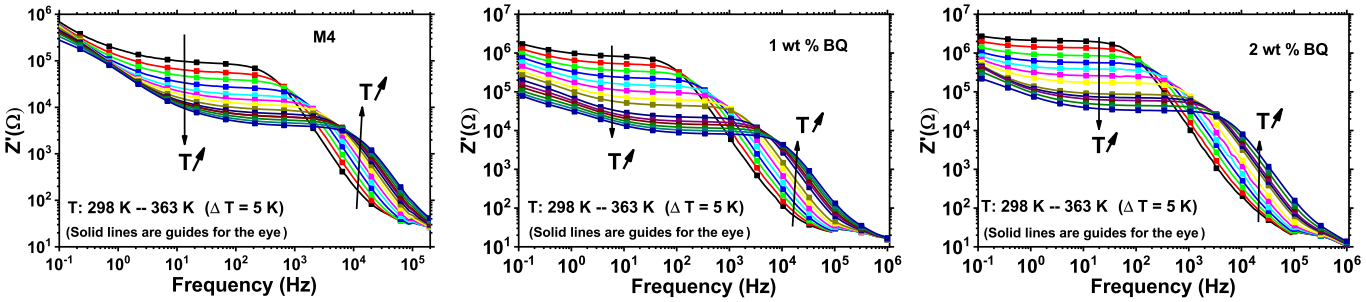
Electronic Supplementary Information (ESI)

Bulk charge-transfer coupling and tunable dielectric relaxation in benzoquinone-doped nematic liquid crystals

Yosr Turki,[a,*] Bochra Bejaoui,[a] Ali Benali,[a] Mohamed Mastouri,[b] Noureddine Raouafi,[b] and Youssef Arfaoui[c]

[a] *Functional Materials and Interfaces Group; University of Tunis El Manar, Tunisia.*
[b] *Sensors and Biosensors Group; University of Tunis El Manar, Tunisia.*
[c] *Laboratory of Characterizations, Applications and Modeling of Materials, Tunisia.*
[*] *E-mail: yosr.turki@fst.utm.tn*

Supplementary Figures



(a) (b) (c)

Figure S1. Complete set of frequency-dependent real impedance spectra (Z') recorded from 298 K to 363 K with a temperature step of $\Delta T = 5$ K for (a) the pristine Merck IV (M4) host, (b) the 1 wt % benzoquinone-doped system (1 wt % BQ), and (c) the 2 wt % benzoquinone-doped system (2 wt % BQ). These data provide the full thermal evolution of the resistive response across the nematic and isotropic phases and complement the representative isotherms presented in Figure 6 of the main text. Solid lines are guides for the eye.

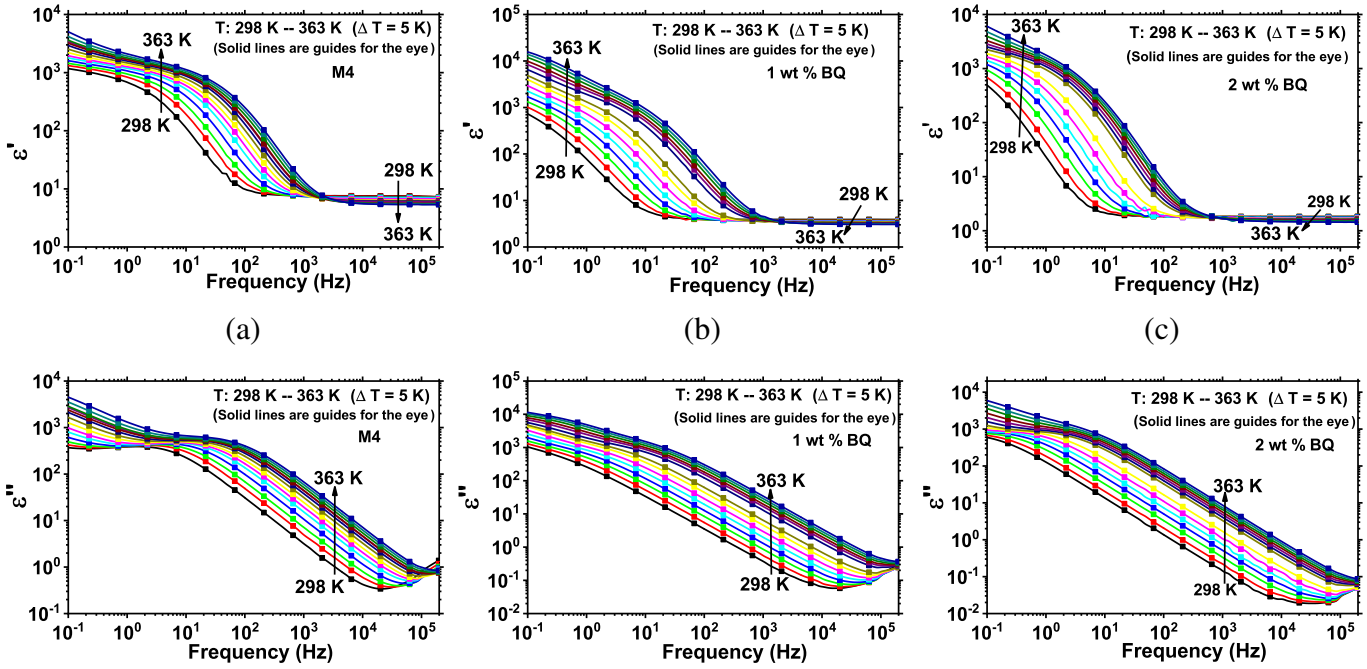


Figure S2. Complete set of frequency-dependent complex permittivity spectra recorded from 298 K to 363 K with a temperature increment of $\Delta T = 5$ K. The top panels display the real part ε', while the bottom panels show the imaginary part ε'' for (a,d) M4, (b,e) 1 wt % BQ, and (c,f) 2 wt % BQ. These spectra supplement the selected isotherms shown in Figure 7 of the main text and provide full thermal resolution of the polarization response.

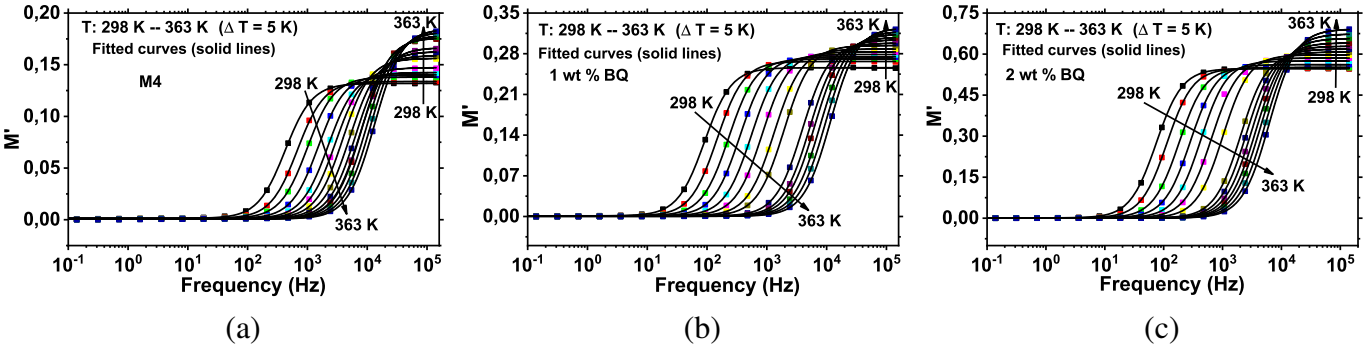
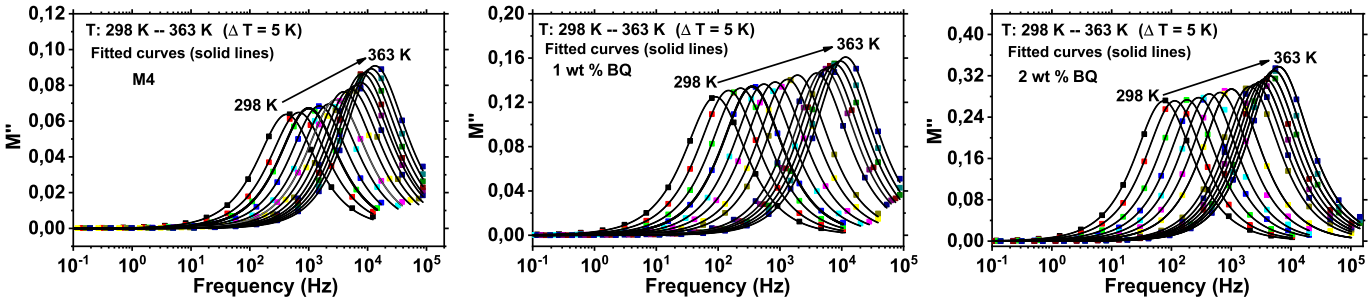
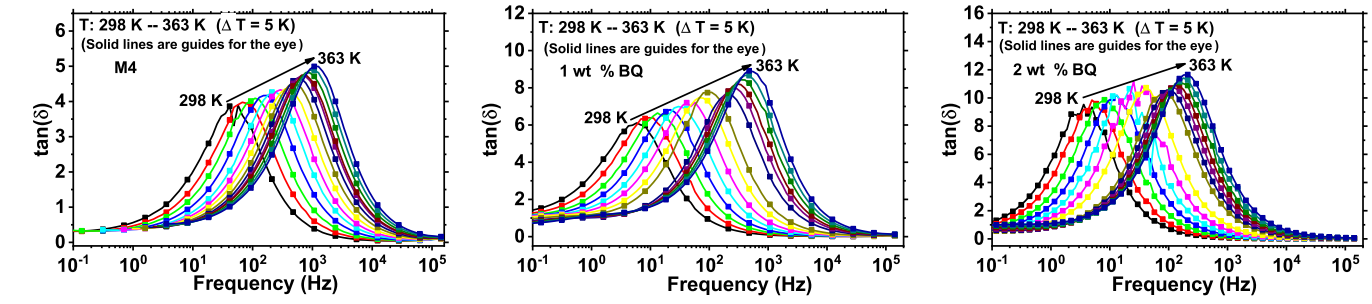


Figure S3. Complete set of frequency-dependent real electric modulus spectra (M') recorded from 298 K to 363 K with a temperature step of $\Delta T = 5$ K for (a) M4, (b) 1 wt % BQ, and (c) 2 wt % BQ. The low-frequency suppression of M' reflects the minimization of electrode polarization effects, while the high-frequency response corresponds to intrinsic bulk dielectric relaxation. These data complement the representative curves shown in Figure 8 of the main text.



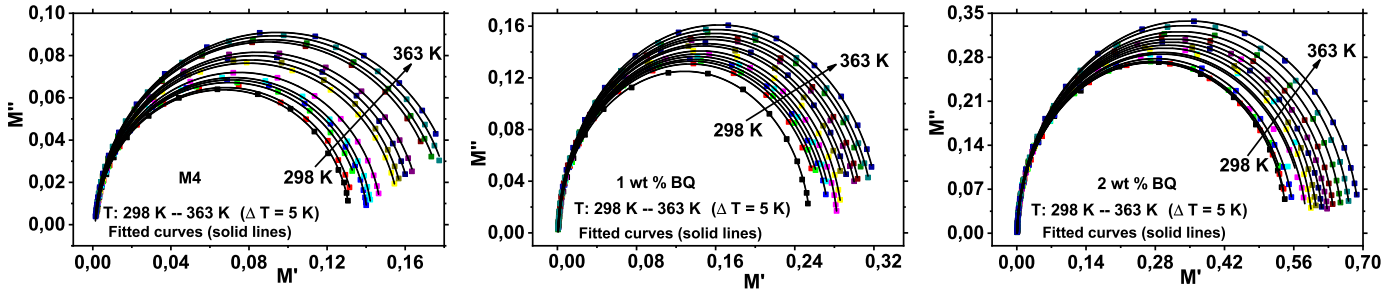
(a) (b) (c)

Figure S4. Complete set of frequency-dependent imaginary electric modulus spectra (M'') recorded from 298 K to 363 K with a temperature step of $\Delta T = 5$ K for (a) M4, (b) 1 wt % BQ, and (c) 2 wt % BQ. These spectra illustrate the systematic thermal shift and broadening of the relaxation peak and supplement the selected isotherms presented in Figure 10 of the main text.



(a) (b) (c)

Figure S5. Complete set of frequency-dependent dielectric loss tangent ($\tan\delta$) spectra recorded between 298 K to 363 K ($\Delta T = 5$ K) for (a) M4, (b) 1 wt % BQ, and (c) 2 wt % BQ. These data complement Figure 16 of the main text and provide a comprehensive view of the evolution of conductive and relaxation contributions with temperature.



(a) (b) (c)

Figure S6. Complete set of Nyquist representations (M'' vs M') recorded from 298 K to 363 K with a temperature increment of $\Delta T = 5$ K for (a) M4, (b) 1 wt % BQ, and (c) 2 wt % BQ. These plots provide the full thermal evolution underlying the representative Nyquist diagrams presented in Figure 17 of the main text.