(1–4). We have also developed theoretical expressions to calculate the effect of electronic relaxation on the SEDM spectra. In this paper we will present the results of a SEDM investigation of such processes in ferrichrome A (5).

REFERENCES

1. BALKO, B., and G. R. HOY. 1974. *Phys. Rev. B.* **10**:36.
2. BALKO, B., and G. R. HOY. 1976. *Phys. Rev. B.* **13**:2729.
3. BALKO, B., and G. R. HOY. 1977. *Physica.* **86–88B**:953.
4. BALKO, B., and G. R. HOY. 1976. *J. Phys. Paris Colloq. C6. Suppl. 12.* **37**:89.
5. WICKMAN, H. H. 1968. *In* Mössbauer Effect Methodology. I. J. Gruverman, editor. Plenum Publishing Corporation, New York. Second edition. 316.

ON MAGNETICALLY INDUCED TEMPERATURE JUMPS

GEORGE H. CZERLINSKI, *Department of Biochemistry, Northwestern University, Chicago, Illinois 60611 U. S. A.*

Any generator of an alternating magnetic field also produces an alternating electric field. These fields may interact directly with ionic solutions or via (ferro-electric and/or -magnetic) mediators. The (local) energy density then has four contributing terms:

$$ {}_xQ'_a = {}_xQ'_{H,} + {}_xQ'_{E,L} + {}_xQ'_{H,M} + {}_xQ'_{E,M}. \quad (1) $$

The various symbols in this equation—as well as in all later equations—are defined in the Glossary of Symbols (Table I). The subscript before Q refers to the x-axis, the direction of the propagation of the field. Fig. 1 below describes the simplified model used and defines the directions of the electric and magnetic field vectors.

At the boundary plane the magnetic field strength is defined by:

$$ H_Z(0, t) = H_0 \sin \omega t. \quad (2) $$

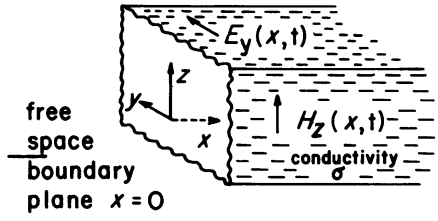

FIGURE 1 Set of definitions of an electromagnetic wave, propagating in the x-direction, and entering a "slab" at $x = 0$.

TABLE I

GLOSSARY OF SYMBOLS

Symbol	Units	Description	Equation
${}_xQ'$	Jm^{-3}	Energy density in x direction	1
H_Z	Am^{-1}	Magnetic field strength in z direction	2
H_0	Am^{-1}	Amplitude of magnetic field strength	2
ω	s^{-1}	Angular frequency	2
t	s	Time of observation	2
δ_e	m	Electric skin depth	3
μ	$Vsm^{-1}A^{-1}$	Magnetic permeability	3
E_0	Vm^{-1}	Amplitude of electric field strength	4
σ	$AV^{-1}m^{-1}$	Electric conductivity	4
D_e	m^2s^{-1}	Diffusion constant of electric field	5
l	m	Effective dimension of inductor-coil	7
λ	m	Wavelength of alternating field	7
ϵ	$Asm^{-1}V^{-1}$	Electric permittivity	8
D_h	m^2s^{-1}	Diffusion constant of heat	11
δ_h	m	Thermal skin depth	11
δ_a	m	Absorption depth	12
κ'	—	Compound loss coefficient	14
κ_3	—	Loss coefficient of magnetization	16
$c_{p,L}$	$Jdeg^{-1}m^{-3}$	Specific heat of liquid component	17
$c_{p,M}$	$Jdeg^{-1}m^{-3}$	Specific heat of particulate material	17
κ_1	—	Loss coefficient of dilution	17
V_L	m^3	Volume of liquid component	17
V_M	m^3	Volume of particle material	17
κ_2	—	Loss coefficient of frequency match	18
τ	s	Relaxation time of heat diffusion	18
r_M	m	Radius of magnetic particle	19
d_{LNK}	m	Half-width of cell with suspension	20
Q''	Jm^{-3}	Loss energy density	21
a	m	Radius of cell with suspension	22
r	m	Radius direction in cylinder	22
${}_\phi Q'$	Jm^{-3}	Energy density in cylinder	23

Symbols are aligned in sequence of appearance with reference equation given in the last column.

The stationary state expressions for the first two terms are given by (1–4):

$$ {}_xQ'_{H,L} = \tfrac{1}{2}\mu H_0^2 \exp(-2x/\delta_e)\omega t, \tag{3} $$

$$ {}_xQ'_{E,L} = \tfrac{1}{2}\sigma E_0^2 \exp(-2x/\delta_e)t. \tag{4} $$

The electrical skin depth in these equations is defined by:

$$ \delta_e = \sqrt{2D_e\omega^{-1}}, \tag{5} $$

with the electrical diffusion constant:

$$ D_e = (\sigma\mu)^{-1}. \tag{6} $$

Eqs. 3 and 4 imply the following conditions:

$$\lambda \gg l, \tag{7}$$

$$\omega^{-1} \gg \epsilon/\sigma, \tag{8}$$

$$t \gg (2\omega)^{-1}, \tag{9}$$

$$\delta_e \gg \delta_h, \tag{10}$$

where

$$\delta_h = \sqrt{2D_h\omega^{-1}}. \tag{11}$$

The last two terms in Eq. 1 refer to energy absorption by a mediator. One obtains under the same conditions stated:

$${}_xQ'_{H,M} = \tfrac{1}{2}\mu H_0^2 \exp(-x/\delta_a)\omega t, \tag{12}$$

$${}_xQ'_{E,M} = \tfrac{1}{2}\epsilon E_0^2 \exp(-x/\delta_a)\omega t. \tag{13}$$

The absorption depth for condition 7 is given by:

$$\delta_a = (\partial\kappa'/\partial x). \tag{14}$$

If condition 7 were not fulfilled, the absorption depth is defined by (5):

$$\delta_a = \lambda(4\pi\kappa')^{-1}. \tag{15}$$

However, condition 7 is fulfilled and Eq. 14 thus applies.

Parameter κ' consists of a product of three terms:

$$\kappa' = \prod_{i=1}^{3} \kappa_i. \tag{16}$$

The first two terms are the same for electric and magnetic fields:

$$\kappa_1 = \frac{c_{p,M}V_M}{c_{p,M}V_M + c_{p,L}V_L}, \tag{17}$$

$$\kappa_2 = \frac{\omega\tau}{1 + \omega^2\tau^2}, \tag{18}$$

with the dissipative time constant given by (6):

$$\tau = \frac{2r_M^2}{\pi^2 D_h}. \tag{19}$$

The third term represents the ratio of two energy (density) terms. The numerator contains the energy reversibly absorbed by the mediator particles, the denominator the energy supplied by the field. Mediator absorption has thus far only been described for magnetic fields (6, 7).[1]

[1]Czerlinski, G. H. In preparation.

If d is the width of the test cell with the particulate suspension, the exponents in Eqs. 12 and 13 become 0.01 κ' for $x = d = 0.01$ m in zero approximation. The lost energy density may easily be derived from Eq. 12 with the condition:

$$2x \leq 2d < l \ll \lambda; \kappa' \ll 1, \tag{20}$$

One obtains for the lost energy density:

$$_xQ''_{H,M} = \tfrac{1}{2}\mu H_0^2 \kappa' 2\omega t. \tag{21}$$

For cylindrical geometry the conditions of Eq. 20 become:

$$2r \leq 2a < l \ll \lambda \text{ and } \kappa' \ll 1. \tag{22}$$

One obtains then for the *lost* energy density:

$$_\phi Q''_{H,M} = \tfrac{1}{2}\mu H_0^2 \kappa' \tfrac{1}{2}\omega t. \tag{23}$$

Quite similar relations are obtained when the lost energy density is computed for systems without particulate mediators. Eqs. 3 and 4 are utilized with conditions 20 and 22, respectively.

Table II presents the results of computer simulations based on parameter values derived from the literature. It is apparent that the magnitude of the field strength determines which one of the terms in Eq. 1 predominates. The absorption by ferroelectric mediators is judged unrealistic and therefore not considered in Table II.

TABLE II

FIELD DIFFUSION LOSSES IN MATTER

Medium	Field amplitude		ΔT for one term only		
	Electric	Magnetic	Electric field	Magnetic field	Magnetic particles
	V/m	*A/m*		°C	
0.1 M NaCl,	0.16	0.16	0.000028	0.00011	0.65
10% suspension	1.16	1.6	0.0028	0.011	3.77
	16	16	0.28	1.07	10.5
0.01 M NaCl,	0.16	0.16	2.8×10^{-7}	0.000011	0.65
10% suspension	1.6	1.6	0.000028	0.0011	3.77
	16	16	0.028	0.107	10.5
0.1 M NaCl,	0.16	0.16	0.000028	0.00011	0.065
1% suspension	1.6	1.6	0.0028	0.011	0.377
	16	16	0.28	1.07	1.02

The suspensions consist of particles with nickel-like properties (and Curie temperature at room temperature, 293°K) of optimum diameter for 0.3 MHz field oscillation. The pulse width is 10^{-4}s, the total cell width $d = 0.01$ m, the simple case denoted in Fig. 1. The temperature rises ΔT refer to the isolated cases ("as if only one loss-process is present") and are obtained from the appropriate loss energy densities (Q'') through dividing them by the specific heats (c_p) involved.

Particulate mediators are not useful at very high field strengths, at very low concentrations, or in a poor match between angular frequency and dissipative time constant (and thus particle size, Eq. 19).

The introductory Eq. 1 treats the individual contributions as additive terms. This is valid only as long as the input energy is insignificantly changed along x. If there is both strong absorption due to electrolyte conductivity and particle mediation, the (local) magnetic energy density is given by:

$$_xQ'_{H,M} = \tfrac{1}{2}\mu H_0^2 \exp(-2x/\delta_e)\exp(-x/\delta_a)\omega t. \qquad (24)$$

This last equation is thus more general than either Eq. 3 or Eq. 12.

REFERENCES

1. KNOEPFEL, H. 1970. Pulsed High Magnetic Fields. North-Holland Publishing Co., Amsterdam.
2. GUY, H. W., J. F. LEHMANN, and J. B. STONEBRIDGE. 1974. *Proc. IEEE.* **62**:55–75.
3. SCHWAN, H. P. 1965. *In* Therapeutic Heat and Cold. S. Licht, editor. Licht Publishing Co., New Haven, Conn.
4. COLE, K., and R. COLE. 1941. *J. Chem. Phys.* **9**:34.
5. ROSSI, B. 1959. Optics. Addison-Wesley Publishing Co., Inc., Reading, Mass.
6. CZERLINSKI, G. H. 1977. *Bull. Am. Phys. Soc.* 43.
7. CZERLINSKI, G. H. 1977. *Biophys. J.* **17**:301*a*. (Abstr.).

KINETIC AND TRANSIENT ELECTRIC DICHROISM STUDIES OF THE IREHDIAMINE-DNA COMPLEX

N. DATTAGUPTA, M. HOGAN, AND D. CROTHERS, *Yale University, New Haven, Connecticut 06472 U. S. A.*

We have used transient electric dichroism and temperature-jump relaxation kinetics to characterize the complex formed between irehdiamine A (preg-5-ene-3β-20α-diamine, IDA) and DNA from a variety of sources. Transient electric dichroism was used to monitor the change in DNA length and base tilt angle due to complex formation. A 5% length increase at saturation with IDA was observed for DNAs from *M. luteus* (70% G·C), *E. coli* (50% G·C), and *C. perfringens* (30% G·C), and also for poly dA·poly dT. The base ultraviolet transition moments in the complex are inclined at an average angle of about 60° to the helix axis. These properties are consistent with the β-kinked B-DNA structure proposed for the complex by Sobell et al. Two DNAs from eukaryotic sources (human placenta and calf thymus) showed a 13% length increase at saturation, whereas poly dG·poly dC showed no length increase. The base tilt angle in the complex was found to be independent of the DNA source.

Temperature-jump relaxation times for the DNA-IDA complex were generally faster than 1 ms, and showed a concentration dependence consistent with a simple bimolecu-