SILICON CARBIDE THIN FILM RADIATORS AND GALLIUM ANTIMONIDE PHOTOVOLTAIC DEVICE LAYERS ON CERAMIC SUBSTRATES FOR SOLAR-THERMOPHOTOVOLTAIC APPLICATION

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ABSTRACT

The global annual energy consumption is projected to rise from its current value of 13 Terawatt-years to about 30 Terawatt-years within the next 40 years. Growing concerns over global warming and diminishing supplies of petroleum have highlighted the need to reduce carbon emissions and employ non-fossil fuels. In contrast to current and past dependence on a single source of energy for virtually all the power generated in the US, future demands are likely to be met by a variety of energy production technologies. It is the feeling of many that the key to developing a reliable and renewable energy source lies with the sun. In fact, it has already been proven that if, one day, we could harness all the energy the sun provides, there will never be a need for fossil fuels. It is this understanding that sparked the interest for the research presented in this thesis. Unfortunately, current technologies only allow us to capture a small percent of the total energy provided by the sun and at a very high-cost. Increasing the amount of power generated from solar radiation will become increasingly important, but without this technology being affordable, it is practically useless. The focus of this research is on two key components of a relatively new photovoltaic technology namely, solar thermophotovoltaics (STPV). In the STPV concept, the solar radiation is concentrated onto a solid (intermediate radiator) that could be heated to higher temperature and which in turn will radiate infrared photons as a blackbody. The photons from the intermediate radiator are then captured and directly converted to electric power by semiconductor photovoltaic devices. The two goals of this research were: (a) to develop a low-cost thin film based SiC radiator and (b) to develop low-cost III-V semiconductor crystalline thin films suitable for photovoltaic devices.

For low-cost radiators, we have successfully developed processes for the growth of silicon carbide (SiC) thin films by the atmospheric pressure chemical vapor deposition (APCVD) technique using Dimethylisopropylsilane (C_5H_8Si), 1,1, Dimethyl 1-silacyclopentane ($C_6H_{14}Si_2$), and 1,1,3,3-Tetramethyl 1,3-disilacyclobutane ($C_{10}H_{24}O_4Si_2$) as single source monomolecular polymeric precursors. By using growth temperatures between 700 and 950 °C and dilution ratios of precursor to hydrogen (carrier gas) between 1:0 (no dilution) and 1:100, optimum conditions could be identified for each precursor chemical that resulted in crystalline SiC films on a variety of substrates such as ceramic SiC, Si, GaAs, and quartz. As-grown films were evaluated for their chemical composition, crystalline quality, and surface morphology using Fourier Transform Infrared Spectroscopy (FTIR), X-ray diffraction (XRD), and Scanning Electron Microscopy (SEM), respectively. SiC films deposited under different conditions were heated to high temperatures to study the blackbody emissive nature. The emission characteristics of the films were found to be similar to bulk SiC.

For low-cost photovoltaic device grade material, we have developed a process for growing thin film GaSb layers on low-cost SiC and AlN ceramic substrates. High-temperature melt epitaxy process has been used to re-crystallize GaSb continuous thin films on SiC and AlN ceramic-grade substrates from pre-synthesized GaSb pellets. Hydrogen ambient has been found to be the most suitable for obtaining highest quality films at 710 °C which is the melting point/growth temperature of GaSb. The chemical treatment of GaSb prior to growth for eliminating thick surface oxide layers has been found to be crucial for sticking of the films on the ceramic substrates. The as-grown films show natural surface texturing (pyramidal micro-textures) which is beneficial for increasing the probability of photon absorption from the incident radiation.

Future research on stacking of thin film photovoltaic material grown using melt epitaxy with the thin film radiator could lead to high efficiency STPV systems that are inexpensive to produce in large scale. This will lead to wide-spread solar energy utilization for electricity generation.