MOCVD Growth of III-Nitride Semiconductor Materials for Optoelectronic Device Applications

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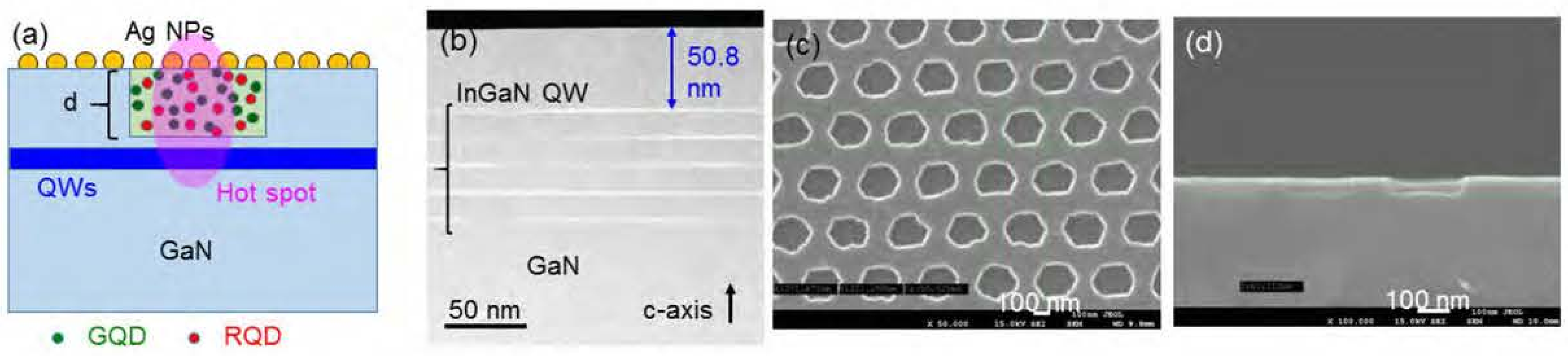
Abstract

III-Nitride semiconductor materials, including AlN, GaN, and InN, are suitable for electronic and optoelectronic applications due to excellent physical characteristics, such as infrared-to-ultraviolet bandgap and high break-down voltage. My current research has two aspects: the high-efficiency color conversion for Micro-LED display applications and the strain relaxation effects on overgrowth crystal quality and emission behavior based on the MOCVD-grown samples.

Research results

Enhanced Color Conversion of Quantum Dots Located in the Hot Spot of Surface Plasmon Coupling



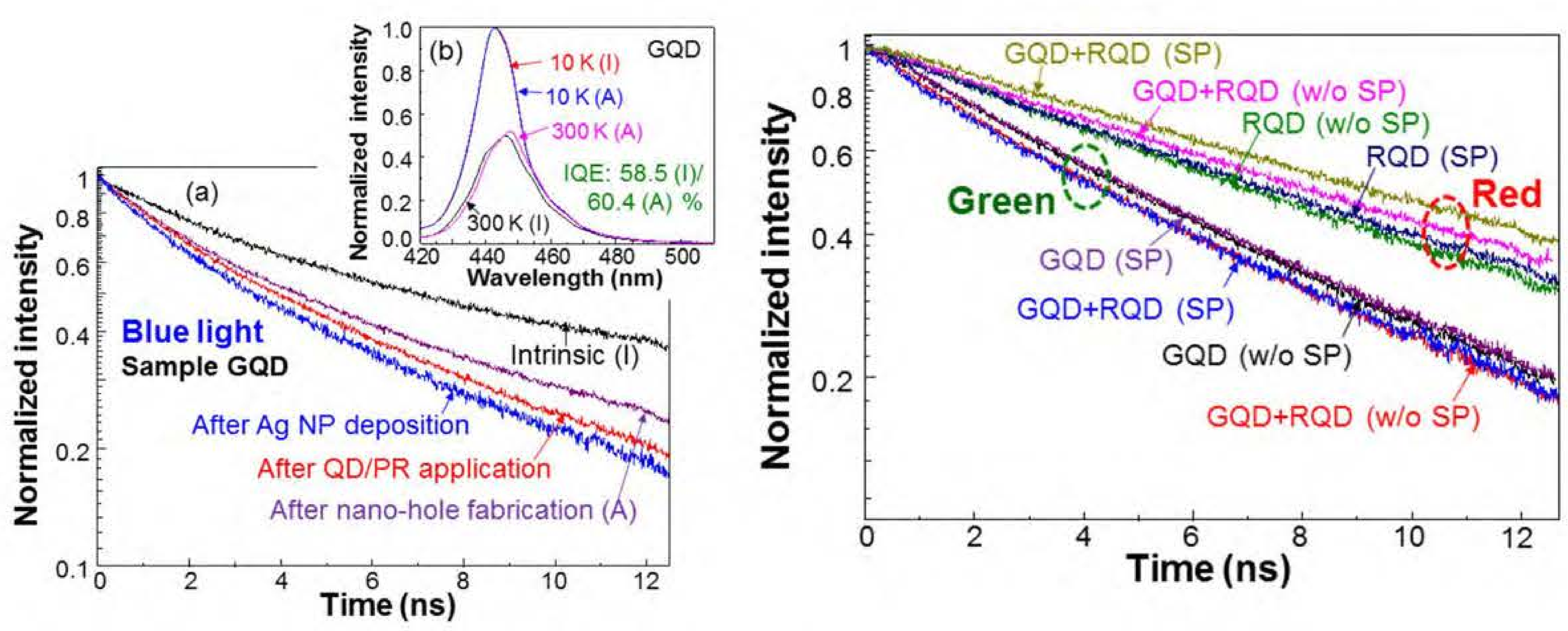


TABLE I

PL Decay Times (in ns) of the Blue (B), Green (G), and Red (R) Lights in the Three Samples at Different Fabrication Stages. The Numbers Inside the Curly brackets (Parentheses) Show the FRET Efficiencies (Integrated Intensity Ratios)

Sample		Intrinsic	After nano-hole fabrication	After QD/PR application	After Ag NP deposition
GQD	B	10.61	7.13	6.46 {9.40 %}	5.81
	G	---	---	7.08 (0.15)	7.23 (0.24/60 %)
RQD	B	10.11	7.26	6.13 {15.57 %}	5.72
	R	---	---	10.11 (0.41)	10.87 (0.77/88 %)
GQD+RQD	B	9.91	7.22	6.01 {16.76 %}	5.45
	G	---	---	6.66 (0.12)	6.77 (0.16/33 %)
	R	---	---	11.75 (0.52)	13.07 (0.72/39 %)

Conclusion I

In summary, by inserting QDs into a nano-hole located between a QW structure and surface Ag NPs, we observed the improved performance of the color conversion from QW energy into QD emission.

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Effects of Surface Plasmon Coupling on the Color Conversion of an InGaN/GaN Quantum-Well Structure into Colloidal Quantum Dots Inserted into a Nearby Porous Structure

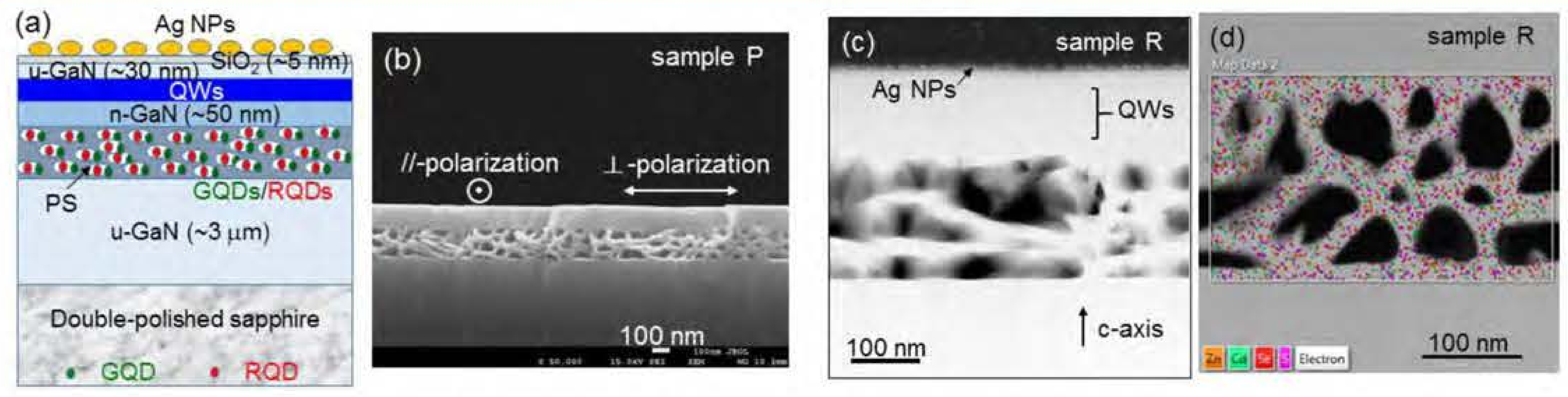

Table 1. Blue-light PL decay times (in ns) in the five samples under study at different fabrication stages. The numbers inside the curly brackets show the corresponding IQEs. The numbers inside the parentheses show the corresponding FRET efficiencies.

Sample		A	P	G	R	G+R
Intrinsic		6.48 {57.8%}	6.36 {57.4%}	6.65 {57.9%}	6.67 {56.5%}	6.46 {57.7%}
After PS fabrication		—	5.89 {67.2%}	6.04 {68.6%}	5.98 {67.7%}	6.00 {68.1%}
After QD insertion	//	—	—	5.32 (11.92%)	4.91 (17.89%)	3.75 (37.50%)
	⊥	—	—	5.26 (12.91%)	4.84 (19.06%)	3.74 (37.67%)
After Ag NP deposition	//	5.71 {63.8%}	5.33 {69.4%}	4.85 (19.70%)	4.64 (22.41%)	2.38 (60.33%)
	⊥		5.23	4.62 (23.51%)	4.49 (24.92%)	2.12 (64.67%)

Table 2. Green- and red-light PL decay times for samples G, R, and G+R in the two polarizations before (w/o SP) and after (SP) Ag NP deposition. The intrinsic PL decay times of GQD and RQD are shown inside the curly brackets in row 1. Also shown in this table are the color ratios, i.e., G/B and R/B ratios, and the polarization ratios (PRs) for the three color components.

Sample	G (//, ⊥) {5.78 ns}		R (//, ⊥) {8.95 ns}		G+R (//, ⊥)	
SP condition	w/o SP	SP	w/o SP	SP	w/o SP	SP
Green decay time (ns)	6.26, 6.22	6.57, 6.48	—	—	3.73, 3.69	3.98, 3.80
Red decay time (ns)	—	—	9.27, 9.23	9.43, 9.39	11.15, 11.09	11.87, 11.84
G/B ratio	0.107, 0.137	0.172, 0.225	—	—	0.114, 0.146	0.174, 0.213
R/B ratio	—	—	0.365, 0.412	0.371, 0.447	0.530, 0.694	0.696, 0.850
Blue PR	0.948	0.901	0.933	0.897	0.914	0.902
Green PR	1.217	1.179	—	—	1.169	1.103
Red PR	—	—	1.084	1.090	1.197	1.102

Conclusion II

In summary, we have designed and implemented a device structure for improving the color conversion performance from a QW structure into QDs inserted into a nearby subsurface GaN PS by introducing the SP coupling between the QW structure and the LSP resonance on surface Ag NPs to the device.

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