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THERMOANALYTICAL STUDIES OF CHEMICAL REACTIONS BETWEEN MERCURY TELLURIDE AND SOME METALS

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ABSTRACT

Chemical interaction between mercury telluride and metals such as Sn, Pb, In, Ga, Cu and Ag has been studied with the use of thermoanalytical studies and microstructural analysys. It has been found that HgTe starts interacting with Sn, Pb, In and Ga immediately after the melting of metal, though the formation of an intermediate layer of tin, lead and gallium tellurides considerably inhibits the progress of the chemical reaction. As the temperature increases, there occurs destruction of the layer formed and an intense chemical interaction which corresponds to exothermic peaks on the heating curves. In the interaction between HgTe and In, the formation of an intermediate layer does not take place, which causes a graduel chemical interaction with the formation of InTe and precipitation of free mercury. Exothermic effects of chemical interaction between Cu, Ag and HgTe appear on the heating thermograms immediately after the melting of HgTe.

INTRODUCTION

The scientific literature contains inadequate information on the nature of physico-chemical interaction between $A^{II}B^{VI}$-type semiconductor compounds and metals [I] . Mercury telluride, being one of the representative compounds of this class, founds ever increasing application in various branches of the modern semiconductor technology. Until now, however, the literature on this problem contains no information on the interaction between HgTe and metals at various temperatures.

In the case of chemical interaction between a metal and HgTe, the metal atoms will displace mercury with the formation of the metal telluride and precipitation of free mercury. As a result, the HgTe-MeTe-Me system is formed instead of the HgTe-Me one, possessing quite different properties.

MEASURING METHODS

The interaction between mercury telluride and metals has been studied with the use of thermoanalytical studies and microstructural analysis [2,3] . The thermoanalytical studies were carried out

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with the use of a microcalorimeter in which a battery of 64 chromel-alumel thermocouples was employed as a differential thermocouple. A simple thermocouple was calibrated beforehand in accordance with fixed points. An evacuated quartz ampoule was used as a reference, which was filled with powder-like graphite. The temperature effects (accuracy of $\pm 5\ ^{o}C$) were determined in the course of heating and cooling specimens containing equimolar amounts of HgTe and Me in evacuated Stepanov's quartz ampoules. Heating and cooling processes were conducted at a rate of 2 to 7 ^{o}C/min. To obtain reliable results, several identical specimens had been prepared for thermoanalytical studies. Following this, the resulting heating and cooling curves were compared to one another and analysed.

The studies of a microstructure of mechanically polished specimens were carried out with the use of the MIM-7 metallographic microscope. All the coexisting phases possessed sufficiently good contrast range, therefore the polished specimens were not subject to etching.

RESULTS AND DISCUSSION

Thermodynamic calculations have demonstrated [4] that HgTe can chemically interact with Sn, Pb, In, Ge, Cd and Ag with the formation of corresponding tellurides and precipitation of free mercury.

The experiments carried out have demonstrated that the two following thermal effects are present on the heating curves of initial mixtures containing equimolar amounts of HgTe and Sn(Pb): an endothermic effect of melting of Sn(Pb) and an exothermic effect of chemical interaction at a temperature of 527 (558) ^{o}C. Moreover, at temperatures above 527 (558) ^{o}C but below the melting point of HgTe (670 ^{o}C), there exists a number of insignificant exothermic effects which are caused by a further interaction between small amounts of non-reacted HgTe and Sn(Pb).

As a result of microstructural studies it has been found that HgTe starts interacting with Sn(Pb) immediately after melting of metals. In this case the surface of HgTe becomes covered with a thin intermediate layer of metal telluride, which results in the inhibition of a further chemical interaction. Elevation of temperature causes melting of eutectic at the HgTe–SnTe(PbTe) boundary [5], thereby removing a formed intermediate layer, which fact promotes an intensive chemical interaction between molten metal and solid mercury telluride. The same effect is observed on the heating thermograms at 527 (558) °C.

The presence of insignificant thermal effects on the heating thermograms within the range of 527 (558) °C t 670 °C can be explained by the fact that following the chemical interaction at 527 (558) °C, insignificant amounts of non-reacted solid HgTe and liquid Sn or Pb remain in the systems, whose interaction leads to the appearance of additional exothermic effects. This assertion is confirmed by the absence of reproducibility of these effects for different specimens, which can be explained by the presence, in each specific case, of different amounts of non-reacted starting materials and their different locations with respect to one another in the starting specimens. Besides, all the exothermic effects disappear in the course of melting of HgTe (670 °).

Thermal effects which belong to liquidus curves in the SnTe (PbTe) - Hg systems are observed on the cooling curves of reacted specimens.

Chemical interaction between HgTe and In or Ga takes place with the formation of monotellurides (InTe and GaTe). In the interaction between HgTe and Ga there occurs a formation of an intermediate layer based on GaTe, which impedes further interaction. Since the HgTe-GaTe system is peritectic, the temperature elevation does not result in the removal of the intermediate layer through the formation of a lower-melting-point eutectic. Only in the course of melting there takes place mixing of two melts accompanied by an intensive chemical reaction. This phenomenon is reflected on the heating thermograms of equimolar mixtures of HgTe and Ga. Upon achievement of the melting point of HgTe, the endothermic effect of melting sharply changes to the exothermic effect of chemical interaction.

In the case of the HgTe-In system, the chemical interaction also starts immediately after melting of In. In this instant however the formation of an intermediate layer does not occur, which fact is evidently caused by the specific nature of the In-Te binary system. InTe, formed in the course of the reaction, is removed from the surface of HgTe as a result of a uniform distribution in liquid In. This results in the fact that new portions of materials come into the interaction. For this reason, no exothermic effects of chemical interaction have been found on the heating thermograms. The microstructural studies have demonstrated that In comes into interaction with HgTe already at the room temperature.

Like in the interaction between HgTe and Sn or Pb, the thermal effects are observed on the cooling curves of reacted HgTe - In(Ga) specimens, which effects belong to the liquidus curves in the InTe(GaTe)-Hg systems.

In the HgTe-Cu(Ag) systems, chemical interaction at low temperatures becomes complicated, which fact is caused by high melting points of Cu and Ag. However the microstructural studies of specimens held at temperatures above the melting point of HgTe for I hr demonstrate that the formation of $Cu_2Te(Ag_2Te)$ takes place in the systems. This fact is also confirmed by the cooling thermograms in which the thermal effects of phase changes of Cu and Ag tellurides are clearly recorded.

CONCLUSIONS

As a result of thermoanalytical studies and microstructural analysis it has been determined that mercury telluride comes into chemical interaction with tin, lead, indium, gallium, copper and silver.

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