IC3100

Acoustical Modeling of IC3100



- Biot limp porous model cannot fit results at low and mid frequencies simultaneously
  - ➢ The modeling was based on the JCA model [8,9], the Biot theory [7] and the incorporation of proper B.C.s [11,12]

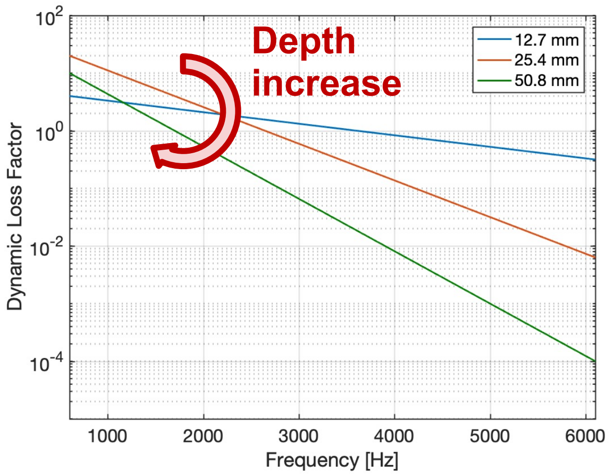
Acoustical Modeling of IC3100



- Biot poro-elastic model allows accurate fit at low frequencies
  - ➢ The modeling was based on the JCA model [8,9], the Biot theory [7] and the incorporation of proper B.C.s [11,12]

Acoustical Modeling of IC3100

IC3100 aerogel granules	σ [Rayls/m MKS]	ϕ	α_∞	Λ [μm]	Λ' [μm]	ρ_b [kg/m³]	E_1 [Pa]	v	η_m
Limp model (12.7, 25.4, and 50.8 mm)	**10.5×10^6**	**0.999**	**3**	**36.08**	**36.08**	**39.86**	N/A	N/A	N/A
Elastic model (12.7 mm)	10.5×10^6	0.999	3	36.08	36.08	39.86	**775**	**0.396**	**Log-spaced (4 to 0.3162)**
Elastic model (25.4 mm)	10.5×10^6	0.999	3	36.08	36.08	39.86	775	0.396	**Log-spaced (20 to 0.0063)**
Elastic model (50.8 mm)	10.5×10^6	0.999	3	36.08	36.08	39.86	775	0.396	**Log-spaced (10 to 0.0001)**



- The fluid-frame visco-thermal dissipation accounted for the **Biot limp porous model [13,14]** was not sufficient to account for the dissipation in low frequency area

- Additional low frequency dissipation was simulated by introducing loss mechanism using the **Biot poro-elastic model [7,11,12]**

Conclusions

- ENOVA IC3100 (particle size 2-40 μm) aerogel granules' acoustical behavior was investigated using the JCA model and the Biot theory, which reveals that the granules are highly flow-resistive and highly porous

- Biot poro-elastic modeling of the material indicates that additional low frequency loss mechanism exists in this type of aerogel granules beyond the viscous and thermal dissipation, and the loss does not necessarily comes from the elasticity of the frame (it could be due to the dissipation from nano-scale pores or from inter-granular friction)

- Different dynamic loss factors were needed to yield "best fits" for 12.7 mm, 25.4 mm and 50.8 mm depths of IC3100, which indicates that the loss factor is dependent on both frequency and depth of the layer

- **An extended journal version of this work has been submitted**
- **See video record of this presentation by clicking this link**
- **Please follow Herrick E-Pubs: http://docs.lib.purdue.edu/herrick/ for more relevant works**

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Thank you for your attention!