

Dielectrics Newsletter

Scientific newsletter for dielectric spectroscopy

Issue november 1999

Ulrich Simon and Marion E. Franke

Impedance Spectroscopy on the Catalyst Zeolite H-ZSM5

The electrical properties of zeolites, which reveal enormous technical importance due to their manifold applications as solid catalysts or in gas separation, have been object of intense studies since more than three decades [1]. Zeolites are nanoporous crystalline, hydrated aluminosilicates, the general formula of which is $M_{2n}O \cdot Al_2O_3 \cdot xSiO_2 \cdot yH_2O$ (n = cation valence, $x \geq 2$) [2]. They consist of an open threedimensional framework structure of SiO_4 - and AlO_4 - edge sharing tetrahedra (fig.1) whereas each negative charge of an AlO_4 -tetrahedron is typically compensated by an exchangeable metal cation like Na^+ or K^+ .

Generally, zeolites exhibit no electronic conductivity, since they reveal a wide electronic band gap of approx. 7 eV [3]. Instead most of them are ionic conductors, since the exchangeable metal cations, which are electrostatically bound to the polyanionic host lattice, can perform translational motion. In H-form Zeolites, where protons are the charge compensating cations, bridged hydroxyl groups on each Al-sites, so-called Brønsted acid sites, are formed. Therefore the question arises whether the proton jumps between the oxygen sites surrounding the Al-centers (on-site motion) or between neighboring Al-sites (inter-site motion). In this term 1H -MAS-NMR spectroscopy has been established to determine directly the local proton mobility [4-7]. With this method small amplitude reorientational jumps between oxygen sites surrounding an aluminum center have been observed. The activation energies range from 11 – 61 $kJmol^{-1}$ and are

found being not directly related to the SiO_2/Al_2O_3 ratio. Sauer et al. obtained the barrier height for the on-site motion from quantum-chemical calculations considering an isolated AlO_4 -tetrahedron [8]. Taking into account complete optimization of the geometry a barrier height of $52 \pm 10 kJmol^{-1}$ for an arbitrary Brønsted site with two energetically equivalent Si-O-Al bridges results. Further it has been shown by this method, that the barrier height depends on the oxygen site where the proton is located and to where it will jump to [9] (see fig. 4).

According to the 1H -MAS-NMR spectroscopy and the quantum-chemical calculations the motion of protons is therefore restricted to an AlO_4 -site (Brønsted-acid site), where the protons can jump between the four oxygen atoms surrounding the Al-center. In contrast to the much bigger metal cations they are expected to be localized on these sites, since an energy of deprotonation, which is necessary for translational motion, is assumed to be larger than 13 eV [6,8]. With respect to the technical impact of zeolites especially the dynamics and energetics of protons are of interest, since they seem to be directly related to the catalytic activity [10]. Therefore we examined the electrical properties of dehydrated zeolite H-ZSM5 with different SiO_2/Al_2O_3 ratios having different spatial separation between the Brønsted sites to analyze its effect on the activation energy for proton mobility.

The samples used in this study were technical products of *Zeolyst Int.* with SiO_2/Al_2O_3 ratios of 30, 50, 80, 150, 280, and 1000. The impedance measurements were carried out in a high temperature measuring cell which allows to heat the samples up to 1000 K under vacuum ($p \leq 0.01$ Pa) (fig.2) [11].

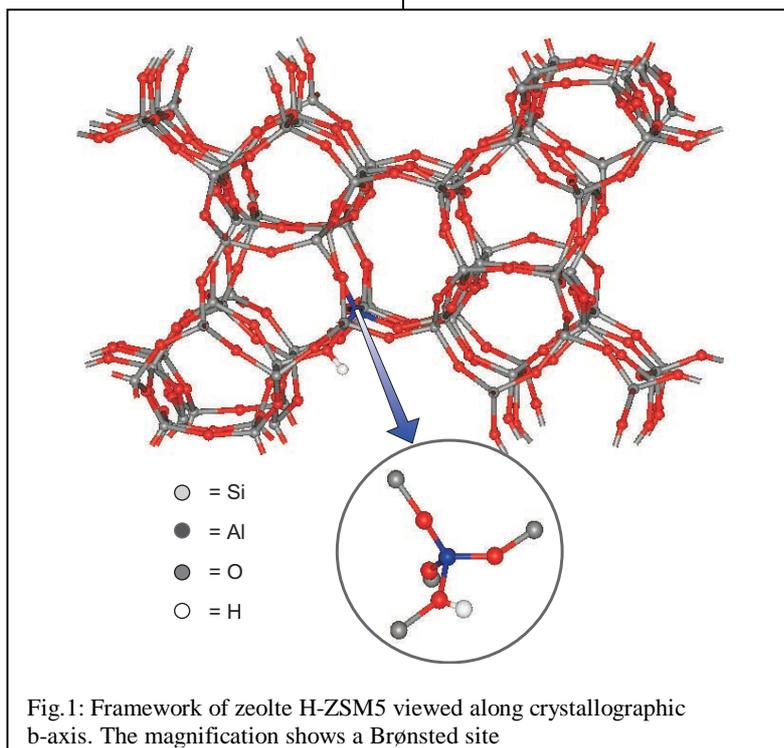


Fig.1: Framework of zeolite H-ZSM5 viewed along crystallographic b-axis. The magnification shows a Brønsted site

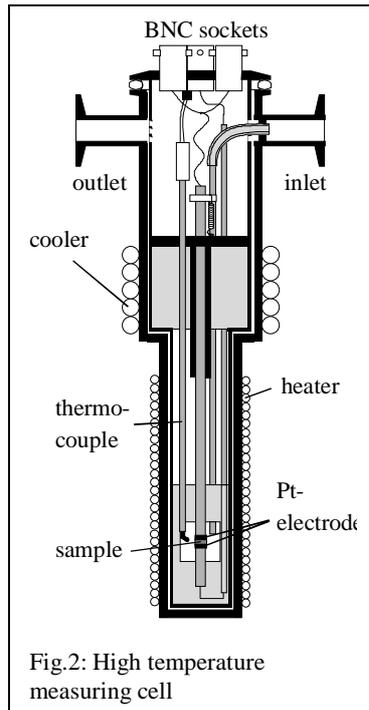


Fig. 2: High temperature measuring cell

Since water has a huge effect on the electrical properties of zeolites, pressed pellets from the powdery sample material were kept 24 h at 673 K and 0.2 Pa Argon for dehydration. Complex impedance $Z^*(\nu)$ was recorded in a frequency range $10^1 \leq \nu \leq 10^7$ Hz and a temperature range from 423 K to 773 K at intervals of 10 K using an impedance analyzer HP 4192 A. Zeolite H-ZSM5 shows two thermally activated relaxation processes with different relaxation times τ_1 and τ_2 . The quantitative analysis of the data was realized by non-linear least square fit giving a circuit equivalent which consists of a series of two Cole-Cole elements. The impedance function of this element is $Z^*(\omega) = [1/R_1 + (i\omega)^{\alpha_1}/A_1]^{-1} + [1/R_2 + (i\omega)^{\alpha_2}/A_2]^{-1}$, ($\omega = 2\pi\nu$, $1/A = C$).

From the temperature dependence of the conductivity, deduced from the resistive parts R_1 (high frequency process) and R_2 (low frequency process) of the circuit, the activation energies E_A have been determined using the Arrhenius relation $\ln(\sigma T) = \ln\sigma_0 + E_A/k_B T$ (see insert in fig. 3) (see also [12]).

According to the Na^+ -form of ZSM5 where Na^+ is the mobile species, the low frequency process reflects the charge carrier relaxation over the volume of the sample, and by this depends on the sample geometry, while the high

frequency one displays a dipolar relaxation process, which may result from local (on-site) motion or from short range ionic motion between neighboring sites (inter-site).

We applied the model for classical hopping transport to distinguish between on-site and inter-site motion, i.e. we interpreted the diffusive atomic motion in terms of random over barrier hopping from site to site (see fig. 4) [13,14]. This model is reasonable as long as the characteristic temperature is small as compared to the height of the barriers [15], which is the case, as we will see in the following. For the correlation between diffusive atomic motion with the diffusion coefficient D and the conductivity σ the Einstein relation is valid.

$$\sigma = n (ze)^2 D/k_B T \quad (1)$$

where ze is the charge of the mobile charge carriers and n the charge carrier density. Connecting this relation with the Arrhenius relation [16] the following expression for the temperature dependent conductivity in a cubic system results

$$\sigma(T) = \frac{1}{3} [(ze)^2 / k_B T] n_i(T) a_0^2 v_0 \exp(-E_A / k_B T) \quad (2)$$

with $n_i(T)$ = temperature dependent charge carrier density, v_0 = oscillation frequency of the

localized charge carrier, a_0 = hopping distance between an occupied and an unoccupied lattice site, and E_A = migration energy, i.e. the energy to create a quasi free ion. In classical hopping transport v_0 is the inverse of the life-time τ_0 of the excited ionic state. This expression was extended to a transport theory for quasi free ions, which involves two phenomenological parameters E_A and τ_0 , postulating that the total energy E_T of a free ion ($\equiv E_A$), is totally transferred into kinetic energy E_x of the ion, given by $E_x = \frac{1}{2} m_{\text{ion}} v_x^2$ (m_{ion} = ion mass, v = velocity of the ion) [17]. Thus, the mean free path l_0 of the ion is

$$l_0 = \tau_0 \sqrt{2E_x / m_{\text{ion}}} \quad (3)$$

Regarding the hopping transport between neighboring aluminum sites, l_0 is identified by the hopping length a_0 , so that for ions with $E_T \geq E_A$ the following expression holds

$$E_A = a_0^2 \cdot \frac{m_{\text{ion}}}{2\tau_0^2} \quad (4)$$

Since the crystal structure of H-ZSM5 is defined by different techniques, we calculated a_0 from the average spatial distance of the aluminum sites \bar{d}_{Al} and the volume of the orthorhombic unit cell V_{EC} (Pnma , $a=20.1$, $b=19.9$ and $c=13.4$ Å) and the $\text{SiO}_2/\text{Al}_2\text{O}_3$ ratio, which determines the number

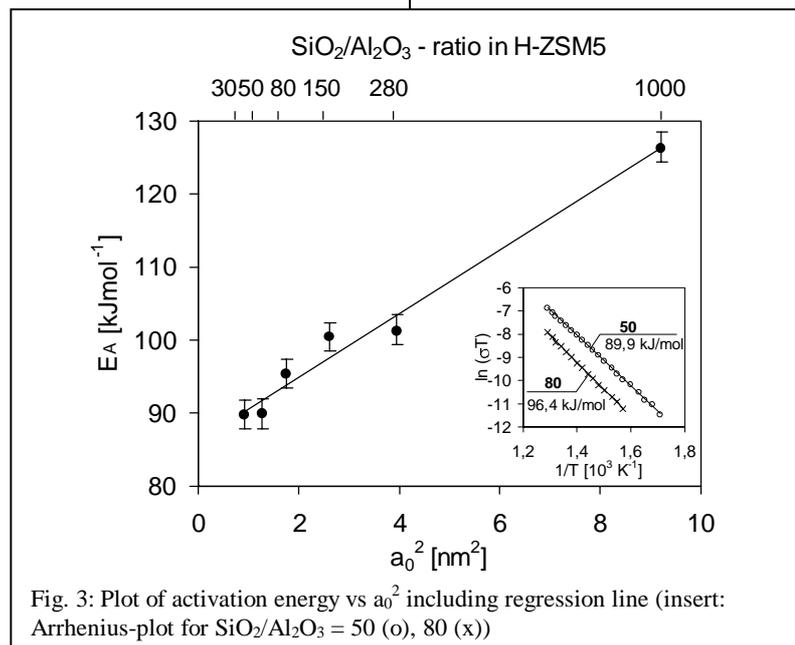
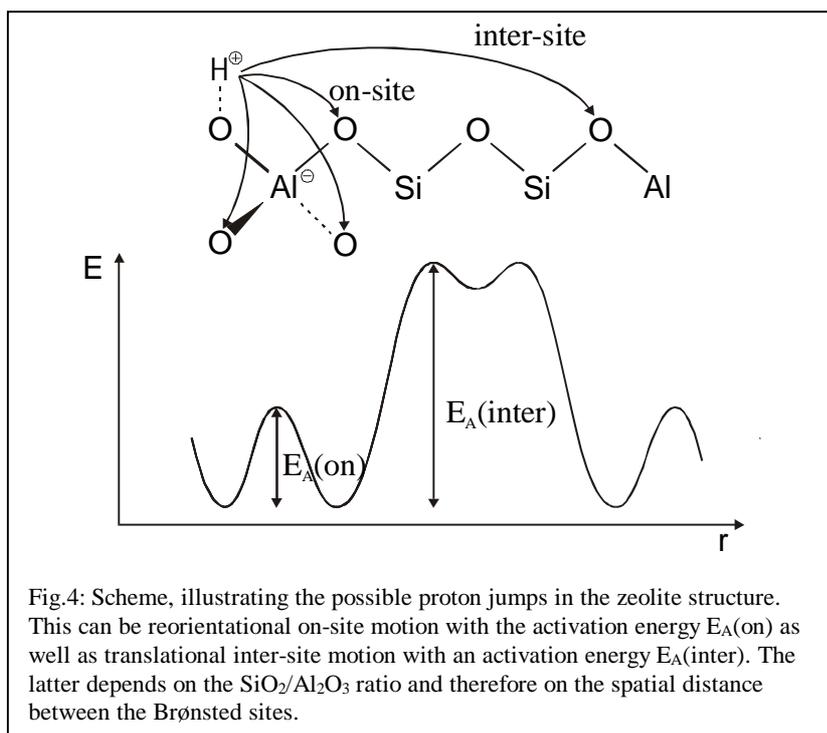


Fig. 3: Plot of activation energy vs a_0^2 including regression line (insert: Arrhenius-plot for $\text{SiO}_2/\text{Al}_2\text{O}_3 = 50$ (o), 80 (x))



of aluminum sites per unit cell Al_{EC} .

$$\bar{d}_{\text{Al}} = 3 \sqrt{\frac{V_{\text{EC}}}{\text{Al}_{\text{EC}}}} \quad (5)$$

Correlating E_A to the $\text{SiO}_2/\text{Al}_2\text{O}_3$ ratio, with a sufficient accuracy a linear dependence of E_A from a_0^2 is found (fig. 3) as it is expected from eq. (4).

Assuming isotropic transport, i.e. it is not taken into account that the crystal structure of H-ZSM5 preferably provides conduction paths along the penetrating channels, it becomes evident that eq. (4) allows a qualitative description of the structure property-relation in the material examined, since $m_{\text{ion}}/2\tau_0$ is constant for classical particles. This leads to the conclusion that the increase of E_A with increasing $\text{SiO}_2/\text{Al}_2\text{O}_3$ ratio in H-ZSM5 reflects proton hopping between neighboring sites despite the expected high activation energy of 13 eV for deprotonation, which is expected to prevent translational motion of protons. This might indicate that the motion of protons does not require full deprotonation which can be understood in terms of proton interaction with Si-O-Si groups bridging neighboring AlO_4 -sites.

This picture is consistent with the mechanism of proton conductivity

described for compact, non-porous solid oxide proton conductors, where the moving protons are assumed to be embedded into the electron density of the lattice oxygen [18].

References

- [1] D.C. Freeman and D.C. Stamires, *J. Chem. Phys.* **35**, 799 (1961); R.A. Schoonheydt and J.B. Uytterhoven, *Molecular Sieve Zeolites-1*, Advances in Chemistry Series 101, American Chemical Society, USA 1971 (p. 456); D.C. Stamires, *Clays Clay Miner.* **21**, 379 (1973); T. Ohgushi, Y. Kawanabe, *Zeolites* **14**, 356 (1994), U.Simon, U. Flesch, W. Maunz, R. Müller and C. Plog, *Micropor. and Mesopor. Mat.* **21**, 111 (1998).
- [2] D.W. Breck, *Zeolite Molecular Sieves*, John Wiley & Sons, New York 1974.
- [3] A.A. Demkov, O.F. Sankey, *Chem. Mat.* **8**, 1793 (1996).
- [4] D. Freude, W. Oehme, H. Schmiedel, B. Staudte, *J. Catal.* **32**, 137 (1974).
- [5] D. Sarv, T. Tuherm, E. Lippma, K. Keskinen, A. Root, *J. Phys. Chem.* **99**, 13763 (1995).
- [6] T. Baba, N. Komatsu, Y. Ono and H. Sugisawa, *J. Phys. Chem. B* **102**, 804 (1998).
- [7] T. Baba, Y. Inoue, H. Shoji, T. Uematsu, Y. Ono, *Microporous Mater.* **3**, 647 (1995).

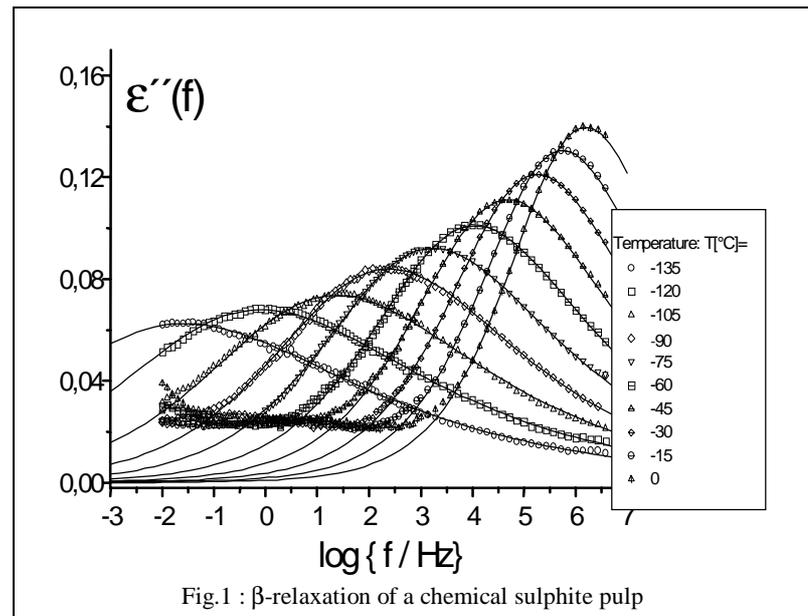
- [8] J. Sauer, C.M. Koelmel, J.R. Hill and R. Ahlrichs, *Chem. Phys. Lett.* **164**, 193 (1989).
- [9] J. Sauer, M. Sierka, F. Haase, ACS Symp. Series 721, American Chemical Society, Washington, 1999, pp 358-367.
- [10] W.E. Farneth and R.J. Gorte, *Chem. Rev.* **95**, 615 (1995).
- [11] W. Lortz, W. Osswald, G. Kelemen and G. Schön, *J. Phys. E Sci. Instrum.* **22**, 93 (1989).
- [12] U. Simon and U. Flesch, *J. Porous Mat.* **6(1)**, 33 (1999).
- [13] M.E. Franke and U. Simon, *Solid State Ionics* **118**, 311 (1999).
- [14] M.E. Franke, U. Simon, *Phys. Stat. Solidi (b)*, in press.
- [15] H. Böttger and V.V. Bryksin, *Hopping Conduction in Solids*, VCH, Weinheim 1985.
- [16] A.J. Dekker, *Solid State Physics*, Prentice Hall, New York 1957.
- [17] M.J. Rice and W.L. Roth, *J. Solid State Chem.* **4**, 294 (1972).
- [18] K.D. Kreuer, *Chem. Mater.* **8**, 610 (1996).

PD Dr. Ulrich Simon and
Dipl. Chem. Marion E. Franke,
Universität GH Essen,
Schützenbahn 70, D-45127 Essen,
Germany

Jürgen Einfeldt

Dielectric Spectroscopy of Cellulose and other Polysaccharides

Polysaccharides like cellulose, chitin or starch are the most abundante available biopolymers with an increasing technical importance. These biodegradable and renewable resources are characterized by excellent and versatile chemical and physical properties. As such, they are subject of intensive and topical scientific and commercial investigations. *E. Wagner* /1/ has already measured the dielectric spectra of cellulose in 1914 in his famous investigations of the dielectric relaxation in heterogenic isolators. Between 1935 and 1953 the main interest in the dielectric spectroscopy of cellulose were directed to paper as electrical isolator. In the last fifteen years the dielectric relaxation spectroscopy has been used more and more as analytical method in the field of fundamental investigation of polysaccharides, too /2-6/. An increasing number of articels are published every year dealing with dielectric properties of polysaccharides. But in all books about cellulose and

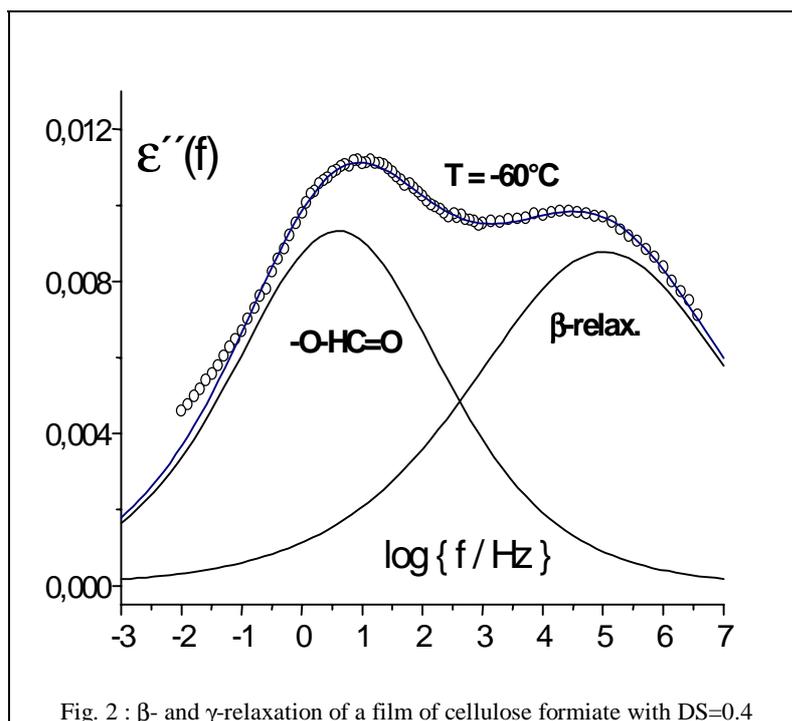


other polysaccharides dielectric spectroscopical results and its discussion play no role or are absent completely. On the other hand in the extensive book literature on dielectric properties of solid polymers [*McCrum, Read, Williams* (1991); *Hedvig* (1977); *Runt, Fitzgerald* (1997) or the reviews by *Williams* (1989, 1992)] a search is in vain for capitals which deals with cellulose or other polysaccharides and discussed the current investigations in this field of biopolymers. But all polysaccharides contains different

polar groups and presents clearly distinguishable dielectric relaxation processes.

In all polysaccharides can be observed four modes of specific dielectric relaxations /10/ : (1.) The so-called β -relaxation was observed at low temperatures (-135°C to 0°C). It is associated to the local dynamics of the main chain. Fig.1 shows the β -relaxation in a chemical sulphite pulp, but this relaxation are qualitatively similar in all polysaccharides.

(2.) The γ -relaxation, which is related to thermal activated side group motion in the repeat unit of the polysaccharides, the anhydro-glucose-unit (AGU). In the case of pure polysaccharides this side groups are the methylol group at C-5 and the hydroxyl groups at C-2 and C-3 of the pyranose ring, but its quick relaxations are out of our frequency window of 1mHz to 1MHz. But in the case of derivatives, where the AGU are functionalized by other substituents with different dipolar moments and an other conformational mobilities, this side group relaxation we can measure in the low temperature range, too. In cellulose derivatives the low temperature relaxation also can split of in the real β -relaxation and different relaxation peaks related to different substituents and positions in the AGU /7/ (Fig.2). (3.) In the middle temperature range (0°C to 60°C), especially in wet or in solvent swollen cellulotics, a futher relaxation process exist, which is named β_{wet} -



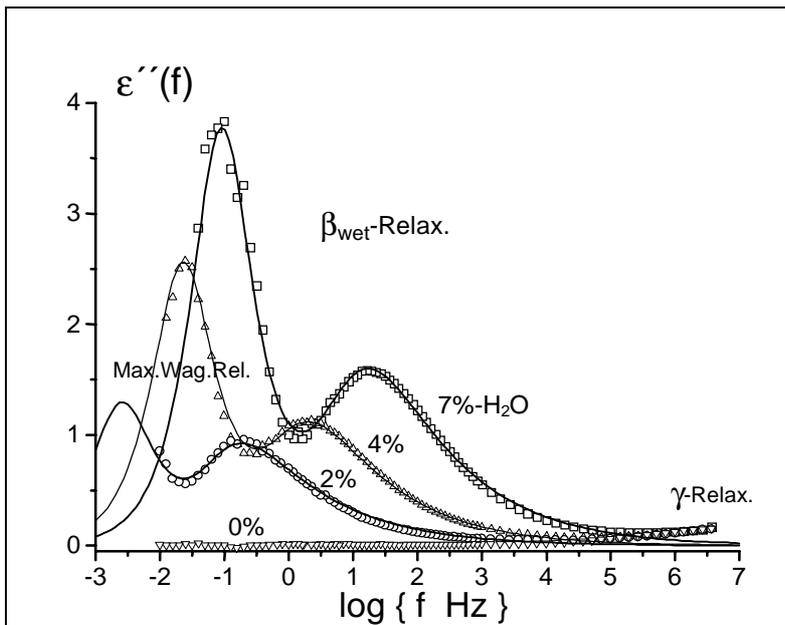


Fig.3 : β_{wet} -relaxation of never dried cotton linters

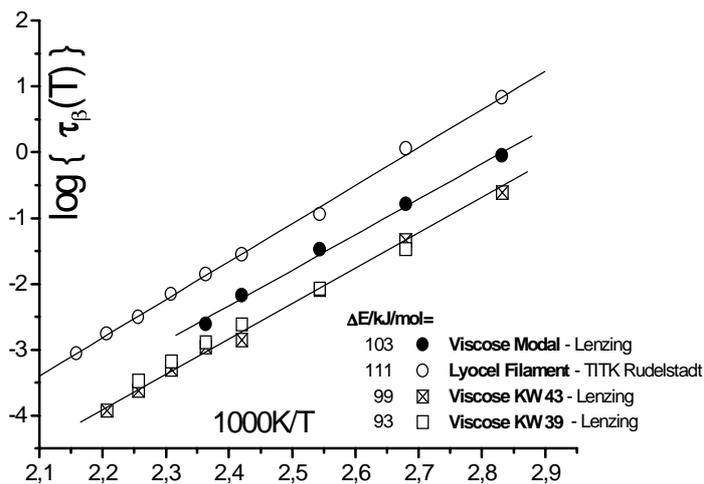


Fig.4 : σ -relaxation of viscose filaments: Arrhenius plot of relaxation time

relaxation. This relaxation is attributed to motions of regions in a biopolymer-solvent mixing state. This relaxation is very sensitive to the water or swelling solvent content. Fig 3 shows this β_{wet} -relaxation in never dried cotton linters with different water contents /8/.

(4.) In the high temperature range (80°C to 180°C) it can be observed a further relaxation process in the dielectric spectra which could not be assigned to any polymer orientational motion. This relaxation is strong related to the DC-conductivity of the biopolymer and due to the proton hopping in the disordered solid material. In the case of technical viscose filaments

this relaxation can represent differences in microscopic morphology of these cellulose materials as shown in Fig.4 as an Arrhenius plot of the relaxation time $\tau(T)$ for two conventional viscose samples, for the modal filament and for the Lyocell filament. These are all products of the Lenzing AG/ Austria.

These new experimental results, obtained with the Novocontrol system DBS-4000 with the Active Sample Cell BDC-S, demonstrate that the dielectric spectroscopy is a successful tool in the field of the polysaccharide investigation. In a new publication we have shown that the dielectric spectroscopical

results correlate in an excellent manner with the accessibility or the chemical reactivity and also with the water retention of chemical pulps /9/.

References

- [1] K.W. Wagner *Arch. F. Elektrotechnik* **2**(1914) 371 ; **3** (1914) 109
- [2] M. Scandola ; G. Ceccuivill *Polymer* **28** (1986) 1953
- [3] G.R. Saad *Polym. Int.* **34** (1994) 441
- [4] H. Montes ; J. Cavaille ; K. Mazeau *Macromolecules* **30** (1997) 6977
- [5] D.J. Crofton ; R.A. Pethrick *Polymer* **22** (1981) 1048 ; **23** (1982) 1609
- [6] V.J. McBrierty *Faraday Disc.* **103** (1996) 254
- [7] J. Einfeldt ; A.Kwasniewski ; D. Klemm ; R. Dicke ; L. Einfeldt *Polymer* (submitted)
- [8] J.Einfeldt *Das Papier* (1999 /12) (in press)
- [9] J.Einfeldt ; D. Meißner ; A. Kwasniewski ; E. Gruber ; R. Henricks *Appl. Macromol. Chem. Phys.* (submitted)
- [10] J.Einfeldt, D. Meißner, A. Kwasniewski *J.Non-Cryst. Sol.* (submitted)

PD Dr. Jürgen Einfeldt
University of Rostock (Germany) /
Dept. of Physics – Polymerphysics
Universitätsplatz 3 ;
D-18051 Rostock
juergen.einfeldt@physik.uni-
rostock.de

Graham Williams and
Dale K. Thomas

**Application Note
Summary :
Phenomenological
and Molecular
Theories of
Dielectric and
Electric Relaxation
of Materials**

The electrical/dielectric properties of materials can be presented in different ways, as the intensive quantities of permittivity, electrical modulus, conductivity and resistivity, which emphasise differently the polarization and conduction behaviour of a material. The measured quantities $Y(\omega)$, $Z(\omega)$ may be re-expressed in terms of these intensive electrical/dielectric quantities, using equivalent lumped circuit theory. It is shown how model circuits lead to classical relaxation and conduction behaviour in the frequency domain. Phenomenological descriptions of relaxation and conduction have been described and it is shown (i) how $M(\omega)$, $\sigma(\omega)$ are related to time-dependent relaxation functions and (ii) how empirical relaxation functions may be used to represent electrical/dielectric behaviour in the t- and f-domains. Molecular theories of the electrical/dielectric properties of systems exhibiting relaxation and conduction have been outlined briefly. It is shown that the reorientational motions of dipolar molecules are conveniently expressed in terms of the dipole moment correlation function $\Phi_{\mu}(t)$ and that $\epsilon(\omega)$ is obtained via the Fourier transform of this time-function. The translational motions of ionic species that lead to electrical conduction in a material are conveniently expressed in terms of the mean squared displacement or the velocity correlation function of the ions and $\sigma(\omega)$ is obtained via the Fourier transform of these time functions. Thus dielectric relaxation due to dipole motions and f-dependent conduction due to ion-motions in materials are understood in terms of molecular properties and the dynamics of molecules and ions.

This account has attempted to make clear the essential theories that underpin the electrical/dielectric properties of materials. It has only summarized the different phenomenological and molecular theories, but sufficient references have been given where the detailed derivations and mathematical analyses are described.

This article should help to answer the following questions:

- How should experimental data be presented ($\epsilon(\omega)$, $M(\omega)$, $\sigma(\omega)$) for molecular materials exhibiting (i) relaxation and (ii) conduction behaviour?
- How do the observed properties ($\epsilon(\omega)$, $M(\omega)$, $\sigma(\omega)$) relate to molecular properties such as dipole moment, ionic-charge, dynamics of rotational and translational motions of species for each system?

A number of aspects of relaxation and conduction have not been considered here. The relaxation strength $\Delta\epsilon = \epsilon_0 - \epsilon_\infty$ for dipolar relaxation behaviour is an equilibrium property of a system. $\Delta\epsilon$ is proportional to the concentration of dipole species and to the mean-squared dipole moment $\langle\mu^2\rangle$ per molecules [1-4]. Thus $\Delta\epsilon$ depends on chemical structure and molecule-conformation as has been explained [1-4].

Owing to the introductory nature of this article, we have not described the coupling-scheme of Ngai and coworkers [6] that is based on the KWW function or the mode-mode coupling approach of Götze and coworkers [7, 8] which is based on a memory-function formalism. Both approaches are widely-applied to dielectric and electrical-conductivity relaxations in polymers and glass-forming liquids. Williams [5, 9] has given a critical account of the application of mode-mode coupling theory to dielectric α -relaxations in polymers and glass-forming liquids.

Finally, we note the increasing interest in the use of microwaves in inorganic and organic synthesis, where reactions are conveniently carried out in shorter times and with possibly different mechanisms when compared with the normal thermal-preparation conditions. This subject has been reviewed [8, 9] and it appears that theoretical treatments of reactions in the presence of the heating generated by microwave dielectric losses will be of some interest in the future.

[1] C P Smyth, *Dielectric Behaviour and Structure*, McGraw-Hill, New York, 1955.

[2] N Hill, W E Vaughan, A H Price and M Davies, *Dielectric Properties and Molecular Behaviour*, Van Nostrand, New York, 1969.

[3] C J F Böttcher and P Bordewijk, *Theory of Electric Polarization*, 2nd Ed., Vol. 2, Elsevier, Amsterdam, 1978.

[4] N G McCrum, B E Read and G Williams, *Anelastic and Dielectric Effects in Polymeric Solids*, Wiley, London 1967 and Dover Publ., New York, 1991.

[5] G Williams in *Keynote Lectures in Selected Topics of Polymer Science*, Ed. E Riande, CSIC, Madrid, 1995, pp 1-39 (ISBN 84-00-07472-6).

[6] K L Ngai in *Non-Debye Relaxations in Condensed Matter*, eds. T V Ramarishnan and M Raj Lakshoni, World Scientific, Singapore, 1987, p. 23.

[7] W Götze and L Sjögren, *Rep. Progr. Phys.*, 1992, **55**, 241.

[8] W Götze in *Liquids, Freezing and the Glass Transition*, eds. D Levesque, J P Hansen and J Zimm-Justin, Elsevier, New York, 1991.

[9] G Williams and J Fournier, *J. Chem. Phys.*, 1996, **104**, 5690.

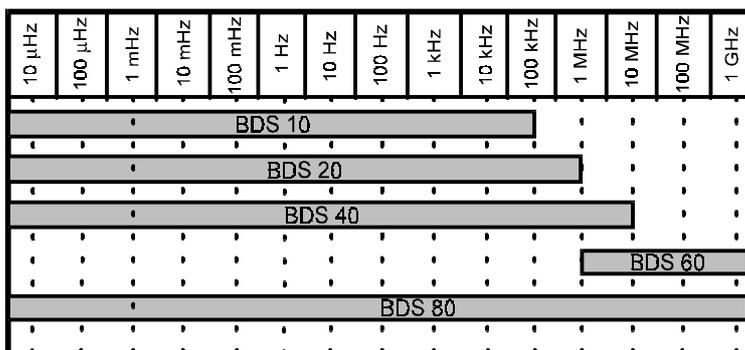
[83] D R Baghurst and D M P Mingos, *Chem. Soc. Rev.*, 1991, **20**, 1.

[9] C Gabriel, S Gabriel, E H Grant, B S J Halstead and D M P Mingos, *Chem. Soc. Rev.*, 1998, **27**, 213.

Prof. Dr. Graham Williams and Dale K. Thomas
Department of Chemistry,
University of Wales Swansea,
Singleton Park,
Swansea SA2 8PP, UK.

The complete application note can be ordered free of charge at Novocontrol.

OVERVIEW
BROADBAND DIELECTRIC SPECTROSCOPY
over 15 decades by NOVOCONTROL



Factory and Head Office

Germany: NOVOCONTROL GmbH
 Obererbacher Straße 9
 D-56414 Hundsangen / GERMANY
 Phone: ++(0) 64 35 - 96 23-0
 Fax: ++(0) 64 35 - 96 23-33
 Email novo@novocontrol.com
 Web <http://www.novocontrol.com>

Editor Dielectrics Newsletter
 Dr. Gerhard Schaumburg

Abstracts and papers are always
 welcome. We can publish max.
 2 pages A4 on each subject.
 Please send your script to the editor.

Agents

Benelux countries:
 NOVOCONTROL Benelux B.V.
 Postbus 231
 NL-5500 AE Veldhoven / NETHERLANDS
 Phone ++(0) 40 - 2894407
 Fax ++(0) 40 - 2859209

South-East Asia:
 ITS Science & Medical Pte. Ltd.
 219 Henderson Road #011-02
 Singapore 159 556
 Phone ++(0) 65 2730-898
 Fax ++(0) 65 2730-810
contact: Mr. Tony Lee

Great Britain:
 NOVOCONTROL International
 PO Box 63
 Worcester WR2 6YQ / GB
 Phone ++(0) 1905 - 64 00 44
 Fax ++(0) 1905 - 64 00 44
contact: Mr. Jed Marson

France:
 Fondis Electronic
 Services Techniques et Commerciaux
 Quartier de l'Europe, 4 rue Galilée
 F-78280 Guyancourt
 Phone: ++(0) 1-34521030
 Fax ++(0) 1-30573325
contact: Mr. Jean-Pierre Ellerbach

USA/Canada:
 NOVOCONTROL America Inc.
 611 November Lane / Autumn Woods
 Willow Springs, North Carolina 27592-7738 / USA
 Phone: ++(0) 919 639 9323
 Fax: ++(0) 919 639 7523
contact: Mr. Joachim Vinson, PhD

Korea:
 HADA Corporation
 P.O. Box 268
 Seocho, Seoul 137-602 / KOREA
 Phone ++(0) 2-577-1962
 Fax: ++(0) 2-577-1963
contact: Mr. Young Hong

Japan:
 Morimura Bros. Inc.
 2 nd chemical division
 Morimura Bldg. 3-1, Toranomom 1-chome
 Minato-Ku
 Tokyo 105 / Japan
 Phone ++(0) 3-3502-6440
 Fax: ++(0) 3-3502-6437
contact: Mr. Nakamura

Thailand:
 Techno Asset Co. Ltd.
 39/16 Mu 12 Bangwa
 Khet Phasi Charoen
 Bangkok 10160
 Phone ++(662) 8022080-2
 Fax ++(662) 4547387
contact: Mr. Narong Phoka

Taiwan (R. O. C.):
 Advantage Scientific Inc.
 P.O. Box 44-238
 Taipei
 Phone ++(02) 2733-2422
 Fax: ++(02) 2737-5575
contact: Mr. Paolo Cheng

Rep. Of China:
 GermanTech Co. Ltd.
 Jing Min Building 2915
 Hua Yan Li No. 10, Chaoyang District
 10029 Beijing
 Phone ++(10) 82073793
 Fax: ++(10) 82070995
contact: Dr. Xiang - Qian Zhou

Information request

Company / Institute

Division

Name

Title

Street

City

Postal Code

Country

Phone

Fax

Dielectric Spectrometers and Modules

- Economical dielectric spectrometers
(3 μ Hz - 300 kHz or 3 μ Hz - 1 MHz)
- Broadband dielectric spectrometer
(3 μ Hz - 10 MHz)
- RF dielectric spectrometer
(1 MHz - 1.8 GHz)
- Temperature control systems
(+20°C .. +400°C or -100°C .. +250°C
or -160°C to +500°C)
- Broadband Dielectric Converter
- MS-Windows software for automatic
measurement of dielectric relaxations,
impedance, electrical and magnetic
material properties
- MS-Windows software for automatic curve
fitting data analysis (WLF, VF) and
equivalent circuit transformation

New Instruments

- TSDC Instruments and WinTSC software
- Pressure dependent dielectric
spectrometers
- ALPHA high resolution dielectric analyzer
(3 μ Hz - 10 MHz)
- Spin Coaters

Application Notes

- Dielectric Spectroscopy on the Dynamics
of Amorphous Polymeric Systems,
by Andreas Schönhals
- Dielectric Spectroscopy of Reactive
Polymers,
by Jovan Mijovic and Benjamin D. Fitz
- Phenomenological and Molecular
Theories of Dielectric and Electric
Relaxation of Materials,
by Graham Williams and Dale K. Thomas

Status of my request

- Urgent demand. Please send me also your quotation per fax.
- Future demand. Please contact me again when I can order your
equipment.
This will be:
- General interest