Integration of Functional Nano-Technology Materials on a Single Chip

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Minimizing Size, Maximizing Functionality

The Army Research Lab and the University of Maryland are working jointly on the integration and characterization of different nanomaterials on single monolithic devices. Nano-materials are chosen for functional characteristics ranging from electrical, optical, mechanical, and biochemical sensing. This project initiates the development by investigating the synthesis, characterization, and integration of one of the most promising nanomaterials: ZnO nanowires/nanorods.

Method of Integration: Thin Film Architecture

• Thin films are grown to create multistacks of nucleation layers and masking layers on Si substrate.

• Catalytic nucleation layers act as the preferred growth site of nanomaterials, while masking layers prohibits growth.

• Side walls of vertically stacked catalytic and masking thin film materials are exposed to lateral growth of nanomaterials that can result in one-dimensional arrays of nanowires.

Schematic of lateral growth of functional nanomaterials:

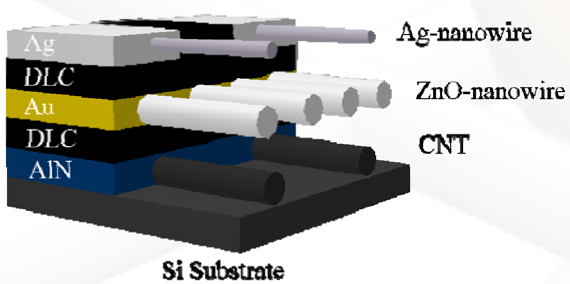

Figure 3: Schematic of architecture

Approach

• Identify the best thin film for nucleating and masking growth of ZnO nanowires from a vertical sidewall.

• Develop optimal condition for the synthesis of controlled ZnO nanostructure type/shape/size, in order to promote growth of aligned nanowires.

• Achieve lateral growth of ZnO the sidewalls of very thin active layers.

Thin Film Structures

Different thin film materials of various thicknesses are deposited on Si substrate by Pulse-Laser Deposition for the identification of nucleating and masking layers.

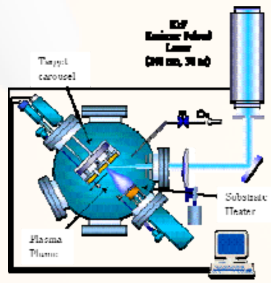

Figure 2: PLD

Thin film (2500Å)	*Growth?*
Au	N
AlN	N
BN	N
DLC	N
Zn	N

Result: There was no growth of ZnO on the various thin films tested. Growth of ZnO nanowires were only observed on Si substrate and AlN/Au (2500Å/2500Å) bi-layers.

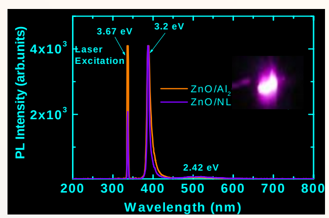

Figure 3: Evidence of ZnO formation on thin films was observed using photoluminescence and SEM.

Patterning of Thin Film Sidewalls

Thin film structures are dry etched using Inductively Coupled Plasma (ICP) etch tool to produce anisotropic and uniform sidewalls. It is believed surface flatness will encourage controlled directed growth of ZnO nanowires off the sidewalls.

Different gas mixes was used to determine etch rates and recipes that would produce smooth thin film sidewalls.

Results:

Material	*Gas mixture (sccm)*	*Rates (ÅPM)*
AlN	$Ar:BCl_3:Cl_2$ (5:20:20)	800
Au	$Ar:Cl_2$ (5:20)	1100
DLC	$Ar:O_2$ (5:30)	1000

ZnO Nanostructures

Catalyst free growth of ZnO nanostructures are synthesized by Solid Liquid Vapor mechanism utilizing present Zn powder as an auto-catalyst. Various parameters of the synthesis process are examined to identify optimal growth conditions for lateral growth of aligned nanowires.

Synthesis parameters experimented			
Temperature (°C)	1000	*850*	600
Gas ratio ($Ar:O_2$)	9:1	*4:1*	9:0
Gas flow rate (bubbles per minute)	90	*60*	30

Note: For each experiment, when the condition of one parameter is varied the conditions in italics are used for the other parameters. Synthesis is done on Si substrate.

SEM Images

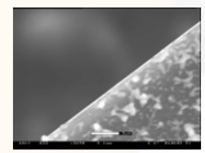

Figure 5: (5um) 9:0 $Ar:O_2$ ratio

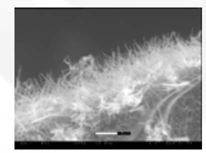

Figure 6: (5um) 9:1 $Ar:O_2$ ratio

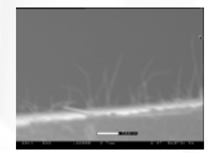

Figure 7: (500nm) 1000°C

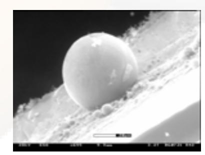

Figure 8: (5um) 600°C

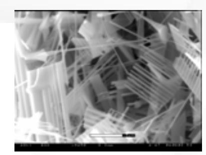

Figure 9: (20um) Effects of gas flow dynamics

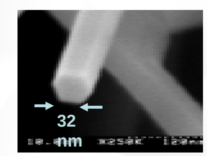

Figure 10: (120nm) Close up SEM done at ARL

Conclusion

Synthesis of ZnO nanowires on different thin films shows that directed nucleation of ZnO nanowires are highly selective to surface composition and structure. It is found that formation of ZnO nanostructures are critically dependent on synthesis parameters such as temperature, and $Ar:O_2$ ratio and flow rates. It is observed that synthesis at higher temperature encourages growth of nanowires with smaller diameters, while high $Ar:O_2$ ratio and low flow rates reduces unwanted ZnO residues on substrate.

Future work will be to take etched thin film multistacks and synthesize ZnO nanowires under the identified optimal synthesis parameters.