

### 3.4.2 Summary to: Dynamic Properties - Dielectric Losses

The frequency dependent current density  $j$  flowing through a dielectric is easily obtained.  $\Rightarrow$

- The in-phase part generates active power and thus heats up the dielectric, the out-of-phase part just produces reactive power
- The power losses caused by a dielectric are thus directly proportional to the imaginary component of the dielectric function

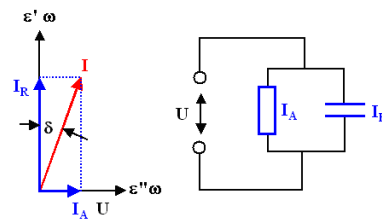
$$L_A = \text{power turned into heat} = \omega \cdot |\epsilon''| \cdot E^2$$

$$j(\omega) = \frac{dD}{dt} = \epsilon(\omega) \cdot \frac{dE}{dt} = \omega \cdot \epsilon'' \cdot E(\omega) + i \cdot \omega \cdot \epsilon' \cdot E(\omega)$$

in phase                      out of phase

The relation between active and reactive power is called "tangens Delta" ( $\text{tg}(\delta)$ ); this is clear by looking at the usual pointer diagram of the current

$$\frac{L_A}{L_R} := \text{tg } \delta = \frac{I_A}{I_R} = \frac{\epsilon''}{\epsilon'}$$



- The pointer diagram for an *ideal* dielectric ( $\sigma(\omega = 0) = 0$ ) can always be obtained from an (ideal) resistor  $R(\omega)$  in parallel to an (ideal) capacitor  $C(\omega)$ .
- $R(\omega)$  expresses the apparent conductivity  $\sigma_{DK}(\omega)$  of the dielectric, it follows that

$$\sigma_{DK}(\omega) = \omega \cdot \epsilon''(\omega)$$

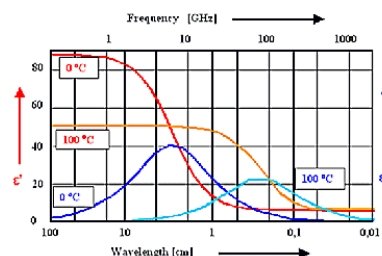
For a *real* dielectric with a non-vanishing conductivity at zero (or small) frequencies, we now just add another resistor in parallel. This allows to express *all* conductivity effects of a real dielectric in the imaginary part of its (usually measured) dielectric function via

$$\epsilon'' = \frac{\sigma_{\text{total}}}{\omega}$$

- We have no *all* materials covered with respect to their dielectric behavior - in principle even metals, but then resorting to a dielectric function would be overkill.

A good example for using the dielectric function is "dirty" water with a not-too-small (ionic) conductivity, commonly encountered in food.

- The polarization mechanism is orientation polarization, we expect large imaginary parts of the dielectric function in the **GHz** region.
- It follows that food can be heated by microwave (ovens)!



## Questionnaire

Multiple Choice questions to all of 3.4