BARRY M. GOLDWATER SCHOLARSHIP
AND EXCELLENCE IN EDUCATION PROGRAM
Nominee's Essay

Discuss a significant issue or problem in your field of study that is of particular interest to you.

Your essay must include a description of the issue or problem, discuss an idea for research that could have significant impact on the issue or problem, describe an aspect of the research in which you would be involved, and explain the relevance of the issue or problem to you as a mathematician, scientist, or engineer. The content and style of your essay will be important to the success of your scholarship application. Assume that your reader is knowledgeable in mathematics, science, and engineering; and will have the expertise to read, review, and understand the complexities of your field of specialty.

If your essay involves research in which you are or were involved, please indicate if you are or were the sole researcher or if you collaborated with another individual.

Include a bibliography, references, or illustrations, when appropriate, as part of the essay. Font size may not be smaller than 12 characters per inch, or 11 point. Your essay **must** be typed and confined to two pages (one side only). **Be sure to include your signature at the end of your essay. Since the form is password protected, if you are including anything other then plain text in your essay, you will need to type your essay as a Word document and then print it off on this essay form.**

Title: Development of low-cost, tunable antennas for novel applications in wireless technology

The advent of wireless technology has revolutionized the way we conduct our daily lives. The growing demand for more versatile handheld products and more efficient and accessible wireless internet requires continual and dramatic improvements in wireless technology. Wireless technology may be advanced through software and hardware developments. Software development optimizes the capacity of data that can be transmitted through hardware; however, the ultimate limit of wireless technology is determined by the hardware components of the device, a problem to be confronted by Materials researchers. As a researcher, I will investigate methods of improving wireless technology in a way that is cost-effective, environmentally safe, and easily transferable to manufacturing.

One example of a limitation that must be overcome is wireless devices must emit signals in all directions in order to communicate with receivers; however, ideal devices would have tunable antennas to emit signals in specific directions in order to minimize power consumption. The effects of such a development would be significant. With less power consumption, battery-operated wireless devices can run longer. Furthermore, by improving the ways in which signals are sent and received, the quality of data transfer can be augmented and larger bandwidths of operation can be implemented. To develop a tunable antenna the materials technology of the internal circuitry requires greater electrical efficiency. As a result of added efficiency, devices will become smaller, weigh less, and most importantly, become more affordable. Finding the means to lower cost and improve quality of wireless devices is relevant to me because, as a Materials scientist, I research new materials and to improve upon existing ones.

Since the early 1990's the development of ferroelectric materials has provided a breadth of possibilities for Materials researchers to develop multifunctional microwave electronics. Ferroelectrics are used in electronic circuits as capacitors, which store charge. To develop a tunable antenna for wireless communication a solid-state ferroelectric, such as Barium-Strontium Titanate (BST), must be integrated with metal electrodes into a thin-film device (1, 2). Note from Figure 1 the relationship between voltage and capacitance for BST. This unique property of BST allows the cutoff frequency for the circuit to be modified simply by adjusting applied voltage, making it ideal for frequency-tunable wireless devices.

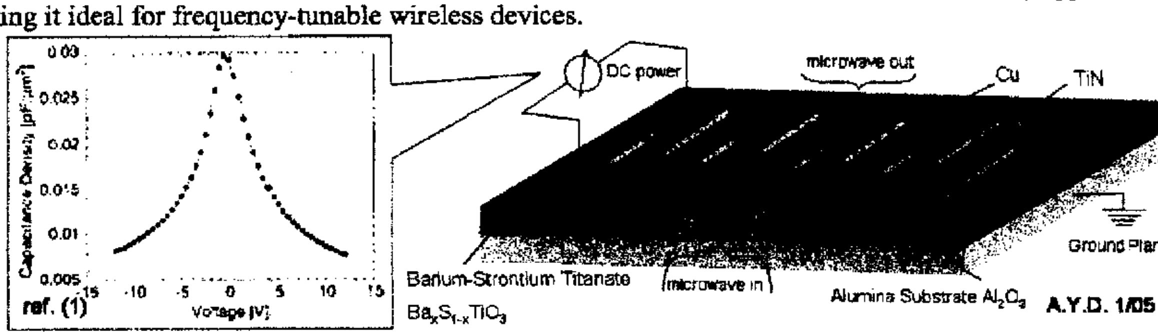

Figure 1: Cu metallization on BST using a TiN adhesion layer for microwave devices

Microwave electronic devices require the deposition of thin metal electrodes on top of ferroelectric material. It is this part of the process that is the focus of my research. Conventional ferroelectric metallization uses noble metal electrodes, such as platinum, which have excellent electrical properties but are costly. Furthermore, the etching of noble metals for device fabrications involves the use of corrosive, environmentally unfriendly acids. Copper, however, is an ideal electrode material because of its high conductivity, ease of processing, and low cost. Although it is an attractive material to integrate into thin-film devices, copper exhibits undesirable properties when deposited directly onto BST (2). To effectively use copper for thin-film electrodes we must overcome: (i) the diffusion of copper into BST which would degrade the thin-film/electrode interface; and (ii) the oxidation of copper electrodes which results in electrodes peeling and diminishing conductivity.

I work with [redacted] in the Department of Materials Science & Engineering at [redacted] to investigate the uses of Titanium Nitride as a feasible interface between copper electrodes and BST thin films. Titanium nitride (TiN) has many appealing properties because it is a stable, conductive metal. It also serves as an excellent diffusion barrier while acting as a strong adhesion layer between copper and BST. Upon deposition, TiN is resistant to oxidation and possesses very low electrical resistivity (3). I use reactive radio-frequency magnetron sputtering to deposit TiN onto silicon substrates. When growing thin-films via sputtering several critical factors must be manipulated during deposition, including sputtering pressure, plasma power, and target-substrate distance. Use of this tool requires a fundamental understanding of crystal chemistry to ensure that the proper stoichiometry of titanium nitride is deposited. I am investigating the set of processing conditions needed to deposit ideal TiN films. My objective is to identify the window of growth parameters within which TiN can be optimally sputtered and to understand why these variables influence the crystal structure and conductive properties of TiN.

An integral part of my research is the careful characterization of the sputtered films. Titanium nitride must be in a crystalline state in order to optimize its conductive properties. I characterize the sputtered TiN with x-ray diffraction to determine the crystal structure of the thin-films. I also employ optical microscopy to evaluate surface roughness of the film, a property which must be considered before depositing copper electrodes. Finally, we conduct four-point impedance tests to measure overall electrical resistivity of the films. All of these analyses enable me to determine whether the preparation methods yield suitable TiN for an electrically conductive adhesion layer. My results so far suggest that our preparation methods yield amorphous TiN, undesirable because of its low conductivity. My next effort will be to perform an annealing procedure in low-pressure atmospheres. Our expectation is that this may promote formation of the conductive, crystalline TiN driven by the thermally activated process of diffusion. Once we determine the sputtering process for ideal TiN, we can construct microwave devices (Figure 1). We use an alumina substrate because of its electrically insulating properties and relatively low price, ideal for large-scale manufacturing.

My results from this research are critical to determine if TiN can be used as a low-cost solution to copper metallization of BST thin-films. By investigating this novel solution to the metallization problem, I learn more about the nature of thin-film materials processing while exploring the factors necessary for ideal sputtering, both of which are relevant to today's Materials scientists. This research also allows me to identify and understand the existing hurdles that face Materials researchers so that I gain an appreciation of the technical challenges I meet as a Materials scientist. My investigation of TiN adhesion layers is my first step toward overcoming a long-standing hurdle in Materials research.

By lowering the cost of manufacturing and increasing device performance, wireless technologies can be incorporated into literally any field without concern for economic factors. Medical professionals can implement wireless communication so that a patient's vital statistics will always be on hand. Our nation's troops have proven the utility of wireless communication by transmitting real-time information efficiently on the battlefield. Reduction in cost of wireless technology will have its greatest effects in third-world nations by bringing the convenience and benefits of instantaneous information transfer and communication to people who cannot afford such luxuries today. I plan to continue a career in Materials research, especially in the field of electronic materials. Advances in Materials research will increase global accessibility and use while decreasing the cost of revolutionary technologies, such as wireless communication, enhancing quality of life by enhancing quality of information transfer.

(1) Padmini P, et.al. App. Phys. Lett. 75 (20): 3186-3188, 1999. (2) W. Fan, et.al. J. Appl. Phys. 94(9): 6192-6200, 2003. (3) M. Kawamura, et.al. Thin Solid Films 287: 115-119, 1996.

Nominee's Signature [redacted] Date [redacted]