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Supporting Information for “High Efficiency NiO/ZnO Heterojuction UV Photodiode by Sol-Gel Processing”

Namseok Park[1], Ke Sun[1], Zhelin Sun[1], Yi Jing[1], Deli Wang[1,2,3,*]

[1]Department of Electrical and Computer Engineering, [2]Material Science Program, [3]California Institute of Telecommunication and Information Technology, University of California - San Diego, CA 92093, USA

Both NiO and ZnO thin films are elaborated in view of film surface morphology by preparing the films with different coating parameters and post-heat treatment. Unless otherwise mentioned, spin-coated films were pre-heated at 300 °C for 10 minutes after each coating and post-heat treated in N_2/O_2 environment at 450 °C for an hour. In this supporting study, a crystalline Si substrate was used instead of a bare glass substrate, in that film coatings on a Si substrate facilitated an acquisition of better quality of SEM image than on a bare glass in particular for films with thickness of less than 100 nm for this study.

Sol-Gel ZnO Thin Films on a Si Substrate

No substantial changes in the ZnO thin film surface morphology are observed as spin rates increase from 1000 rpm to 4000 rpm as shown in Figure S1, which in turn determines the thickness of the films. Although the morphological evolution of ZnO films in Figure S1 is difficult to quantify in an absolute term, as the spin rate increases the surface morphologies of coated films show continuous and closely interconnected pore structures. The spin rate was directly related to the thickness of single-layer ZnO thin films. For example, a film spin-coated at

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1000 rpm shows a thickness of 75 nm and a film prepared at 4000 rpm becomes thinner about 30 nm. The film thickness measured on each film is indicated in Figure S4 (left).

The number of spin-coatings is another parameter to play a role on the morphological evolution of sol-gel ZnO thin films. As the coated layer increases from 1 to 3, film surfaces become more continuous and densely packed (Figure S2). By varying the number of coating, in fact, the film thickness increases linearly proportional to the number of stacks of coating as shown in Figure S4 (right).

Pre-heat treated films were additionally annealed in a furnace by flowing N_2 and O_2 at different post-heat temperatures. Temperatures changed from 350 °C to 550 °C. The surface morphology changes turn out distinguishable from those mentioned previous. Changes in both interconnected grain sizes and dimensions of pore network are developed during the post-heat treatment at each annealing temperature. The grain size increases at increasingly higher annealing temperatures.

Sol-Gel NiO Thin Films on a Si Substrate

As shown in Figure S5 & S6 the morphology of continuous and very dense single-layer NiO thin films by sol-gel is little influenced by both the spin coating rate, as in Figure S5, and the number of spin coatings, as shown in Figure S6. The thickness of coated films can be controlled by changing the spin rate from about 80 nm to 30 nm. In addition, it shows a linear dependence on the number of coatings, as shown in Figure S8.

The post-heat, treatment of the NiO films affects the film morphology in a way that increasing the annealing temperature leads to less porous and continuous film surfaces.

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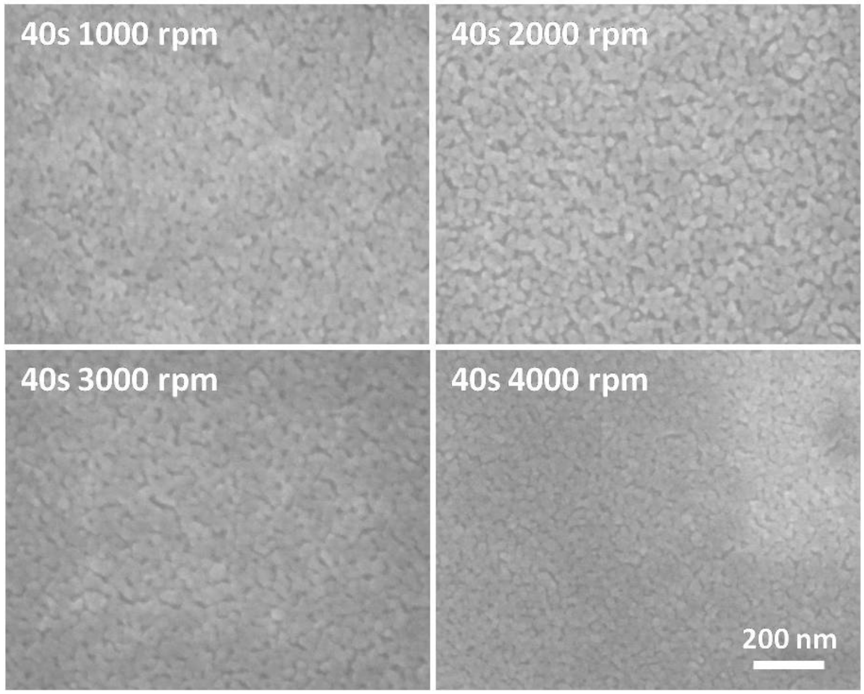

Figure S1 Sol-Gel prepared ZnO thin film surface morphologies vs spin-coating rate. Single-layer coated ZnO thin films were spin-coated on Si substrates by varying the spin-coating speed. The spin coating duration was the same i.e. 40 seconds.

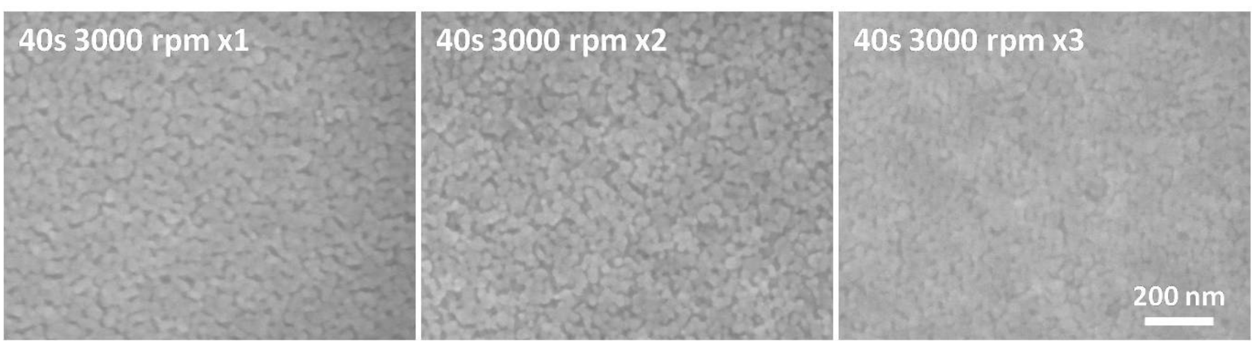

Figure S2 Sol-Gel prepared ZnO thin film morphology dependence on the number of spin-coatings on Si substrate.

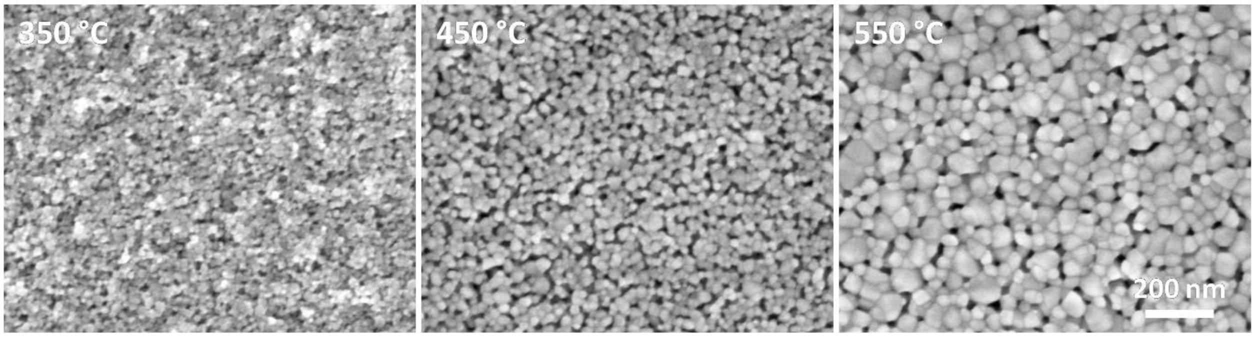

Figure S3 Surface morphology of post-heat treated Sol-Gel prepared double-layer ZnO thin films by spin-coating at 3000 rpm. The films were annealed in N_2/O_2 environment at different annealing temperatures (i.e. 350, 450, and 550 °C)

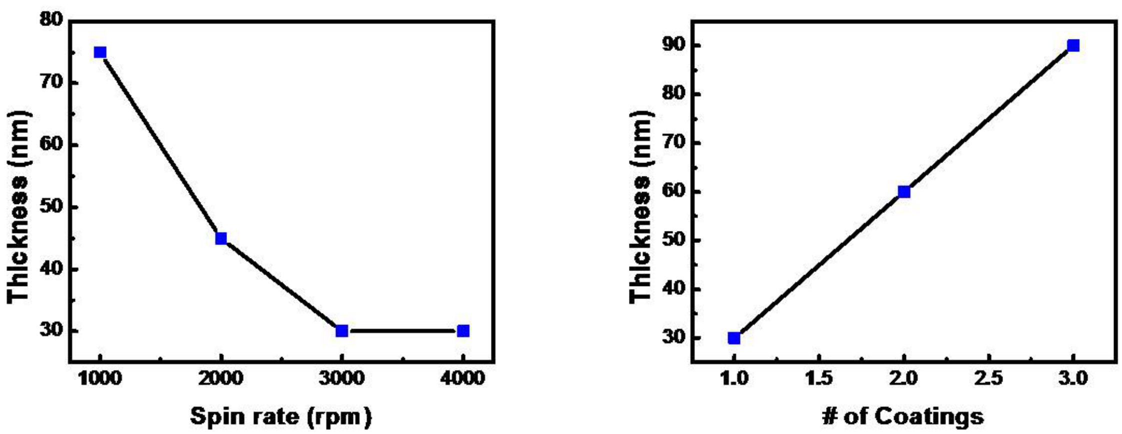

Figure S4 Spin-coating speed versus ZnO film thickness (left) and the number of coatings versus ZnO film thickness (right).

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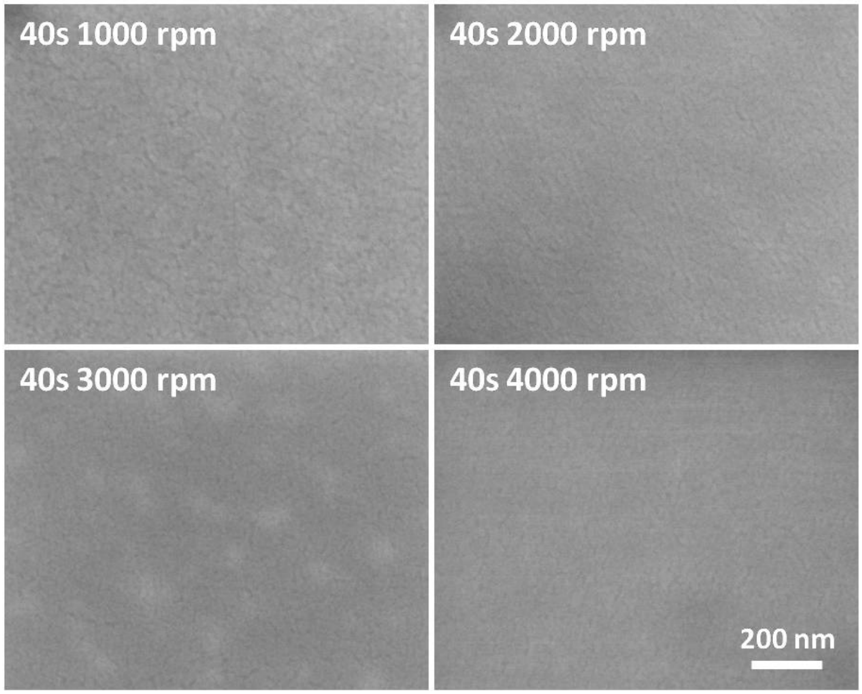

Figure S5 Sol-Gel prepared NiO thin film surface morphologies vs spin-coating rate. Single-layer coated NiO thin films were spin-coated on Si substrates by varying the spin-coating speed. The spin coating duration was the same i.e. 40 seconds.

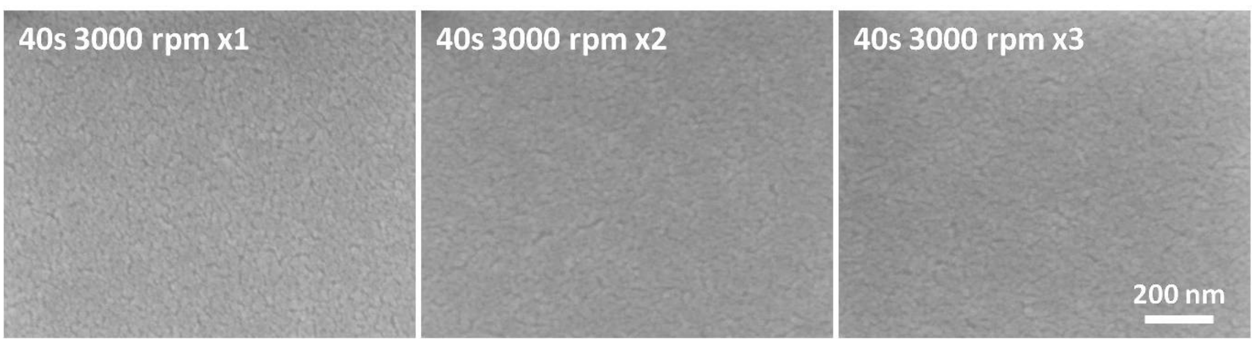

Figure S6 Sol-Gel prepared NiO thin film morphology dependence on the number of spin-coatings on Si substrate.

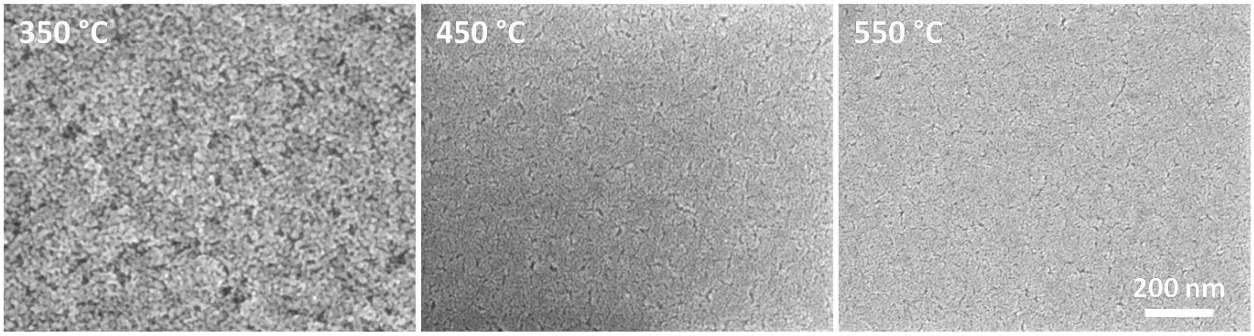

Figure S7 Surface morphology of post-heat treated Sol-Gel prepared double-layer NiO thin films by spin-coating at 3000 rpm. The films were annealed in N_2/O_2 environment at different annealing temperatures (i.e. 350, 450, and 550 °C)

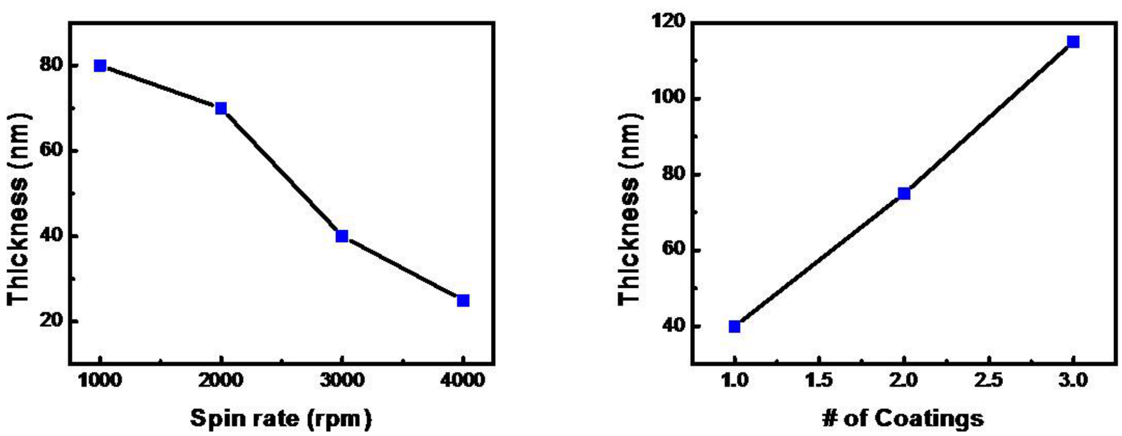

Figure S8 NiO film thickness versus spin-coating speed (left) and the number of coatings versus ZnO film thickness (right).