Asian Journal of Chemistry; Vol. 26, No. 6 (2014), 1754-1756

ASIAN JOURNAL OF CHEMISTRY

http://dx.doi.org/10.14233/ajchem.2014.17346

Dielectric Spectroscopy of Coking Coal with High Sulphur Content†

CHUAN-CHUAN CAI[1,*], MING-XU ZHANG[2] and FAN-FEI MIN[2]

[1]School of Earth and Environmental, Anhui University of Science and Technology, Huainan 232001, Anhui Province, P.R. China
[2]School of Material science and Engineering, Anhui University of Science and Technology, Huainan 232001, Anhui Province, P.R. China

*Corresponding author: E-mail: flychuan2006@126.com

Published online: 10 March 2014; AJC-14886

Using reflection transmission method to measure the permittivity of coking coal from Shanxi province in the frequency range between 200-600 MHz. Results shows that the real part and imaginary part of dielectric constant of three coal samples all decreased with the increase of frequency. The loss tangent of raw coal and clean coal decreases with the increase of frequency. There is a good linear relationship between log ε', log ε" and log f by data fitting processing.

Keywords: Coking coal, Dielectric spectrum, Frequency, Data fitting.

INTRODUCTION

The sulphur content in coal is of great concern owing to its harmful effect on boilers where sulphates cause corrosion, its lowering of the quality of metallurgical coal and atmospheric pollution.

Desulphurization of coal using high power microwave energy was previously investigated[1-3]. The primary advantage of microwave processing is the specificity of microwave energy absorption, allowing volumetric heating of materials. Based on the principle, the interaction of microwave energy and coal sample can be written[4]:

$$P = 55.63 \times 10^{-12} fE^2\varepsilon'' \qquad (1)$$

where P is the absorbed energy of the coal media (W), f the operating frequency (Hz), E the intensity of the electric-field (V/m) and ε" the imaginary part of relative complex permittivity. Under the given microwave frequency and microwave field intensity, coal absorption power is proportional to the imaginary part of the complex dielectric constant.

Many researchers studied on dielectric properties of coal[5-8]. In previous studies, dielectric property of coal is mainly concentrated in the different ranks; research on high sulphur coking coal is relatively rare. This paper chooses typical high sulphur coking coal to measure the permittivity of the sample. Summarize the rule of variety by fitting analysis. These consequences are of significance to coking coal desulphurization by microwave.

EXPERIMENTAL

Preparation of the coal sample: Coal sample was collected from Shanxi province, China. The coal sample was pulverized to pass through a 200 mesh sieve (< 75 μm), after drying under natural air and stored in a glass desiccator until further experiments. Industry analysis and ultimate analysis results are listed in Table-1.

Test method: The transmission/reflection (TR) method is relatively simple, as well as high accuracy in wide band frequencies. Thus, transmission/reflection technique is used for the measurements of the complex permittivities of coal samples. Test frequency: 200-600 MHz; test temperature: 20 ºC, test instruments: Agilent E8363A vector network analyzer.

RESULTS AND DISCUSSION

The dielectric properties of coal samples were measured. The tan σ calculated by using formulae:

$$\tan\sigma = \frac{\varepsilon''}{\varepsilon'} \qquad (2)$$

The results are shown in Table-2. We made graphs and abscissa is frequency, vertical use ε", ε', tan σ separately (Figs. 1-3).

According to the Fig. 1, real part of dielectric constant of three different coal samples rapidly decreased with the frequency increased; then kept in a certain level after 500 MHz.

†Presented at The 7th International Conference on Multi-functional Materials and Applications, held on 22-24 November 2013, Anhui University of Science & Technology, Huainan, Anhui Province, P.R. China

TABLE-1
PROXIMATE AND ULTIMATE ANALYSIS OF XINYU COAL SAMPLE

Sample	Proximate analysis (%)				Ultimate analysis (% daf)				
	Mad	Vd	Ad	FCd	Cdaf	Hdaf	Ndaf	St,d	O*daf
Raw-coal	1.03	27.81	18.02	54.17	84.21	4.45	1.52	2.68	6.55
Clean-coal	1.11	17.65	10.28	71.27	88.04	1.22	0.11	2.20	8.43
Coal seam sample	0.77	20.19	5.89	73.15	91.36	1.27	0.10	4.10	4.44

TABLE-2
TEST DATA

Test frequency	Raw-coal			Clean-coal			Coal seam sample		
f (MHz)	ε'	ε''	tan σ	ε'	ε''	tan σ	ε'	ε''	tan σ
200	40.3064	10.5535	0.2618	20.0153	5.9754	0.2985	15.1967	2.0971	0.1380
222	30.8720	7.6105	0.2465	16.0938	4.6024	0.2860	12.8402	1.8723	0.1458
245	24.4908	5.7157	0.2334	13.3110	3.6662	0.2754	11.0511	1.6746	0.1515
267	19.9904	4.4420	0.2222	11.2714	3.0019	0.2663	9.6679	1.5077	0.1559
289	16.7124	3.5486	0.2123	9.7410	2.5154	0.2582	8.5826	1.3624	0.1587
311	14.2643	2.9032	0.2035	8.5661	2.1511	0.2511	7.7172	1.2403	0.1607
334	12.3912	2.4265	0.1958	7.6528	1.8742	0.2449	7.0211	1.1377	0.1620
356	10.9369	2.0625	0.1886	6.9300	1.6547	0.2388	6.4567	1.0513	0.1628
378	9.7830	1.7846	0.1824	6.3510	1.4805	0.2331	5.9944	0.9789	0.1633
400	8.8568	1.5661	0.1768	5.8872	1.3399	0.2276	5.6137	0.9158	0.1631
422	8.1089	1.3902	0.1714	5.5110	1.2279	0.2228	5.3014	0.8610	0.1624
445	7.4935	1.2495	0.1667	5.2090	1.1336	0.2176	5.0457	0.8160	0.1617
467	6.9893	1.1327	0.1621	4.9639	1.0569	0.2129	4.8341	0.7770	0.1607
489	6.5707	1.0362	0.1577	4.7678	0.9938	0.2084	4.6618	0.7460	0.1600
512	6.2249	0.9577	0.1538	4.6114	0.9378	0.2034	4.5228	0.7176	0.1587
534	5.9349	0.8915	0.1502	4.4904	0.8931	0.1989	4.4135	0.6938	0.1572
556	5.6974	0.8369	0.1469	4.3991	0.8564	0.1947	4.3283	0.6742	0.1558
578	5.4977	0.7890	0.1435	4.3346	0.8222	0.1897	4.2645	0.6561	0.1538
600	5.3340	0.7476	0.1402	4.2915	0.7949	0.1852	4.2216	0.6418	0.1520

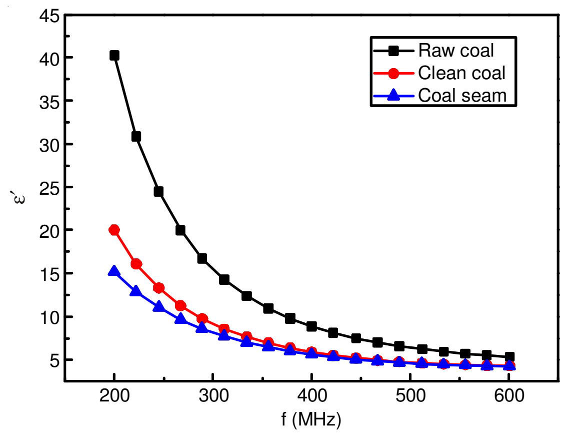

Fig. 1. Curves of the real part

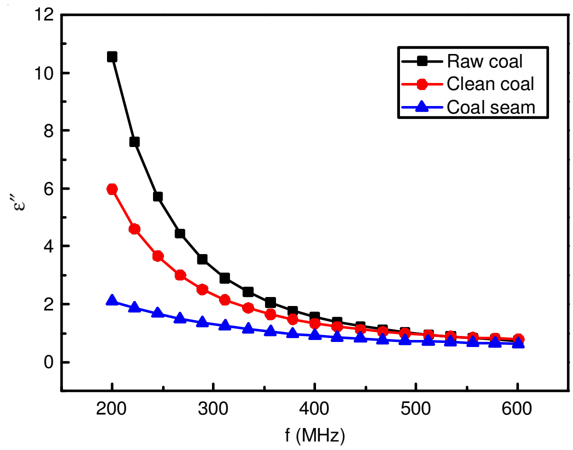

Fig. 2. Curves of the imaginary part

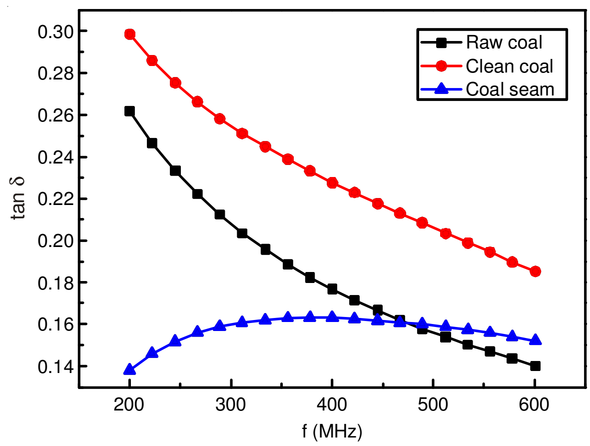

Fig. 3. Curves of the loss angle tangent

Polar molecules in coal under the applied electric field should be through a polarized towards and regular arrangement to demonstrate the regularity of polarization. At lower frequencies, the alternating electric field change needs a longer time, polar molecules to be easier, polarization phenomenon obviously. So that coal sample has a higher dielectric constant at the lower frequency band. As the frequency increases, alternating electric field in the direction of the same time will be shorter, polar molecules have not enough time to steer, dielectric constant has less value.

As shown in Fig. 2, ε'' of test coal varies with the frequency can be found similar with ε'. According to Fig. 3, dielectric loss angle tangent value of raw coal and clean coal with the frequency increasing linearly declining; coal seam has a slight

TABLE-3
FITTING RESULTS

Sample	Functional relation	Fitting result	R^2
Raw coal	ε' – f	log ε' = 5.7308 – 1.8239 log f	0.9918
	ε" – f	log ε" = 6.4498 – 2.3894 log f	0.9893
	tan σ – f	log tan α = 0.7190 – 0.5655 log f	0.9999
Clean coal	ε' – f	log ε' = 4.4411 – 1.3955 log f	0.9667
	ε" – f	log ε" = 4.8917 – 1.8174 log f	0.9841
	tan σ – f	log tan α = 0.4505 – 0.419 log f	0.9948
Coal seam	ε' – f	log ε' = 3.8318 – 1.1730 log f	0.9742
	ε" – f	log ε" = 2.8712 – 1.1124 log f	0.9941
	tan σ – f	log tan α = 6.5923 + 4.4885 log f – 0.8676 $(\log f)^2$	0.9968

increased. Dielectric loss of clean coal is greater than raw coal and coal seam.

Data fitting by data processing system: The curve between log ε', log ε", log σ and log f was fitted through the software of DPS (Data Processing System). The fitting results and determination coefficient (R^2) are shown in Table-3.

Prediction results showed that log ε' and log ε" of three coal sample was linearly related to the log f; log tan σ of raw coal and clean coal was also linearly related to the log f. There is a quadratic curve relation between log tan σ of coal seam sample and log f.

Conclusion

The following conclusions can be attained:

• Real part of dielectric constant of three different coal samples rapidly decreased with the frequency increased; then kept in a certain level after 500 MHz.

• Dielectric loss angle tangent value of raw coal and clean coal with the frequency increasing linearly declining; coal seam has a slightly increased. Dielectric loss of clean coal is greater than raw coal and coal seam.

• The log ε' and log ε" of three coal sample was linearly related to the log f; log tan σ of raw coal and clean coal was also linearly related to the log f.

• There is a quadratic curve relation between log tan σ of coal seam sample and log f.

ACKNOWLEDGEMENTS

The authors gratefully acknowledge the financial support from the Financially Supported by National Basic Research Program of China under Grant 973 Program (Grant No. 2012CB214900).

REFERENCES

1. P.D. Zavitsanos, K.W. Bleiler and J.A. Golden, Coal desulphurization using alkali metal or alkaline earth compounds and electromagnetic energy, US Patent 4152120 (1979).
2. G.C. Elsamak, N.A. Öztas and Y. Yürüm, *Fuel*, **82**, 531 (2003). (J).
3. J. Mi, J. Ren, J.-C. Wang, W.-R. Bao and K.-C. Xie, *J. China Coal Soc.*, **33**, 435 (2008).
4. Z.W. Yin, Dielectric Physics, Science Press, Beijing (2003).
5. X.-M. Feng, J. Chen, N. Li, H.-J. Cui and J.Y. Liu, *J. Taiyuan Univ. Technol.*, **38**, 405 (2007).
6. J.-C. Giuntini, J.-V. Zanchetta and S. Diaby, *Fuel*, **66**, 179 (1987).
7. Z. Peng, J.-Y. Hwang, B.-G. Kim, J. Mouris and R. Hutcheon, *Energy Fuels*, **26**, 5146 (2012).
8. A.M. Nicolson and G.F. Ross, *IEEE Trans. Instrum. Meas.*, **19**, 377 (1970).