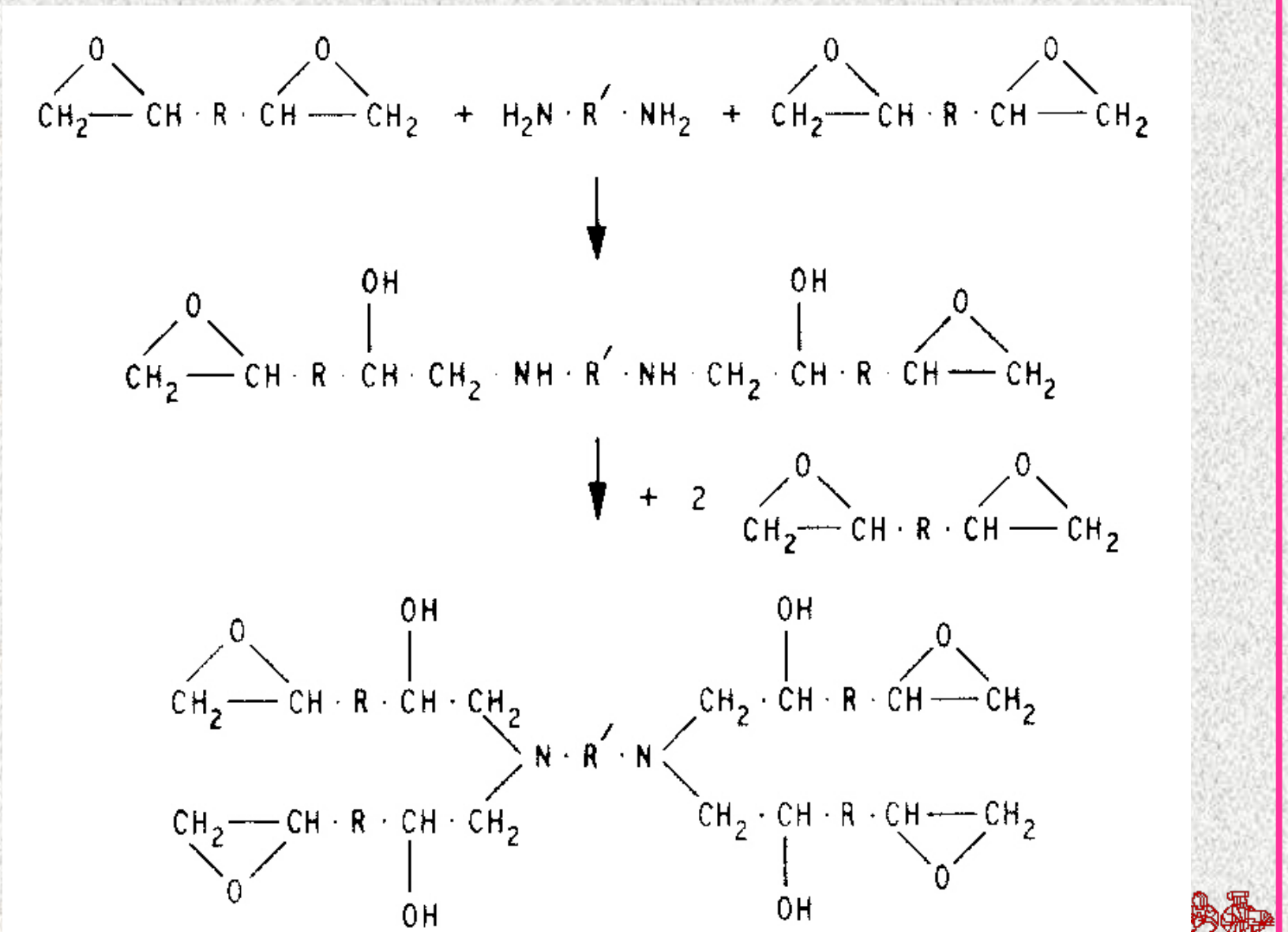
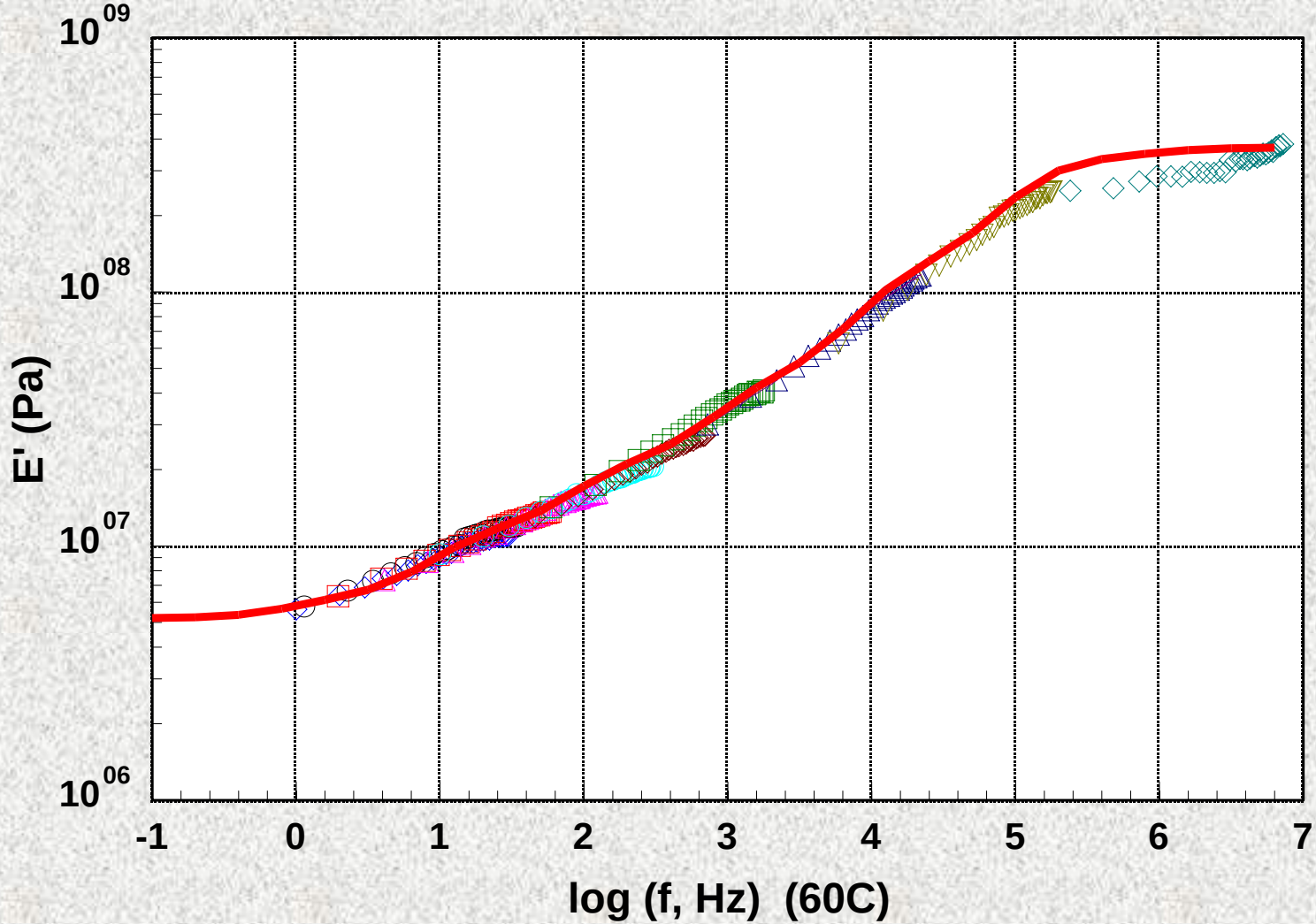
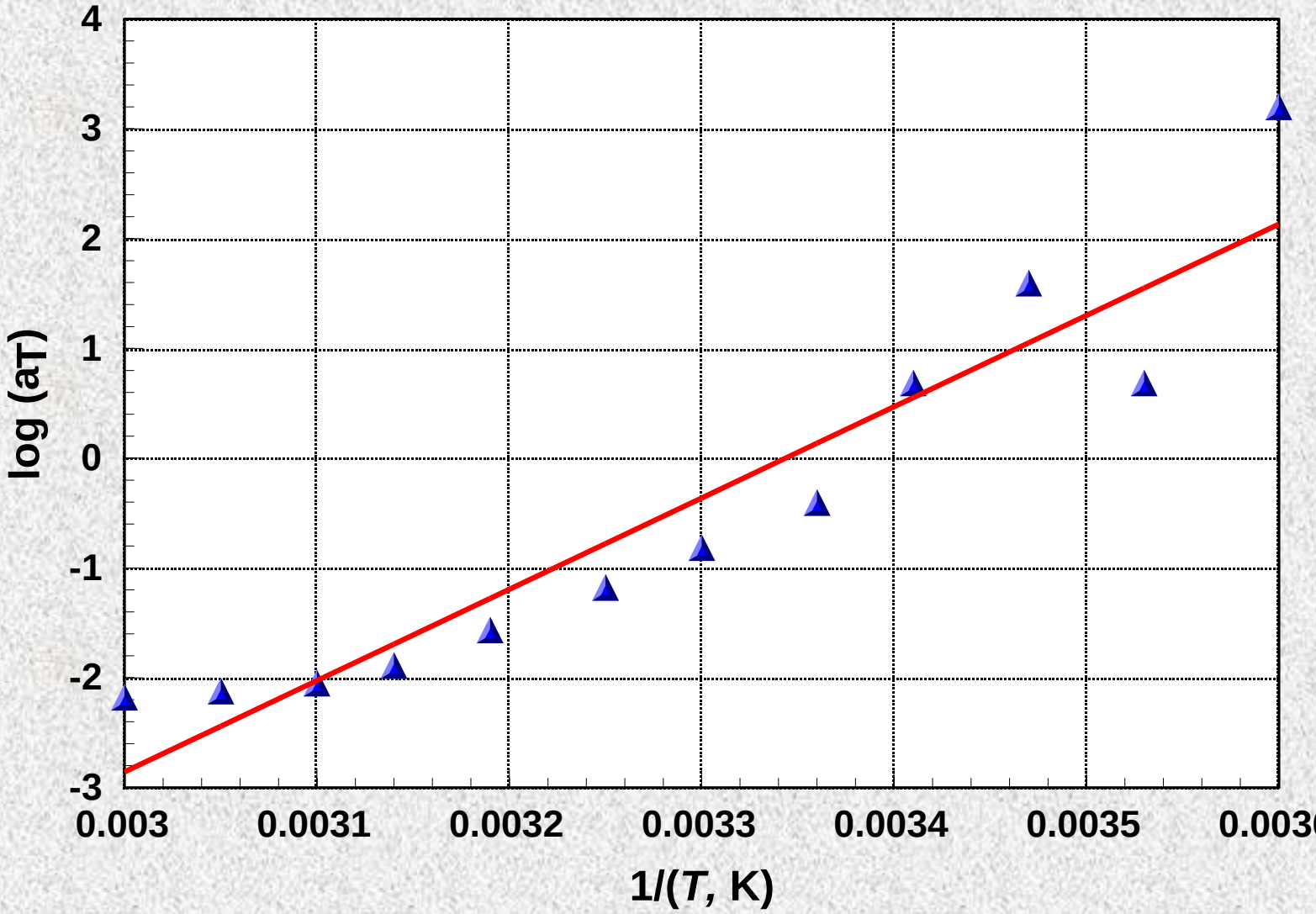
Ultrasonic Consolidation

Photo of apparatus removed due to copyright restrictions.

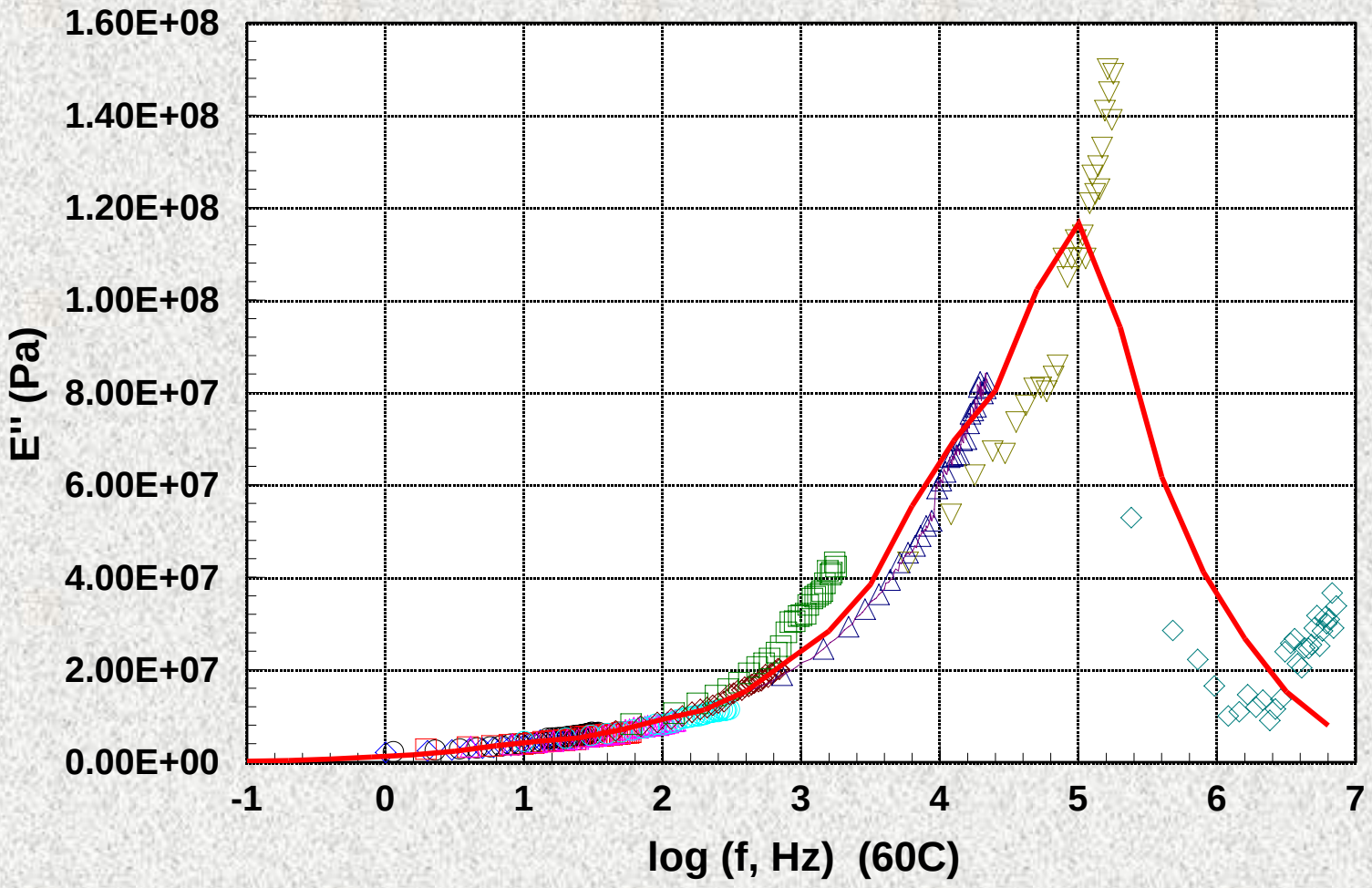


E' Master Curve and Model Fit




4
3
2
1
0
-1
-2
-3
log (aT)
0.003
0.0031
0.0032
0.0033
0.0034
0.0035
0.0036
1/(T, K)

E'' Master Curve and Model Fit



Process Model

- Ultrasonic heating

$$\frac{dT}{dt} = \frac{Q}{\rho c}, \qquad Q = f \cdot \pi E'' \varepsilon_0^2 + R_r \Delta H_r$$

- Dynamic modulus

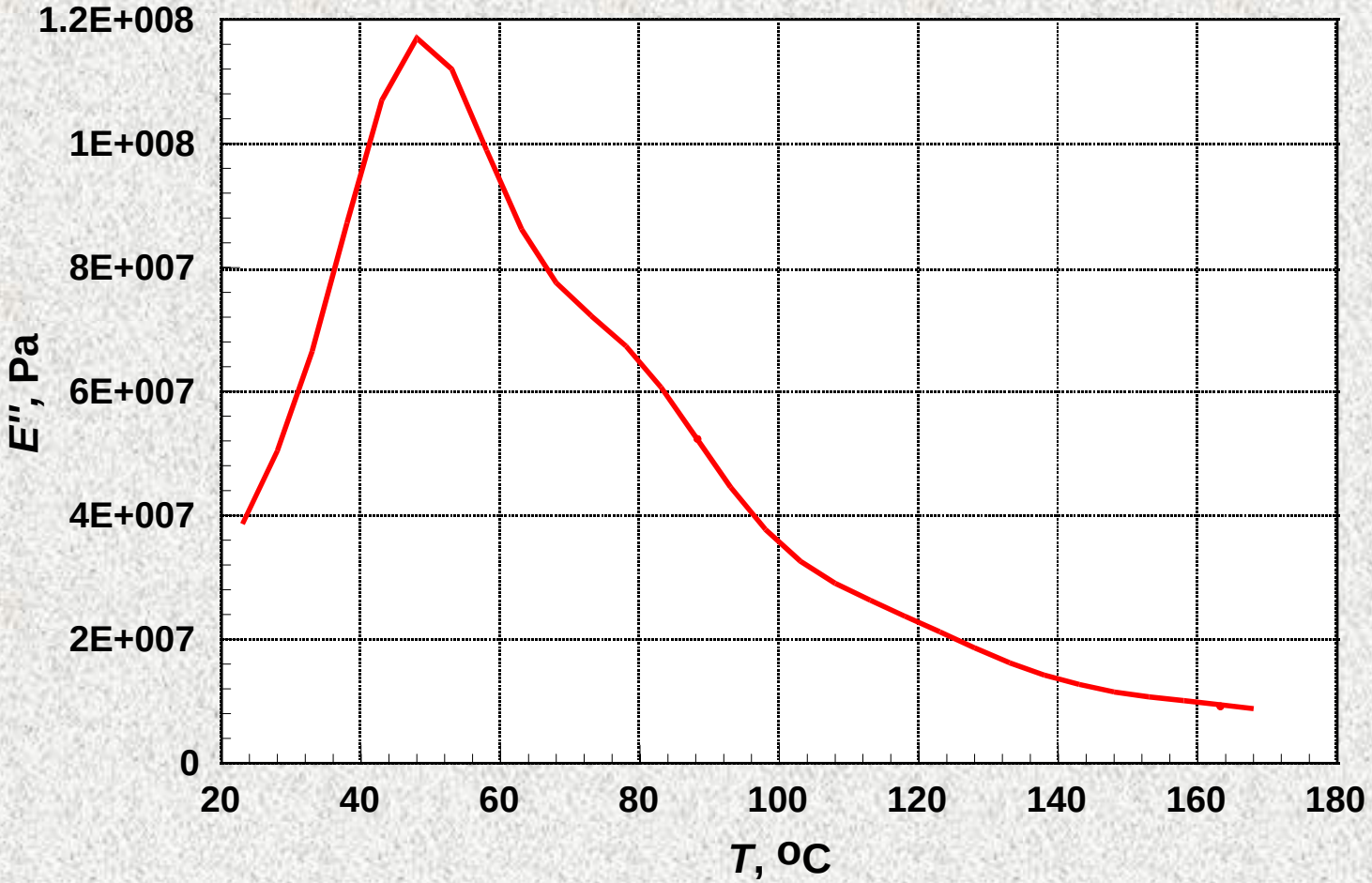
$$E' = k_0 + \sum_{j=1}^{N} \frac{k_j \left(\omega \tau_j\right)^2}{1+\left(\omega \tau_j\right)^2}, \qquad E'' = \sum_{j=1}^{N} \frac{k_j \left(\omega \tau_j\right)}{1+\left(\omega \tau_j\right)^2}$$

$$\tau_j = \tau_{0j} \exp\left(\frac{E^\tau}{R_g T}\right)$$

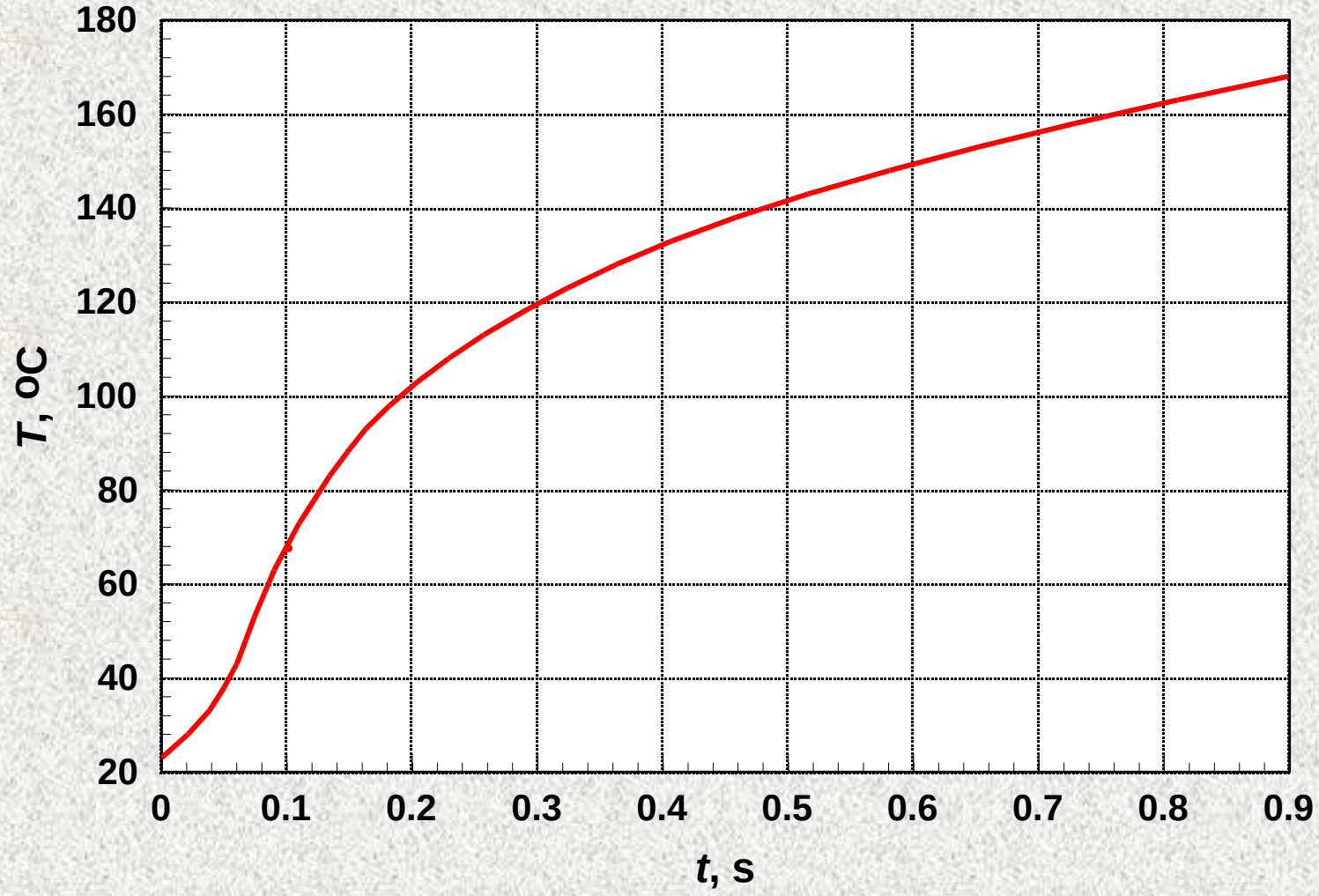
- Curing reaction

$$\frac{d\alpha}{dt} = k_0 \exp\left(\frac{-E^r}{R_g T}\right) \cdot \alpha^{m1} \left(1-\alpha\right)^{m2}$$

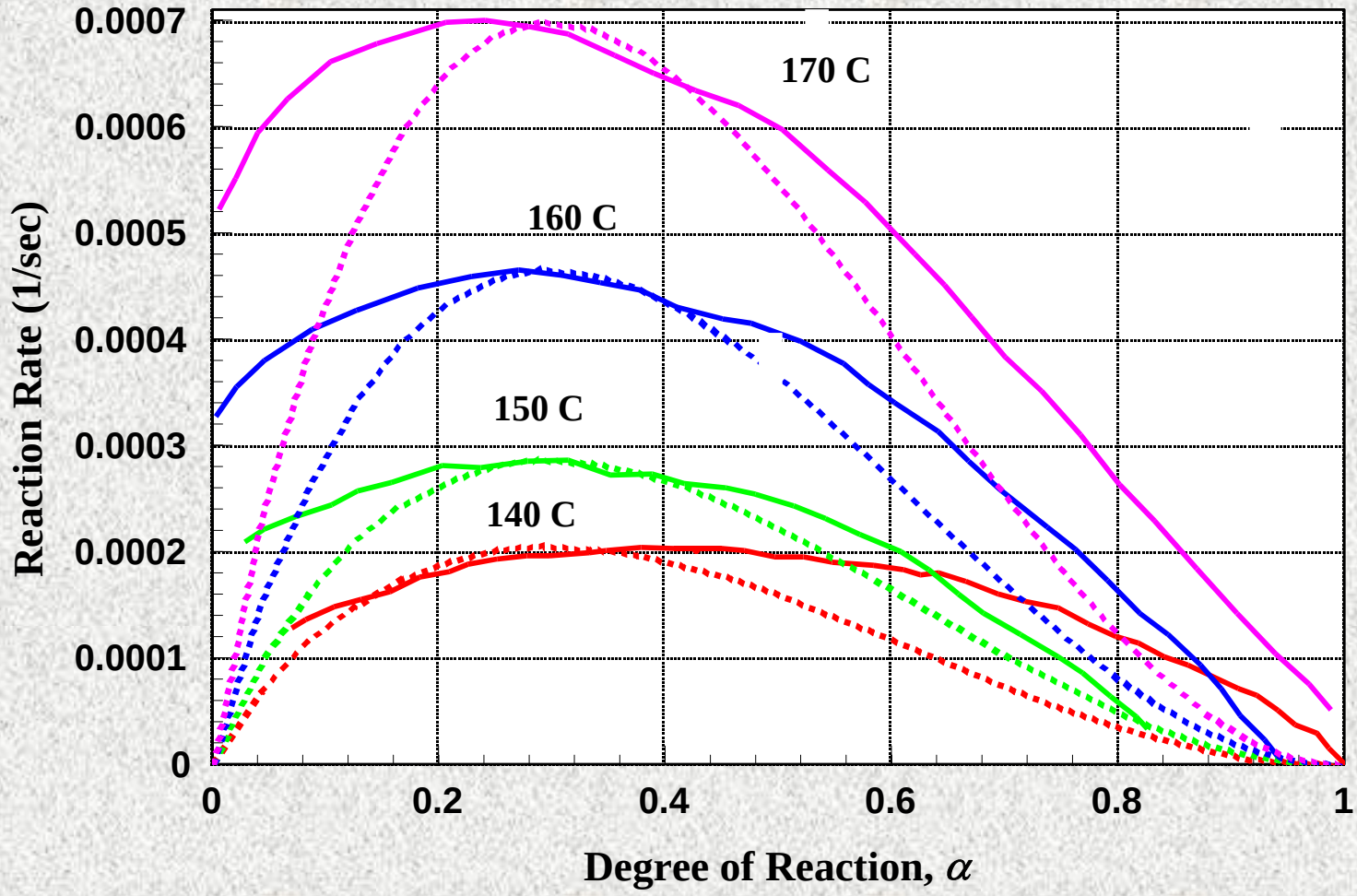
Temperature Dependence of E'' at 40MHz

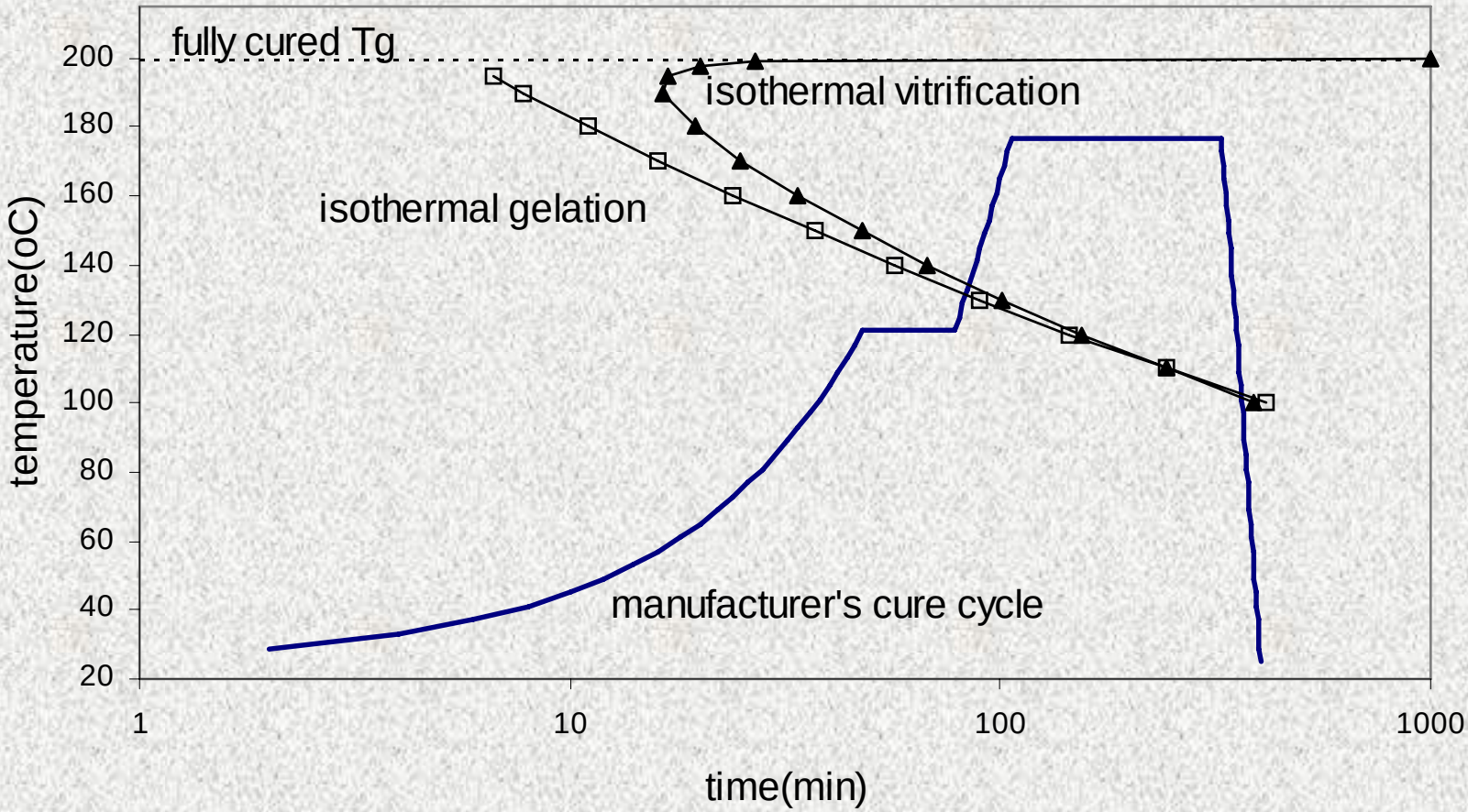


Carbon/8552 composite, ε_o = 1.4%, f = 40 kHz.



DSC Cure Scans and Model Fit




fully cured Tg
isothermal vitrification
isothermal gelation
manufacturer's cure cycle
temperature(oC)
200
180
160
140
120
100
80
60
40
20
1
10
100
1000
time(min)

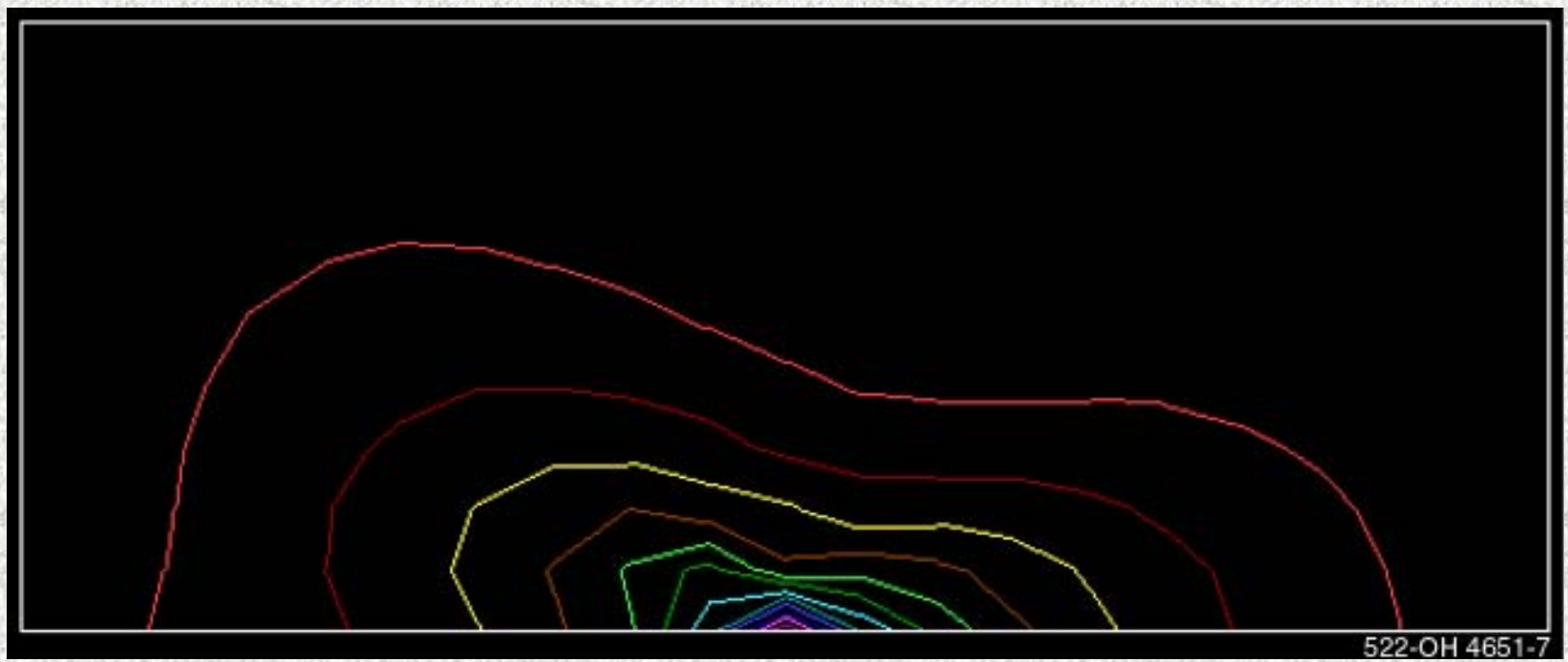
Finite Element Analysis (FEA)

$$\rho\left[\frac{\partial u}{\partial t}+u\nabla u\right]=-\nabla p+\nabla\left(\eta\nabla u\right)$$

$$\rho c\left[\frac{\partial T}{\partial t}+u\nabla T\right]=Q+\nabla\left(k\nabla T\right)$$

$$\left[\frac{\partial C}{\partial t}+u\nabla C\right]=R+\nabla\left(D\nabla C\right)$$

FEA - Displacement (u_x) Contours



FEA - Temperature Contours