ELECTROCHEMICALLY DEPOSITED THIN FILMS OF Bi_2Te_3 FOR THERMOELECTRIC DEVICE APPLICATIONS

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Bi_2Te_3 is a material that has been used for thermoelectric cooling, and this and related compounds are considered to be among the best materials available for such applications [1,2]. Electrochemical deposition of compound semiconductors is a field that has grown considerably in recent years, primarily with applications to solar cells or optoelectronic. devices [3-S]; application of this technique to fabrication of films of Bi_2Te_3 for thermoelectric. devices follows logically from that work. Electrochemical deposition of Bi_2Te_3 has recently been demonstrated [6,7]. 'J'his paper presents a study of deposition conditions and substrates for fabrication of thin films of Bi_2Te_3 and related compounds,

Bi_2Te_3 may be deposited potentiostatically from an acidic, aqueous solution of BiO^+ and $HTeO_2^+$, and may bc deposited on a variety of substrates, including plat inure, nickel, gold and bismuth. We have studied the effect of electrolyte composition, and of deposition potential and current density on composition and grain size of Bi_2Te_3 films, as well as the effect of different substrate. materials. Films have been deposited from HNO_3 and H_2SO_4/HCl solutions; different acids were used to protect substrates from dissolution. Composition may bc varied by changing the relative ratio of BiO^+ and $HTeO_2^+$ in solution and by changing the deposition potential and/or current density during deposition, Grain size of the film is dependent on the growth rate, which is in turn, dependent on the current density during deposition. Films ranging in thickness from 500 A to several microns may bc made.

Bi_2Te_3 may bc deposited as n-type, or 'J'e.-rich films, or as p-type, or Bi-rich films.. Previous workers [6,7] have reported both Bi [6] and Te [7] rich films, and that Bi content in the film is affected by the ratio of Bi to l°c in the electrodeposition solution and by the current density during deposition, The ratio of Bi to Te in both Bi and Te rich films may be outside the usual limits of stoiciometric deviation in single. crystal Bi_2Te_3. This study has found that there is an effect of Bi/Te ratio in the solution, but that deposition potential is the major factor in controlling the composition in deposited films.

X-ray diffraction studies and compositional analysis of the films indicate that Bi rich films may be a combination of Bi_2Te_3 and BiTe. Te rich films may contain some elemental Te. The films arc pol ycrystalline with some preferential orientation, The degree of orientation appears to be related to grain size, and does not appear to be related strongly to the orientation of the substrate.

Electrodeposited films have been characterized for thermoelectric properties, including majority carrier concentration (N), resistivity (ρ) and Seebeck coefficient (α) in order to determine their suitability for use in thermoelectric cooling, These properties correspond well to literature. values of properties measured in single crystal Bi_2Te_3. Applications of these films to cooling in electronic devices will be discussed.

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