Thin-film Fabrication for High Pressure Thermoelectric and Electrical Resistivity Studies

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Abstract

Thermoelectric materials are of interest for applications such as thermoelectric coolers in microprocessors and power generators in cars. The efficiency of thermoelectric materials is quantified by a figure of merit ZT, where Z is the thermoelectric property of the material and T is the absolute temperature. High pressure plays an important role in understanding these changes for the figure of merit of thermoelectric thin-films. To study the thermoelectric thin-films a direct approach was used by fabricating the thin-film on the surface of a diamond anvil, so that the pressure dependence of structure and transport properties can be investigated easily. Also, in recent years superconductivity has attracted great attention of various research groups since the discovery of recent iron based superconductors with transition temperatures (Tc) comparable to high temperature superconductors.

Diamond cell with proper electrical probes is a necessity in order to investigate the structure Tc relationship with high pressure. If we could successfully fabricate the electrical probes by depositing thin-films on a diamond, then it reduces the use of electrical wires as probes inside the diamond cell, as the wires are easily breakable at high pressure. Hence, we have studied different Molybdenum (Mo) electrode fabrication and alternate methods to deposit thermoelectric thin-films using sputtering deposition (physical vapor deposition). Here we describe various stages of fabrication of the probes with the thin-films.

Thin-film Fabrication

The Mo thin-films were prepared with a RF magnetron sputtering system in the solid state laboratory at the Electrical Engineering Department of UNLV. • The growth process of the thin films were deposited under Ar atmosphere and the gas flow rate into the chamber was then controlled by fine leak valve. • The yield of the sputtered films were controlled by various sputtering conditions, such as inert gas pressure, applied voltage and target substrate distance. • We used a 2x10⁻⁴ Torr as the base pressure in the chamber before the growth of the thin films, and for the cleaning of the substrates we used diluted nitric acid HNO₃, de-ionized water and alcohol. • We carried out our work with a Molybdenum (Mo) sputtering target of 2” diameter, 0.125” thick and 99.95% pure.

Why Fabrication of Thin Films on Diamond Anvil Cell?

The diamond anvil cell is used as a mechanical pressure device to study materials under extreme conditions. Such experiment will allow us to study the phase transition in various materials and hence linking this to the change in their properties. Since our interest is to investigate electrical and thermoelectric properties of different materials, we are required to modify the DAC device to take measurements in-situ. Such investigation will required the design and fabrication of a four probe circuitry device on top of the diamond cell which will allow us to conduct electrical and thermoelectric properties measurements. The fabrication of the microcircuit was done by masking and applying a thin-film deposition as described before. The microcircuit was fabricated with Molybdenum because of its stability at high pressures and great electro conductivity.

Progress

• The first problem that we faced was the substrate contamination; we defined the cleaning condition to improve the adhesion of Mo to the diamond substrate. • The second problem was the undesired growth of columnar structures and islands during the sputtering deposition of the Mo thin-films; we improved the thickness of the mask and decrease the substrate target distance. • The third problem was the undesired stress on the Mo thin film because of the difference in thermo conductivity between the Molybdenum and the diamond. We changed the sputtering time to avoid high changes in the substrate temperatures during the sputtering process. • We have found that the adhesion coefficient of the Mo thin-film on diamond can be improved by changing the sputtering deposition conditions, such as power and pressure. • We have developed a technique to create stencil mask using electro discharge machining (EDM).

Impacts and Applications

The interest in Thermoelectric and superconducting materials is crucial for renewable energy. The efficiency of this materials is heavily dependent on interrelated material properties. The shift from bulk to a low dimensional structure material is essential to increase the power factor and the critical temperature in thermoelectric and superconductors respectively. Such research will allow our group to study the properties low-dimensional structure under high pressure and low temperatures. Finding of such promising materials can lead to the development of efficient TEG’s-Thermoelectric generation’s, where wasted heat can directly be converted into electric power, also high Tc superconductors can be used to fabricate power transfer lines, in which power loss would be avoidable.

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