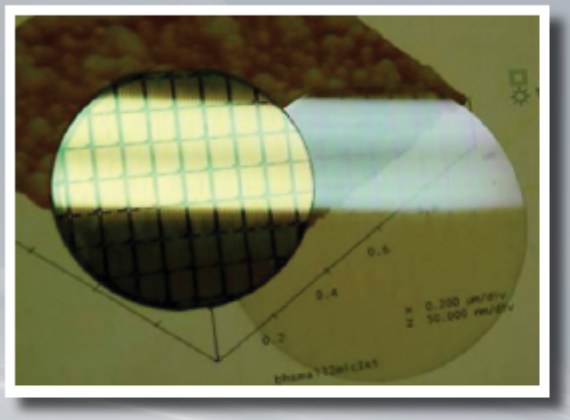
**Nano-Crystalline Zinc Oxide for High-Performance Thin Film Transistors**

*Supporting Agency:* Air Force

## Nano-Crystalline Zinc Oxide for High-Performance Thin Film Transistors

***Accomplishment:*** Zinc oxide thin film transistors were produced to give the highest performing thin film transistors to date. It was shown for the first time that thin film transistors can be used for microwave applications.



***Impact:*** These results give initial validation that thin film transistors can be used for high performance electronics, enabling integration with other electronic and mechanical systems to give improved reliability and reduced weight, volume and cost. New capabilities, such as application of thin film transistors to microwave devices, are now feasible. The added function of optical transparency enables an optical sensor to be placed on top of a radio frequency (microwave and radar) sensor, improving target location and identification and solving physical space issues in systems where volume and weight are severely limited, such as satellites and unmanned air vehicles (UAVs).

***Motivation and Approach:*** Conventional solid state transistors are typically produced on semiconductor single crystals that are expensive and restricted to sizes less than a few hundred millimeters in diameter. Thin film transistors are far less expensive since they can be produced on any substrate and can be made in dimensions exceeding 1 meter. They can be integrated with other devices and can be deposited on thin films that are flexible and conformal. Current thin film transistors have poor electronic performance, including low current densities and low operation frequencies, and rely on rare elements such as indium. Thin film transistors are a widely-used enabling technology for liquid crystal displays (LCDs), but their poor electronic characteristics severely limit other applications that require high performance, high speed capabilities.

In this work, careful control of the structure and processing of nanocrystalline zinc oxide films have produced dramatic improvements in thin film transistor performance. Magnetron sputtering and pulsed laser deposition, both commercial fabrication techniques, are used with post-deposition heat treatment to optimize the nanocrystalline grain size and defects of the deposited transistors. Current densities more than 1000 times higher than previous values have been produced, and on/off current ratios 1 million times higher than previously possible have been achieved. An operation frequency of 500 Megahertz has been demonstrated with nanocrystalline zinc oxide thin film transistors on a gallium arsenide substrate, giving a dramatic increase in operation frequency and demonstrating for the first time feasibility for microwave signal amplification. These are record values for zinc oxide thin film transistors. When doped (alloyed) with aluminum, these zinc oxide thin film transistors can be made optically transparent, opening up a new range of applications.

***Team:*** The research was led by Dr. Burhan Bayraktaroglu and Dr. Kevin Leedy at the Sensors Directorate, with funding from the Air Force Office of Scientific Research (Dr. Kitt Reinhart, Program Manager).