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Research Statement

I would like to state that I have a strong interest in advancing scientific research in the fields of material physics and engineering. I want to investigate the research and development of high performance thermoelectric materials and their applications in power generation and cooling, magnetic materials microfabrication and their applications as sensors and transducers. I plan to continue working as a researcher to reaffirm my long-term scientific goal of understanding how to fabricate cost-effective and efficient thermoelectric materials and devices to convert waste heat into useful electrical energy, as an alternative cleaner energy source as well as for vapor-compressor free cooling applications, and thin film magnetic materials to be used as multiferroic applications. These research projects will help to create an opportunity for undergraduate and graduate students to involve in research and understanding of the physics and engineering problems to improve the status of research capability of a university.

My three specific interests are: (1) Physics and engineering of high performance thermoelectric and magnetic materials growth in a cost-effective way, (2) Methodology and application of high performance thermoelectric power generators, coolers and sensors, and (3) microfabrication of transducer devices using magnetic materials.

(1.) Physics and engineering of high quality thermoelectric and magnetic materials

I was a co-inventor of the Nanocomposite approach for high performance thermoelectric materials when I was a graduate student at Boston College. The method was successfully demonstrated in different thermoelectric materials such as Bismuth Telluride (Bi_2Te_3), half-Heuslers (HHs), Bismuth Antimony (BiSb) and Silicon Germanium (SiGe) in my PHD thesis. The thermoelectric materials are efficient only in their specific temperature regions and can be used for various applications such as thermoelectric coolers and lower temperature power generation ($Bi_{0.4}Sb_{1.6}Te_3$ and $Bi_2Te_{2.7}Se_{0.3}$), waste heat recovery in vehicles (HHs), and high temperature power generators (HHs and SiGe). National Aeronautics Space Administration (NASA), National Science Foundation (NSF), and Department of Energy (DOE) funded these research projects. In addition to recovering waste heat, I have also contributed to convert solar energy into electrical energy using thermoelectric materials as an alternative energy source.

However, the efficiency of thermoelectric devices is still low to compete with conventional refrigerators and power generators and additional research is necessary to study more efficient thermoelectric materials. In GMZ Energy/Evident Thermoelectrics, Sheetak, and nanohmics, I have been leading a team of scientists and technicians to find more efficient materials such as Bi_2Te_3 based materials including flexible devices at fiberglass matrix, half-Heuslers, and skutterudites using the nanocomposite technique, mostly funded by the Department of Energy (DOE), NASA and US-Navy. Recently, I co-invented efficient and cost-effective HH material to be used in power generation under DOE grant and flexible BiTe devices under NASA grant. Moreover, I am also collaborating with different Universities faculties and Scientists to find high cooling capacity materials and new class of half-Heuslers as topological insulators, and understating physics behind nanostructure mechanism.

In recent couple of years at Nanohmics, I am intended to extend my micro and nano materials fabrication base to design and grow materials such as permalloy, Terfenol-D, Galfenol and ferrite compounds to use in AFM applications under DOE SBIR grants. The high quality thin film materials were grown using different techniques such as sputtering, electron beam evaporation and electroplating and characterized using SEM/TEM/XRD, Vibrating Sample Magnetometer (VSM), frequency dependent susceptibility measurement, and magnetostrictive coefficient measurements.

I will be continuing these research projects and collaborations to fabricate efficient thermoelectric materials for power generation, cooling and bio-sensing applications, which promise to be a cleaner, and cheaper alternative energy source along with high quality thin film magnetic materials fabrications and characterizations. These types of research projects are generally funded by NSF, DOE, DARPA. I am confident these research projects will provide an opportunity to undergraduates to understand real problems and also contribute significantly to grow the research programs of the Texas Tech University.

(2.) Methodology and application of high performance thermoelectric power generators, coolers and sensors

In addition to high performance materials, I want to take one step further: develop methods to cost effectively assemble thermoelectric modules. Currently, I am involved in studying thermoelectric modules to convert waste heat from vehicles and Industry to electrical energy. Also, I am working on devices to be used as heat pump/cooler by applying electrical power through the thermo elements. To make such thermoelectric devices with higher efficiency, proper size of thermo elements, the metallization on the thermo elements for their connections, and the heat losses are equally important. Amidst these, at GMZ Energy/Evident, Sheetak and Nanohmics, I am leading to develop thermoelectric modules using nanostructured BiTe, HH and skutterudite materials for cooling, and vehicle and Industrial waste heat power generation The module fabrication process basically includes the identification of strong, reliable and lowest resistive contact metallization on p- and n-type thermo elements and designing those metalized elements according to specific applications to achieve highest power output with maximum efficiency. In the past couple of years, we were able to produce efficient and cost-effective modules using nanostructured HHs. Those modules have been used to fabricate 1kW thermoelectric power generator for exhaust waste heat from Bradley Fighting Vehciles under DOE grant of $11M and to make a self-powered Boiler with a world-known commercial Boiler manufacturer. Moreover, I am also involved to make an efficient heat pump/cooler by using the nanostructured thermoelectric materials with the University collaborator. The full project proposal is submitted to DOE for $2.5M grant.

With all these experiences, I plan to continue and collaborate these research projects of fabricating thermoelectric devices and modules for cooling, power generation applications and biosensors. However, there are many challenges, including thermo-elements contact resistance, to engineer such devices and I will leave no stones unturned to examine the ways to overcome the challenges.

(3.) Microfabrication of transducer devices using thin film magnetic materials

Besides thin film magnetic materials fabrication, I am also involved on microfabricated transducer devices which used multiple steps including lithography, deep reactive ion and inductive coupled plasma etching, multiple thin layer depositions of permalloy and ferrite compounds using sputtering and electron bem evaporation. The process essentially fabricated micro cantilevers to use as transducers and sensing devices. These microfabricated cantilevers could also be used as energy harvester devices using shape memor alloys, piezoelectric materials and magnetoelastic materials. I will continue to pursue my experience on thin film magnetic cantilever devices with magnetic and magnetostrictive materials.

Overall, I am working on thermoelectric and thin film magnetic materials and device research, specifically on discovering efficient thermoelectric materials by using a cost-effective nanocomposite approach to convert waste heat energy into useful electrical power as well as a thermoelectric cooler, and microfabrication of cantilevers. All of these research projects align well with your departmental research focus and can utilize most common micro/nanofabrication techniques, which will significantly reduce the research start-up fund. I believe that, the projects I seek to investigate have a high level of potential to involve undergraduate and graduate level students where they can realize the physics and engineering principles and enhance the research capability of the university in scientific community.

Sincerely,
Giri Joshi