# Self-Assembled Silica Nano-Spheres for Dual Metal Junction-Barrier-Schottky Diodes

**CNF Project Number: 2350-15**

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*Primary CNF Tools Used: ABM contact aligner, wet chemistry bench, Zeiss Supra/Ultra SEM, odd hour e-beam evaporator, AJA sputter, PT-770 ICP RIE, photoresist spinner, hotplate, optical microscope*

## Abstract:

**We report on a time and cost-effective method of selectively depositing thin metal films onto substrates. Silica nanospheres of 50 nm diameter were hexagonally packed using Triton X-100 surfactant on the DI water/air interface, and were transferred onto bulk n type gallium nitride substrates. After inspection using the scanning electron microscope, 20 nm thick metal was deposited on top. After stripping of the silica, a triangular shaped array of metal deposits remained. This technique will enable a quick, simple method of fabricating dual metal junction-barrier-Schottky-diodes, which use the difference in work function of two metals to reduce reverse leakage as in a *p-n* diode, as well as retain the low turn-on voltage of Schottky barrier diodes.**

## Summary of Research:

Gallium nitride (GaN), with its superior Baliga's figure of merit, is an excellent candidate for high power, high speed devices. GaN Schottky barrier diodes (SBDs) have shown the highest power efficiency in the < 1 kV breakdown voltage range [1], but show high reverse leakage current compared to those of *p-n* diodes, which is detrimental to achieving high breakdown voltage. One method of reducing the reverse leakage current is by fabricating a junction-barrier-Schottky-diode. (JBSD) [2]. This structure combines the large breakdown voltage of *p-n* diodes, and the low turn on voltage of SBDs into one device. Due to the difficulties in ion implantation and regrowth technologies in GaN, designing trench patterns in the *p*-type GaN and exposing the *n*-type GaN and making metal contacts on them could circumvent the issue. Results of these trench JBSD devices are further expressed in references. [3] A schematic of the JBSD device is depicted in Figure 1.

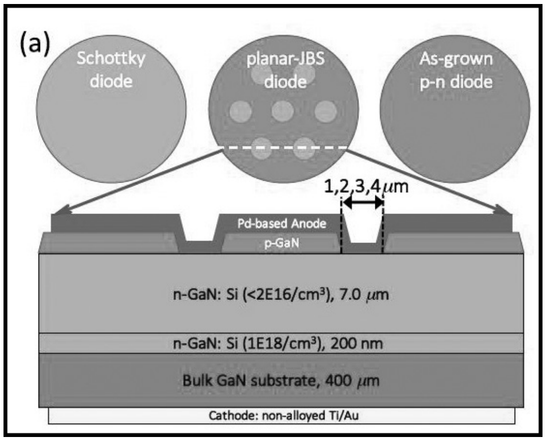

*Figure 1: Schematic of trench-JBSD device with* p*-type GaN and Schottky metal contact on* n*-GaN [3].*

The *p*-type GaN could be viewed as a Schottky metal contact with a work function of ~ 3eV. Thus, another approach could be taken to replace the *p*-type GaN with another metal. Due to the difference in work function of the two metals, similar effects as a *p*-GaN/metal JBSD could be achieved. The goal of this research at CNF was to fabricate a dual metal JBSD. In order to achieve this local metal stack structure, a hard mask consisting of self-assembled monolayer of nano-scale silica spheres was used. The densest packing structure of spheres would be hexagonally close packed structures. However, in that packed structure, there would be an interstitial between every three spheres. Our strategy was to use this interstitial to selectively deposit metal.

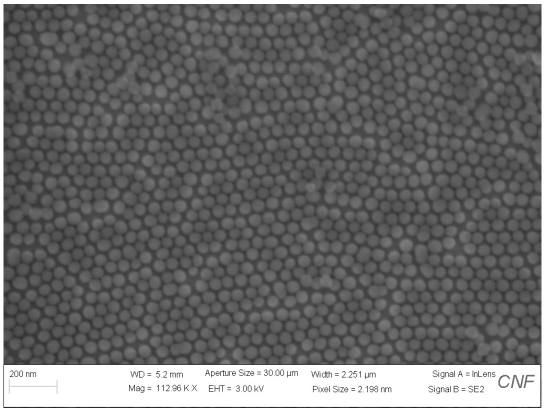

*Figure 2: SEM image of HCP monolayer of silica nanospheres with 50 nm diameter.*

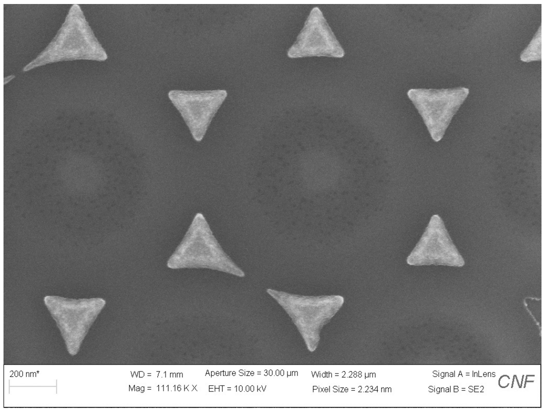

*Figure 3: SEM image of 20 nm metal deposition remaining on interstitial area of HCP silica nanosphere monolayer.*

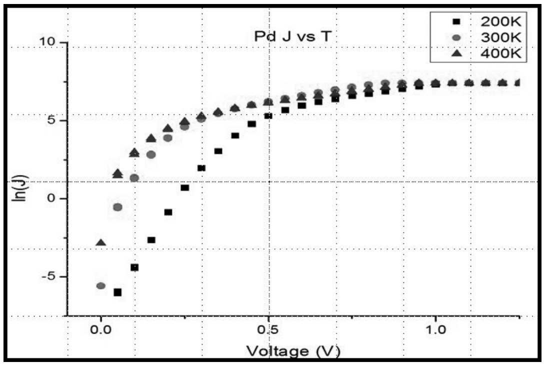

*Figure 4: SEM image of 20 nm metal deposition remaining on interstitial area of HCP silica nanosphere monolayer.*

Silica nanospheres were self-assembled on the interface between DI water and air using Triton X-100 surfactant, and then was transferred onto an *n*-GaN substrate and dried. After inspection of the layer with SEM, metal was deposited onto the structure. Figure 2 is an SEM image of the monolayer assembled onto a bulk GaN substrate. When the silica was stripped off using hydrofluoric acid, only the metal which was deposited in the interstitial points has remained. Thus, it is able to selectively deposit metal without use of nano-scale patterning such as e-beam lithography. It reduces the process time as well as cost required to pattern nanoscale features. Figure 3 is an SEM image of the resulting metal depositions on a bulk GaN substrate. Here, 20 nm of titanium and 5 nm of palladium was deposited. (Palladium is deposited to protect the highly oxidizing titanium. Since the second layer of metal in future processes would be palladium, the same metal was chosen to be the protective layer.)

After forming local depositions of the first metal, the rest of the process was as if fabricating a normal diode. The diode patterns were formed via photolithography, and 50 nm of palladium was deposited via the odd hour electron beam evaporator. After liftoff of the photoresist, the cathode of the device, consisting of titanium-aluminum-platinum was deposited via the AJA sputter system. The sputter system was used since it had a higher vacuum as well as faster deposition times. S1813 photoresist was deposited on the top surface to protect the devices.

Figure 4 is a temperature dependent J-V curve of the palladium control devices. The goal is to achieve lower turn-on as well as lower leakage than this device in the dual metal JBSD structure.

## References:

[1] S. Chowdhury and T. P. Chow, "Comparative performance assessment of SiC and GaN power rectifier technologies," Phys. Status-Solidi C, vol. 13, nos. 5-6, pp. 360-364, 2016.

[2] B. J. Baliga, "The pinch rectifier: A low-forward-drop high-speed power diode," IEEE Electron Device Lett., vol. 5, no. 6, pp. 194-196, Jun. 1984.

[3] W. Li, "Design and realization of GaN trench junction-barrier-Schottky-diodes", IEEE Transactions on Electron Devices, vol. 64, no.4, pp.1635-1641.