PS Multi-frequency Dielectrics Response Interpretation in Carbonate Rocks Using New Modeling Parameters*

Tianhua Zhang[1], Weishu Zhao[1], and Mahmood Akbar[1]

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[1]Schlumberger SDCR, Dhahran, Saudi Arabia (TZhang1@slb.com)

Abstract

Rock multi-frequency dielectric response depends on rock chemical composition, water saturation and pore/grain structure. Current models for rock dielectric response interpretation use randomly distributed inclusions with one or two types of ellipsoidal shapes to idealize the pore space and rock texture. However, these simple inclusion geometries inverted from measurements do not always agree with observations in thin sections, especially for highly cemented rocks.

We propose here to improve the ellipsoid inclusion model by using multiple solid and fluid components, all with different shapes in term of aspect ratio. Sensitivity studies show that the rock dielectric response is sensitive to different types of solid and pore shapes. Single aspect ratios for pore and solid may not be able to account for complex rock texture. A new parameter, namely radiation factor, is introduced to model the electromagnetic dynamic radiation effect caused by the presence of irregular-shaped cement.

A case study is carried out on outcrop samples with similar porosities but different cement amounts. To reduce unknowns during inversion, rock component aspect ratios and concentrations are quantified from thin sections. The radiation factor is used to explain the anti-correlation between low frequency dielectric permittivity and gas permeability that is observed in experiments. Simulations also indicate that bound water percentage is proportional to the cement amount in rock samples with same lithology. Results on cementation factors and multi-frequency dielectric dispersion curves match well with lab measurements. The new model parameters presented in this paper can be used in multi-frequency dielectrics response interpretation and dynamic rock typing.

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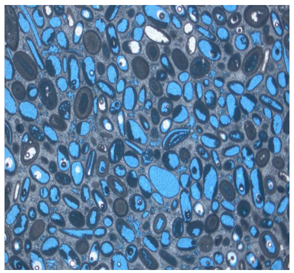
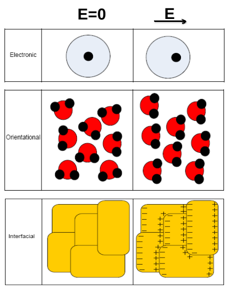
A case study is carried out on outcrop samples with similar porosities but different cement amounts. As a proposed way to reduce unknowns during inversion, rock component aspect ratios and concentrations are quantified from thin sections. The radiation factor is used to explain the anti-correlation between low frequency dielectric permittivity and gas permeability that is observed in experiments. Simulations also reveal that bound water percentage is proportional to the cement amount in rock samples with same lithology. Results on cementation factors and multi-frequency dielectric dispersion curves match well with lab measurements. The new model presented in this paper can be used in multi-frequency dielectrics response interpretation and dynamic rock typing.



Thin section

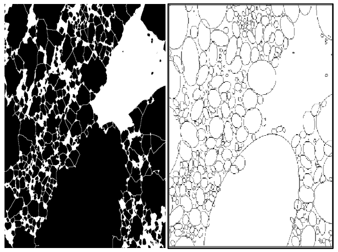


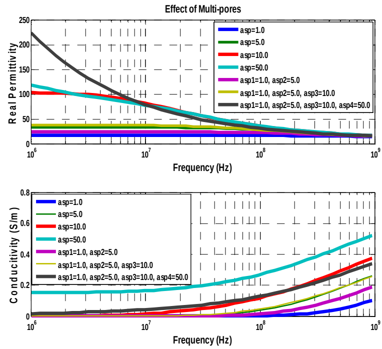
Interfacial polarization
Molecular orientation
Electronic polarization

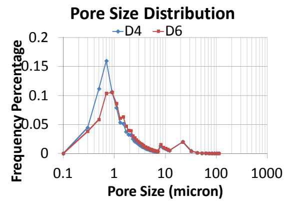
$$\int_v [\sum_{k=x,y,z} \frac{(\varepsilon_i^* - \varepsilon^*)}{\varepsilon^* + (\varepsilon_i^* - \varepsilon^*) L_k / R_g} \cos^2 \phi_{ki}] dv_i = 0$$

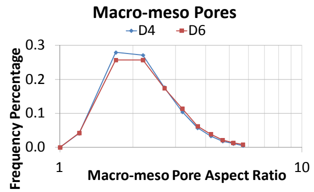
Real Rock Structure – Multi Pore/Solid Modes

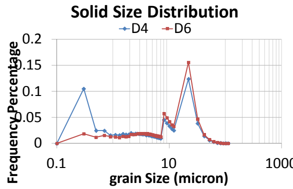
Aspect Ratios from petrographic analysis

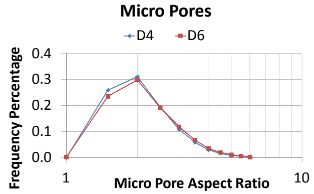




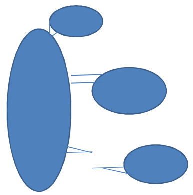




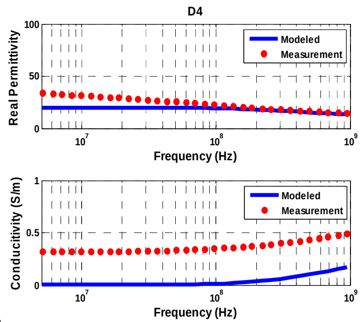




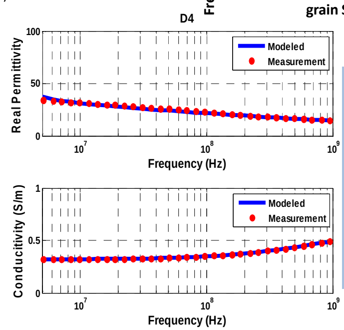
Radiation factor



Electrodynamics radiation effect can boost up low frequency dielectric constant.
Radiation factor is an indicator of pore connectivity and permeability.



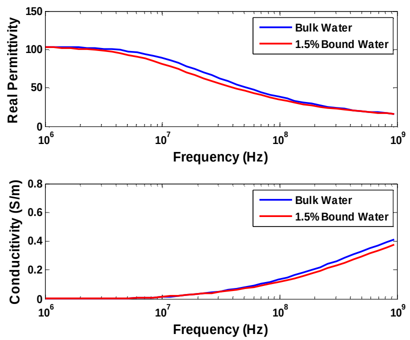
Without Radiation factor



With Radiation factor

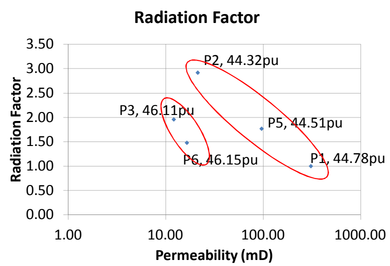
Mode	Pore Aspect Ratio (a/c)	Solid Aspect Ratio (a/c)	Pore Portion	Solid Portion	Radiation Factor	Bound Water
Macro -meso 1	1.31	1.29	0.0409	0.5033	1.0	0.7%
Macro -meso 2	2.11	1.79	0.1173	0.2811	7.75	0.7%
Macro -meso 3	3.91	3.78	0.0198	0.0028	1.0	0.7%
Micro 1	2.10	1.57	0.0152	0.0198	7.45	0.7%

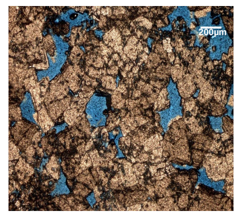
Bound Water

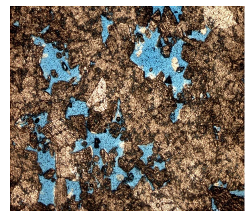


$$\frac{1}{\varepsilon_w^*} = \frac{f_1}{\varepsilon_{w1}^*} + \frac{f_2}{\varepsilon_{w2}^*}$$

Application of the new modeling – geology rock typing







- ✓ A new multi-frequency dielectrics model has been proposed
  - Start from real geology parameter – incorporate multi-grain/pore modes
  - New modeling parameters – Radiation Factor and Bound water effects
- ✓ Direct application in real time rock typing