

ALPHA-A: Nonlinear Dielectric, Conductivity, Electrochemical and Impedance Spectroscopy

With the Alpha-A series, Novocontrol provides a turnkey solution for nonlinear dielectric, conductivity, electrochemical and impedance spectroscopy. For this purpose, the Alpha-A mainframe and all test interfaces (except G22) support measurements of the sample voltage and current in terms of DC components, harmonic base waves and higher harmonics up to the interface upper frequency limit.

Nonlinear evaluation is fully supported by DETACHEM software, which reads and graphically displays all voltage and current base, and higher harmonic components. In addition, other parameters like DC material parameters, linear impedance, permittivity, conductivity and the corresponding higher harmonic terms are processed.

The higher harmonic current components $I_n(\omega)$ are calculated by the Alpha analyzer like the base wave ($n=1$) by complex Fourier Transform from the sampled current $i(t)$, where n denotes harmonic $n-1$.

$$I_n(\omega) = \frac{2}{nT} \int_0^{nT} i(t) \cdot \exp(jn\omega t) dt$$

Applications in impedance mode include:

- Characterizations of nonlinear materials properties
- Component under test properties

In gain phase mode, non-sinusoidal signal components in the measured voltages are detected by harmonic analysis.

Important publications

- Richert, R (ed.), Nonlinear Dielectric Spectroscopy, Springer International Publishing, 2018.
- Albert, S., Bauer, T., Michl, M., Biroli, G., Bouchaud, J.P., Loidl, A., Lunkenheimer, P., Tourbot, R., Wiertel-Gasquet, C. & Ladieu, F. 2016. Fifth-order susceptibility unveils growth of thermodynamic amorphous order in glass-formers. *Science* 352 (2016) 1308.
- Michl, M., Bauer, T., Lunkenheimer, P. & Loidl, A. 2014. Cooperativity and Heterogeneity in Plastic Crystals Studied by Nonlinear Dielectric Spectroscopy. *Phys. Rev. Lett.* 114, 067601 (2015).
- Bauer, T., Lunkenheimer, P., Kastner, S. & Loidl, A. 2013. Nonlinear dielectric response at the excess wing of glass-forming liquids. *Phys. Rev. Lett.* 110:107603.
- Bauer, T., Michl, M., Lunkenheimer, P., Loidl, A., Nonlinear dielectric response of Debye, α and β relaxation in 1- propanol. *J. Noncryst. Solids* 407:66.
- Michl, M., Bauer, T., Lunkenheimer, P. & Loidl, A. 2015. Nonlinear dielectric spectroscopy in a fragile plastic crystal. *J. Chem. Phys.* 144 (2016) 114506.
- Casalini, R., Fragiadakis, D. & Roland, C.M. 2015. Dynamic correlation length scales under isochronal conditions. *Journal of Chemical Physics* 142:064504.
- Patro, L. N., Burghaus, O., Roling, B. Nonlinear ion transport in the supercooled ionic liquid 1-hexyl-3-methylimidazolium bis(trifluoromethylsulfonyl)imide: Frequency dependence of third-order and fifth-order conductivity coefficients. *Journal of Chemical Physics*:142:064505.
- Patro, L. N. / Burghaus, O. / Roling, B. Nonlinear permittivity spectra of supercooled ionic liquids: Observation of a "hump" in the third-order permittivity spectra and comparison to double-well potential models. *Journal of Chemical Physics* 146:154503.
- Patro, L. N. / Burghaus, O. / Roling, B. Anomalous Wien Effects in Supercooled Ionic Liquids. *Physical Review Letters* 116:185901.

