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Frequency factor of the semiempirical model for the radiation-induced conductivity in spacecraft polymers

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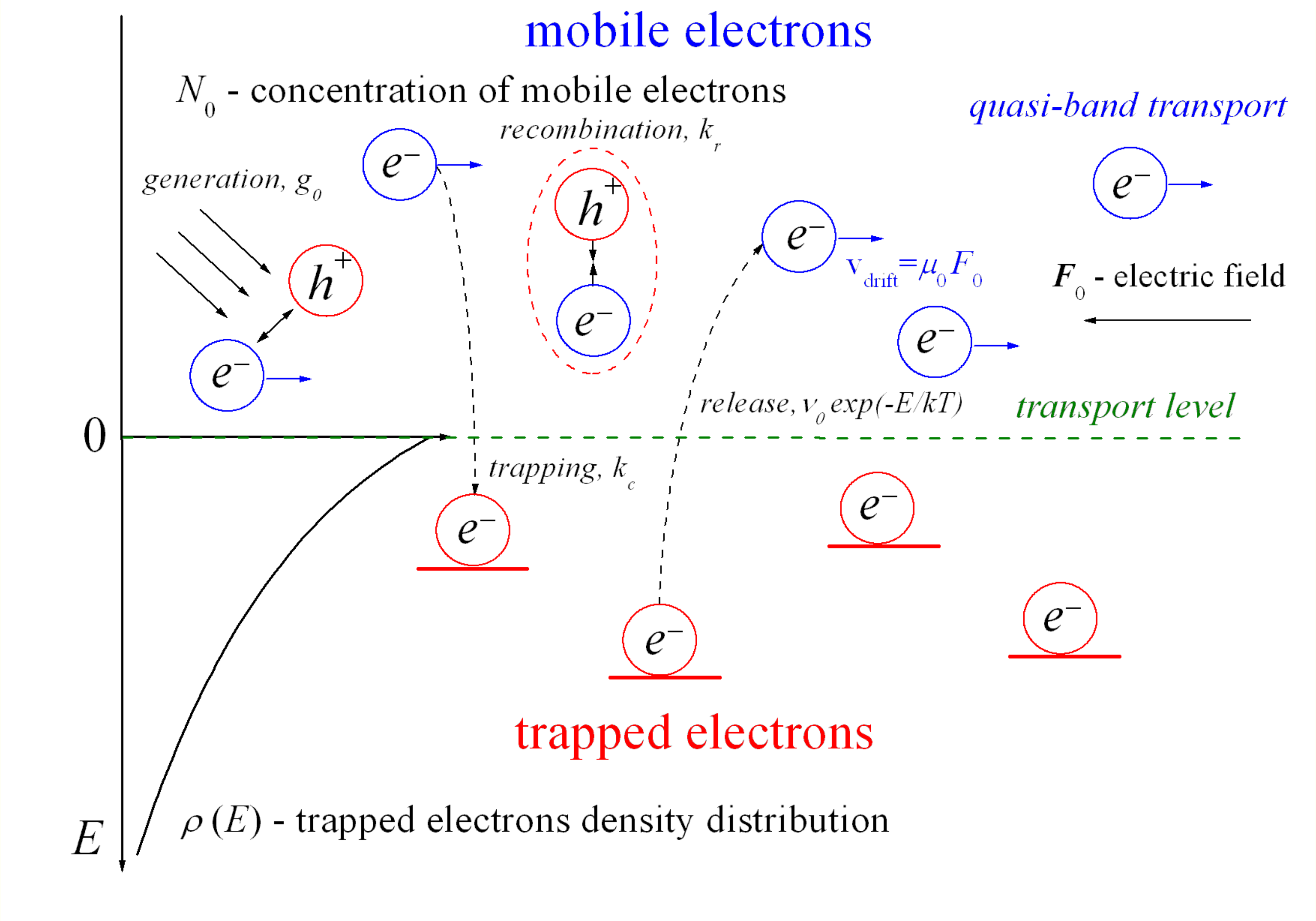
RFV-model: multiple trapping mechanism



mobile electrons

N_0 - concentration of mobile electrons

quasi-band transport

generation, g_0

recombination, k_r

$v_{drift} = \mu_0 F_0$

F_0 - electric field

release, $\nu_0 \exp(-E/kT)$

transport level

trapping, k_c

trapped electrons

$\rho(E)$ - trapped electrons density distribution

RFV model equations

$$\begin{cases} \dfrac{dN}{dt} = g_0 - k_r N_0 N, \\ \dfrac{\partial \rho}{\partial t} = k_c N_0 \left[\dfrac{M_0}{E_1} \exp\left(-\dfrac{E}{E_1} \right) - \rho \right] - \nu_0 \exp\left(-\dfrac{E}{kT} \right) \rho, \\ N = N_0 + \int\limits_0^\infty \rho \, dE. \end{cases}$$

$$\gamma_r(t) = e\mu_0 N_0(t)$$

Radiation-induced conductivity (RIC)

$$\alpha = kT / E_1 \text{ , } \tau_0 = (k_c M_0)^{-1}$$

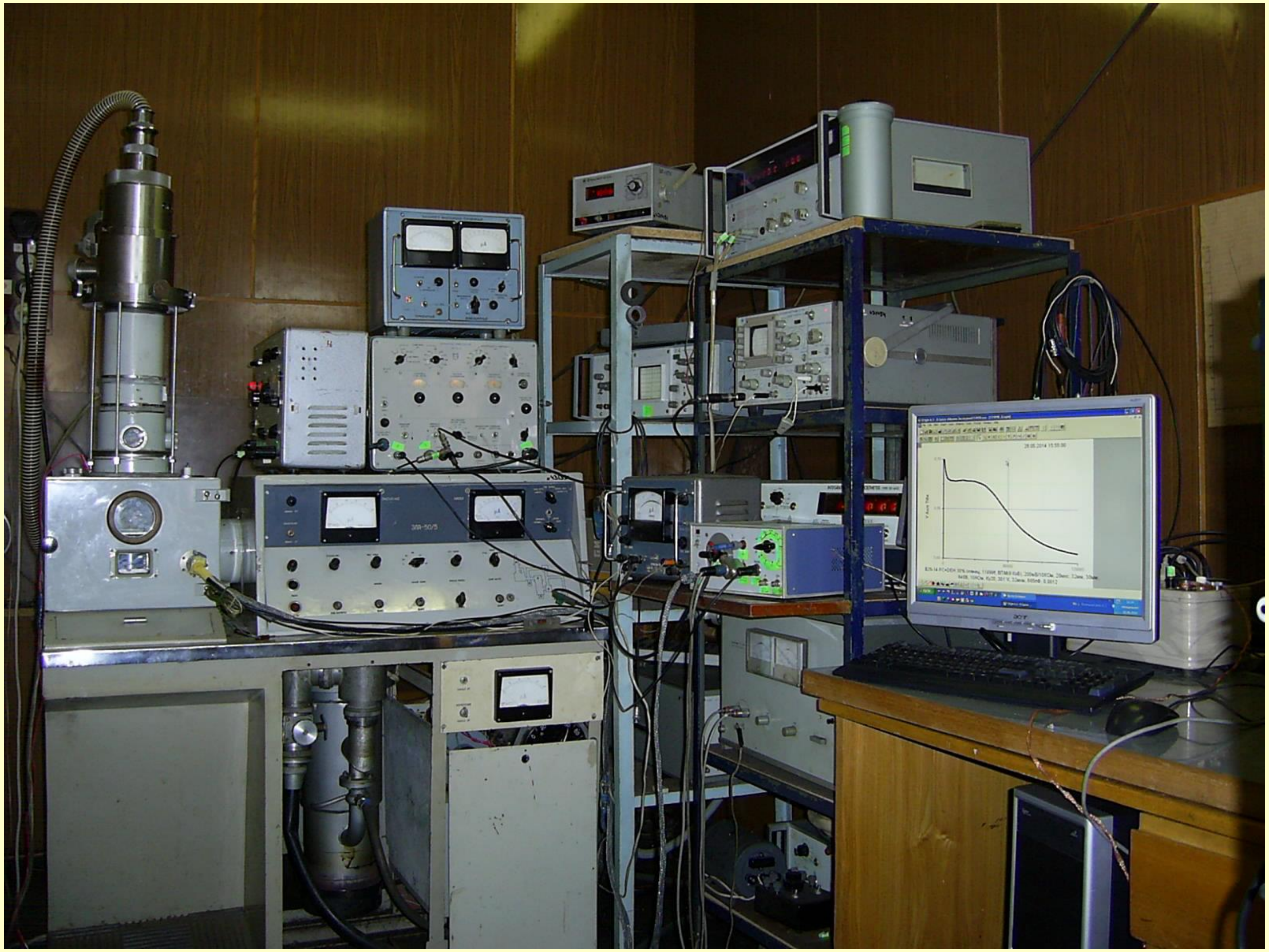
$$g_0 \mu_0 \tau_0 e$$

Table. List of investigated polymers and sample characterization

Polymer	Sample thickness, μm	Electric field, V / μ m
Kapton	25	10-40
PM-1-OA	12	5-100
Low density polyethylene (LDPE)	20	10-60
Teflon-FEP	25	40
Polyethyleneterephthalate (PET)	12	5-100
Polystyrene (PS)	20	2.5-60
Molecularly doped polymer (30% DEH:PC)	10	10-100

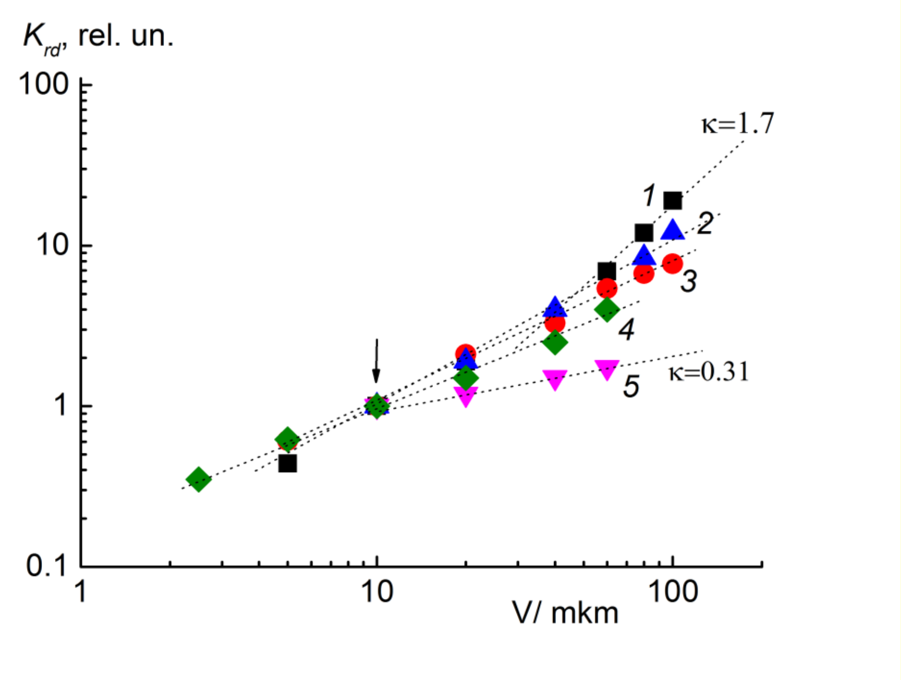
Samples were 40 mm in diameter, aluminized on both sides (32 mm circular electrodes).

ELA-65 electron-gun facility



ELA-65 supplying pulsed beams of monoenergertic electrons (2 to 50 keV energy) irradiating polymer films stressed by an applied electric field.

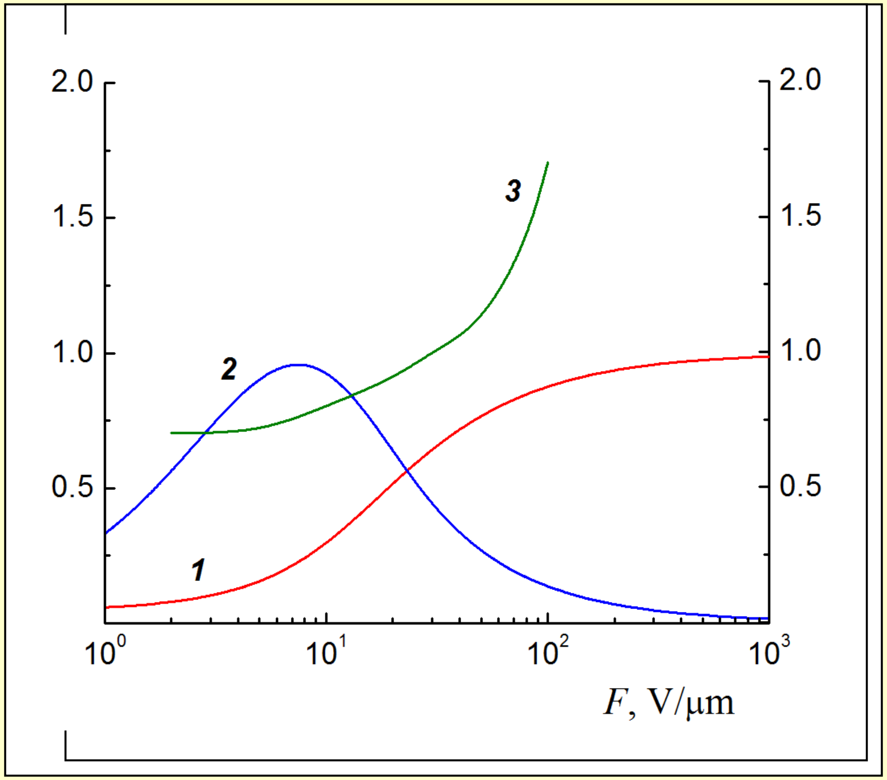
Field dependence of the reduced RIC delayed component taken 10 microseconds after the end of the pulse 20 microseconds long



1- 30%DEH:PC
2 – PM-1OA
3- PET
4- PS
5- LDPE

$K_{rd}(t_{\bar{p}})$ **is the delayed RIC per unit dose rate (for a small signal regime, it is a legitimate characterization parameter) and kappa is the local slope of these curves.**

Onsager theory (constant mobility) versus experimental data



$$\Omega_\infty = \exp\left\{\frac{r_c}{r_0}\cdot\frac{[\exp(-\varsigma)-1]}{\varsigma}\right\}$$

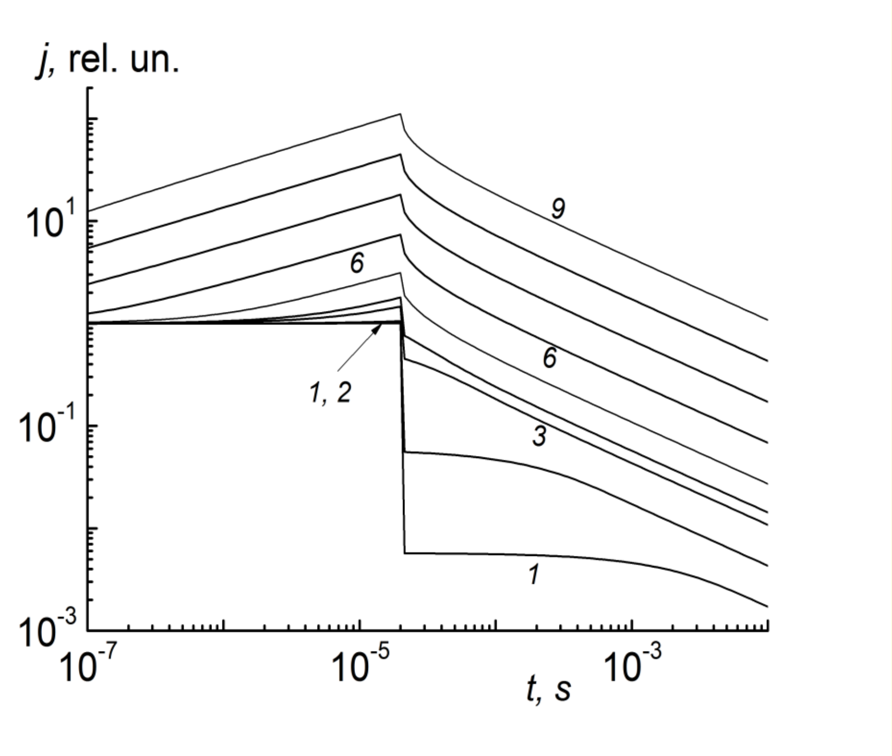
$$r_c = e^2/(4\pi\varepsilon\varepsilon_0 kT)$$

$$\varsigma = eFr_0/kT$$

$$\xi = d\ln\Omega_\infty / d\ln F$$

$$\kappa = d\ln K_{rd} / d\ln F$$

- Computed values of Ω_∞ (*1*), ξ (*2*) and an experimental κ (*3*) for 30% DEH:PC plotted as a function of the electric field (r_0 = 6 nm,
- $r_c =$ 18 nm).



For curves *1* and *2*, reciprocal frequency factor equals plateau length.

For curves *3* and *4* current falls as a straight line and in this case

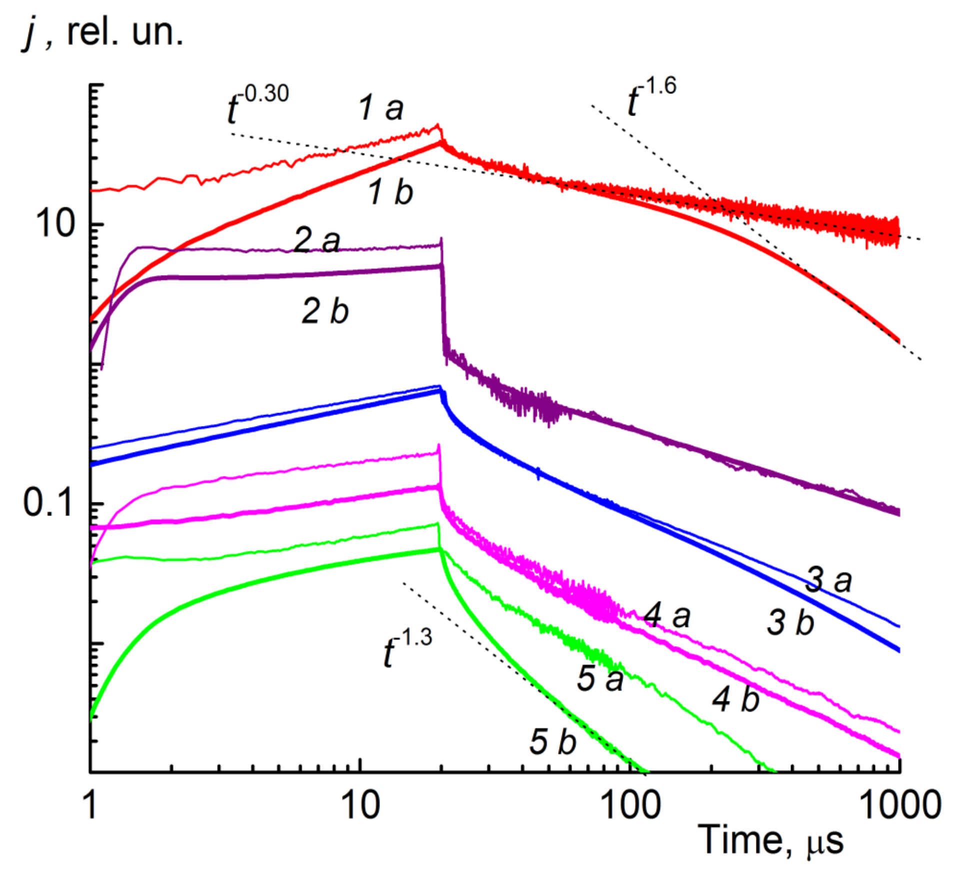
$$\nu_0 t_p \approx 4$$

As frequency factor gets larger and larger, the amplitude of the decaying current at the pulse end progressively increases but its decay shape tends to become almost universal. This limits our ability to determine it.

Calculated RIC curves (in units of the prompt component) for various values of $\nu_0 =$ 10^3 (*1*), 10^4 (*2*), 10^5 (*3*), 2 10^5 (*4*), 10^6 (*5*), 10^7 (*6*), 10^8 (*7*), 10^8 (*8*) and 10^{10} s^{-1}(*9*). For all curves, dispersion parameter $\alpha = 0.4$.

(Arkhipov V.I., J. Non-Cryst. Solids, 1993, V. 163, pp.274-282)

Probing of the frequency factor field dependence



. RIC current densities measured for a fixed dose rate (3 10^5 Gy/s) for a pulse length 20μs grouped in pairs for the lowest (a) and the highest (b) electric field (for different polymers curves are not to scale). The curves were made to coincide just after the pulse end (so that their delayed components were equal). Polymers tested: 30% DEH:PC (*1*), LDPE (*2*), PM-1OA (*3*), PS (*4*) and PET (*5*) for pairs of fields 10 and 100 (*1, 3, 5*) and 10 and 60 V/μm (*2, 4*).

Conclusions

- The field dependence of the delayed conductivity at strong fields contradicts the traditional Onsager theory. To overcome this discrepancy, we introduced the field dependence of the frequency factor in terms of the RFV model. Accommodating this fact would require some readjustment of the existing values of the product $\mu_0\tau_0$ decreasing it to some extent.

Thank you for your attention!