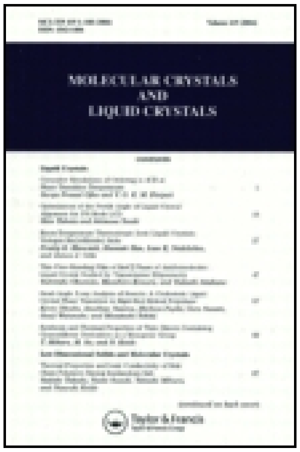


Molecular Crystals and Liquid Crystals Science and Technology. Section A. Molecular Crystals and Liquid Crystals
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/gmcl19

# Electroluminescence and Electron Emission in a System: Organic Films - Metal Nanoparticles

R. D. Fedorovich [a] & O. E. Kiyayev [a]

[a] Institute of Physics, National Academy of Sciences of Ukraine, Prospekt Nauki, 46, Kyiv 22, UA, 252022, Ukraine E-mail:

Version of record first published: 04 Oct 2006

To cite this article: R. D. Fedorovich & O. E. Kiyayev (1998): Electroluminescence and Electron Emission in a System: Organic Films - Metal Nanoparticles, Molecular Crystals and Liquid Crystals Science and Technology. Section A. Molecular Crystals and Liquid Crystals, 324:1, 1-6

To link to this article: http://dx.doi.org/10.1080/10587259808047125

*Mol. Cryst. Liq. Cryst.*, Vol. 324, pp. 1–6
Reprints available directly from the publisher
Photocopying permitted by license only





# Electroluminescence and Electron Emission in a System: Organic Films - Metal Nanoparticles

R.D. FEDOROVICH, O.E. KIYAYEV
Institute of Physics, National Academy of Sciences of Ukraine
UA-252022, Kyiv 22, Prospekt Nauki, 46, Ukraine,
e-mail: fedorov@marion.iop.kiev.ua

The paper deals with the investigation of the electrical conductivity, the electron and the light emission in the system involving gold islands and organic stearon molecules $(C_{17}H_{35})_2$ CO. The conduction current-voltage curve acquires a non-monotone character: there appears a section of the voltage controlled negative resistance (VCNR). The current-voltage characteristics of the conduction current strongly change in passing from the constant operation mode to the alternating one. The growth of the conductivity in the alternating mode may occur owing to the contribution of additional channels and to reduction of the Coulomb blockade. The highest light intensity is observed in the VCNR region. The light intensity changes in this region correlate with the changes in the conduction current. The light emission in the VCNR region from organic molecules may be excited by hot electrons.

Keywords: island films; metal nanoparticles; organic molecules; switching phenomena; electroluminescence

## INTRODUCTION

The electron and light emission are observed from an ensemble of metal nanoparticles coupled by tunneling[1]. This emission is caused by the non-equilibrium heating of electrons in small metal particles on insulating substrates[2]. The deposition of adsorbed films lowering the work function (example BaO) results in a pronounced increase of the conduction current. The electron emission current and the intensity of photon emission are considerably increased as well. The shape of the voltage-current characteristics of the electron emission current as well as the shape of the voltage dependence of the light intensity remain unchanged.

The deposition of an organic film on metal islands in the strong electric field leads to both the increase in the conduction and emission current and the appearance of a section of the voltage-controlled negative resistance (VCNR) on the current-voltage characteristic of the conduction current. At the same time the shape of the voltage dependence of the emission current and of the light intensity changes[3].

The aim of this work was to investigate the electrical conductivity, electroluminescence and electron emission in the system containing gold nanoparticles covered with a stearon $(C_{17}H_{35})_2CO$ layer.

## EXPERIMENTAL

Planar structures were used in our experiments. They were quartz substrates with metal film electrodes separated by a narrow gap (Fig. 1). The gold island films were deposited by the thermal evaporation in vacuum. The mass thickness of the island films comprised 60-70 Å. After the deposition island films were subjected to a forming procedure by the passage of electrical current through it that resulted in the formation of current channels in the gap between film electrodes. One emission centre arises in any current channel. Several tens of the emission centres of this kind were formed at a usual sample geometry shown in Fig. 1, inset. After a forming procedure, organic adsorbates of the mass thickness equal to 10-30 Å were deposited on the formed island films in vacuum. Measurements were performed in high vacuum conditions in the continuous operation mode as well as in the alternating one (50 Hz-20 kHz). The film structure was investigated both by transmission and scanning electron microscopes. Spectral characteristics of the photon emission were measured in the range between 0.4 and 0.7 μm.

## RESULTS AND DISCUSSION

Initial metal island planar structures subjected to a forming procedure had smooth current-voltage characteristics of the conduction current and electron emission current, and of voltage dependence of light intensity. Electrons and photons are emitted from separate sites of submicron size. The centres of the electron and photon emission coincide.

The adsorption of some organic molecules on island films with formed current channels results in appearance of voltage-controlled negative resistance (VCNR). Simultaneously the voltage dependences of the electron and light emission are also changed (Fig. 2, inset). These findings are ascribed to the influence of organic molecules on the conductivity of interisland gaps within emission sites. The electromigration of the polar molecules to these sites where the electric field is the highest can enhance the conductivity and impart qualitatively new features to the film.

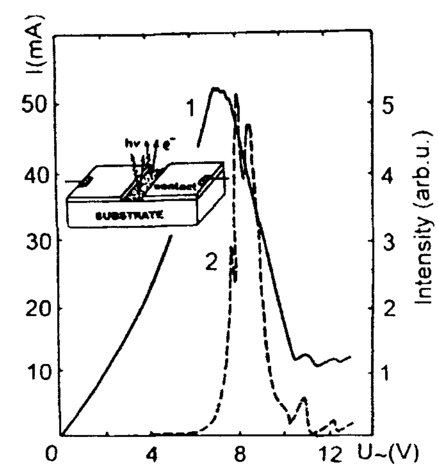


FIGURE 1 Conduction current (1) and light intensity (2) as functions of the voltage applied to the specimen. The light intensity was measured at $\lambda$=615 nm. Inset: schematic diagram of sample.

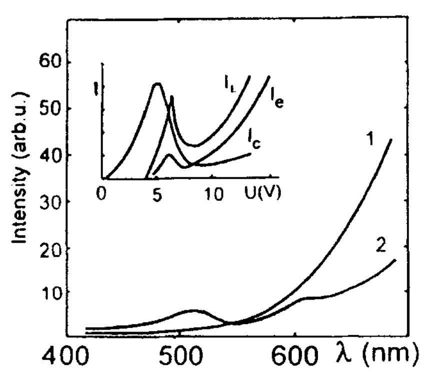


FIGURE 2 Light emission spectra in rising (1) and falling (2) section of the $I_c$-V curve. Inset: conduction current $I_c$, emission current $I_e$ and light intensity $I_l$ versus voltage applied to an Au island film covered with stearon.

As the voltage applied to the film is increased, the molecules can be evaporated by resistive heating and the conductivity regains its initial value. The process can be reversibly repeated many times.

The measurements were carried out both in the continuous and in the alternating (50 Hz-20kHz) operation mode. The current-voltage characteristics of the conduction current strongly change in passing from the constant operation mode to the alternating one. This manifests itself in a sharp increase (by a factor of $\cong$20) of the ratio of resistances in high ohmic and low ohmic states. The growth of the conductivity in the alternating mode may occur owing to the contribution of additional channels and to reduction of the Coulomb blockade.

The highest light intensity is observed in the VCNR region. The light intensity changes in this region correlate with the changes in the conduction current (Fig. 1). The spectral characteristics of light emission were measured in various regions of the electrical conductivity I-V curve. There is a difference between the light spectra corresponding to the rising and falling (VCNR) sections. In the former case the spectrum is nearly structureless, but shows an intensity growth in the red and infrared region ($\lambda$>600 nm). In the latter case there are two broad maxima at $\lambda\approx$510 nm and $\lambda\approx$610 nm, and the intensity strongly increases at $\lambda$>700 nm. The light emission in VCNR region is caused by excitation of organic molecules by hot electrons.

## CONCLUSIONS

1. VCNR appearance can be caused by two competing processes. On the one hand, organic molecules, migrating in a region of the strong electric field within current channel, increase the channel conductivity, and on the other

hand, the influence of the joule heating, evolving in the current channel at sufficiently large current density, results in distruction of a high-conductivity state.

2. The current-voltage characteristics of the conduction current strongly change in passing from the constant operation mode to the alternating one. The growth of the conductivity in the alternating mode may occur due to the contribution of additional conductive channels and to reduction of the Coulomb blockade.
3. The highest light intensity is observed in the VCNR region. The light intensity changes in this region correlate with changes in the conduction current.
4. The obtained experimental finding may be explained by the electroluminescence of organic bridges which are excited by hot electrons injected into them from adjacent metal islands. It would now be premature to suggest a more exact model for this process.



## References

[1.] P. Borziak, D. Dan'ko, R. Fedorovich, O. Kiyayev and A. Naumovets, *Progr. in Surface Sci.*, **53**, 171(1996).
[2.] E. Belotskii and P. Tomchuk, *Surface Science*, **239**, 143 (1990).
[3.] R. Fedorovich, A. Naumovets, and P. Tomchuk, *Condensed Matter Physics*, **7**, 5 (1996).