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# Influence of Cr concentration and photon energy excitation on the photoluminescence of Ruby microcrystals

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**Abstract** – Light-emitting structures with microscopic dimensions have been produced after thermal annealing Cr-doped amorphous AlN films in an oxygen atmosphere. Thermal treatments up to 1050 ºC induce the formation of structures that emit red light (at approximately 690 nm) at room temperature. Because of their typical size and spectral features these structures are designated by Ruby microstructures (RbMS's). The light emission characteristics of these RbMS's are highly influenced by the Cr concentration (Fig. 1), temperature, and the photon excitation wavelength during the photoluminescence experiments (Fig. 2).

Aiming at the development of new *photonic* devices and looking for materials with impressive optical-electronic properties different classes of compounds have been systematically investigated along the last years. Indeed, the achievement of new properties simply by changing the composition and/or structure of certain pre-existing compounds was the basis of our modern micro-electronics industry, where quite different characteristics were obtained by suitably inserting impurity elements in a semiconductor matrix. With these ideas in mind we carried out an experimental investigation on amorphous aluminum-nitride (a-AlN) thin films doped with chromium.

The a-AlN films were prepared by radio frequency sputtering an Al target in an atmosphere of pure nitrogen. The films were deposited on crystalline Si and quartz substrates kept at 200 °C. The doping of AlN was achieved by partially covering the aluminum target with small pieces of Cr. Following this approach, the Cr-to-Al relative area determines the Cr content, which stayed in the 0.0001–3.33 at.% concentration range. In order to investigate the effects of $Cr^{3+}$ in the AlN matrix, the films were submitted to thermal treatments in the 300–1050 ºC temperature range in an atmosphere of oxygen. The experimental spectroscopic investigation included: energy dispersive x-ray spectrometry, photoluminescence (as a function of the photon excitation energy and temperature), Raman scattering, and optical transmission measurements.

According to the experimental results the Ruby microstructures develop only after thermal annealing at ~ 1050 $^{o}$C and are randomly distributed on the surface of the film. Moreover, films containing increasing Cr concentrations present, in addition to the $R_1$ and $R_2$ lines, an enhancement of the vibronic sidebands as well as optical transitions that are associated to the exchange-coupling between pairs of $Cr^{3+}$ ions (Fig. 1). The spectral position of the $R_1$ and $R_2$ lines, in particular, also depends on the photon energy used to excite the RbMS's, a phenomenon that is associated to the electronic energy levels of the $Cr^{3+}$ ions when inserted in a $Al_2O_3$ matrix (Fig. 2). Further details concerning sample preparation and spectroscopic characteristics of the present RbMS's will be present and discussed in view of the experimental results.

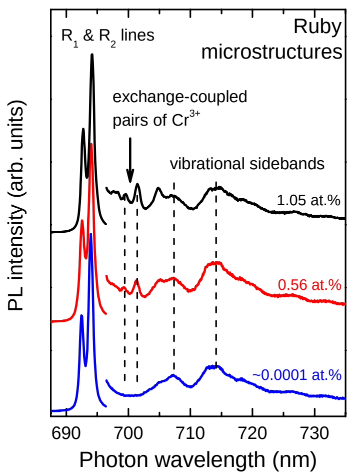


**Figure 1:** Room-temperature PL spectra as a function of Cr concentration, with 488 nm photon excitation. The spectra was normalized and vertically shifted for comparison. The region between 696 and 735 nm has been multiplied by a factor 5.

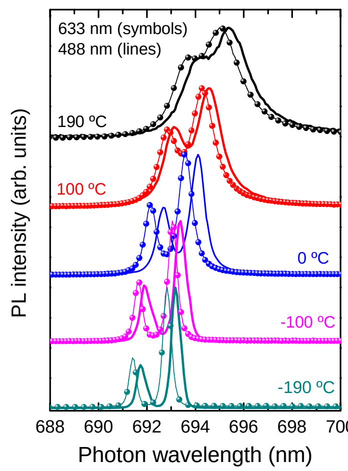


**Figure 2:** Photoluminescence spectra of a Cr-doped AlN film annealed at 1050ºC as a function of the temperature of measurement. The solid lines stand for 488 nm whereas the symbols for 633 nm photon excitation.