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**Dielectric Spectroscopy on Ga Nanoparticles in Glassy Matrix: Negative Capacitance Effect**

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Investigations on the frequency-dependent complex permettivity stressed, in the recent years, the non trivial phenomenon of the negative capacitance effect (NC) (i.e. negative values of the capacitance when the oscillations of charge lag behind the driving variable voltage). In literature the NC behavior has been reported in different semiconductor electronic devices both heterostructures and homostructures (e.g. Ge, $Ga_xTe_{1-x}$, Schottky diodes, GaAs/AlGaAs QWIP) besides electrolytic systems and attributed to

The presented investigation concerns with the negative capacitance effect firstly detected in systems of metallic (Ga) nanoparticles embedded in a insulating $SiO_x$ matrix. The phenomenon was evidenced to take place in the low-frequency range of $4x10^5$ Hz-$8x10^5$ Hz, both at the temperature RT and 20 K.

The results are interpreted on the basis of the inertial component of the transient current that, instead of the impulse-like component, is time depending. It was shown that the NC may rise if the time-derivative of the transient current is positive or nonmonotonic with time. As a consequence the phenomenon appears when the conductivity is inertial (i.e. a microscopic physical process causes a delay in the current response to applied voltage) and the relaxation component of the transient current is larger than the displacement part.

In a very good agreement with the theory, the reported data evidence a very close correspondence between the current values and the onset and intensity of the NC effect that occurs in the frequency range where the conductivity values are higher and becomes relevant with the current (Figs.1,2).

In order to explore the dependence of the NC phenomenon on the gallium nanoparticles size, for the samples a growth technique was adopted that allows to obtain a rather regular shape of the gallium nanoparticles (np) and a relative low size dispersion (= 20%). Moreover TEM measurements were accomplished for performing samples analysis. The dependence of the NC phenomenon on the nanoparticles size (3 nm and 9 nm in radius) shows a relevant enhancement of the effect with the size reduction (Fig. 4) In particular the data give indication that, specifically at 20 K temperature, the NC amplitude with respect to the nanoparticles size, follows the 1/r law (r being the np radius).

Besides the NC dependence on the applied field, displays the characteristic feature of the formation of space charges at the Ga np/$SiO_x$ interfaces so indicating the main process responsible of the current delay. More generally, the obtained results suggest that the nanometric structures similar to those here investigated are preferential for the occurring of the NC phenomenon.

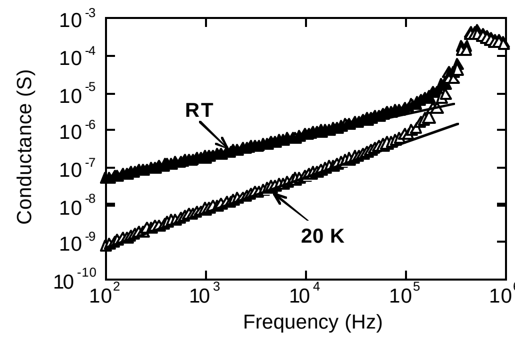


Fig. 1. Conductance vs frequency in the dielectric part of the system, at RT and 20 K, for 0.5V as example.

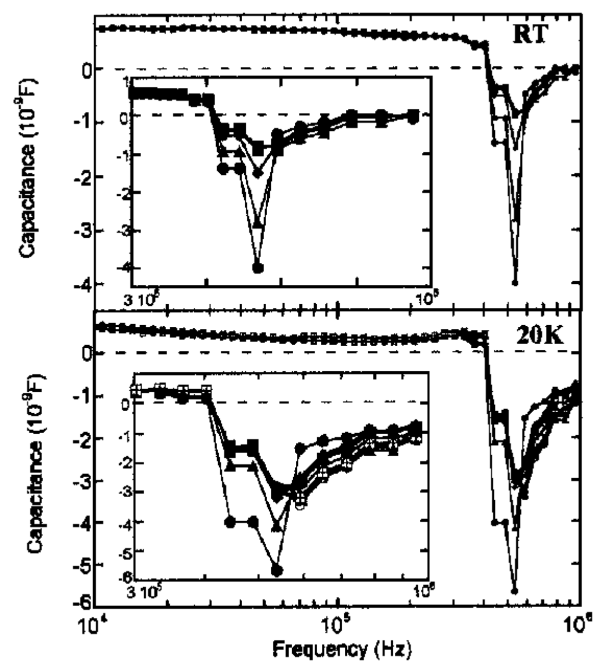


Fig.2. Capacitance vs frequency of the system with nanoparticles, (3 nm), for RT and 20K. In the insets the voltage dependence of the NC effect is evidenced: (? ) 0.2V, (x) 0.4V, (¦ ) 0.5V, (? ) 0.6V, (? ) 0.7V, (●) 0.8V.

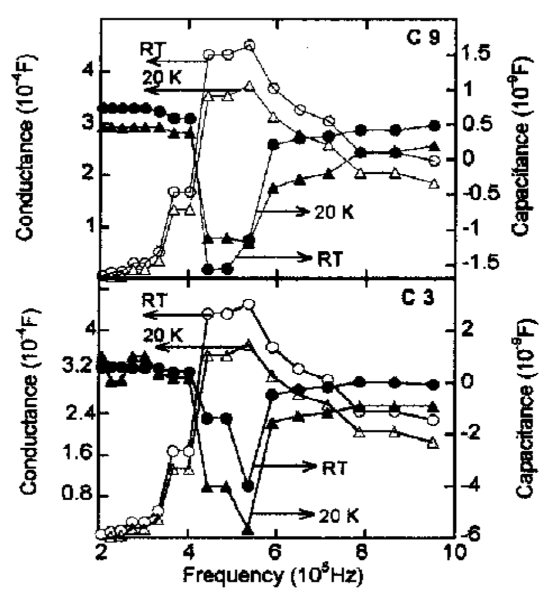


Fig. 3. Frequency dependence of the conductance in the dielectric part (open symbols), and of the capacitance in the system with nanoparticles (full symbols), for RT (?,?) and 20 K (△, ▲), in (9 nm above) and (3 nm below).