

THIN FILM INTERDIFFUSION OF Au AND In AT ROOM TEMPERATURE

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Results on the thin film interdiffusion of Au and In at room temperature are presented. Indium films 56–3000 Å thick were deposited by vacuum evaporation onto previously deposited gold films of thicknesses ranging from 200 to 1600 Å. The interdiffusion of Au and In occurs quickly at room temperature and the intermetallic compounds AuIn₂, AuIn, Au₇In₃ and Au₄In are formed. Which compound will be formed depends on the Au:In ratio in the layer and on the diffusion time.

1. INTRODUCTION

According to Powell and Braun¹ the bulk diffusion of Au and In occurs at high pressures and at a temperature of 150°C over a period of 500–1000 h. The compounds AuIn₂, AuIn, Au₄In, Au₃In and Au₉In are formed. Finstad *et al.*² found that thin film interdiffusion of Au and In can occur at room temperature in a system containing more than 20% In, and they identified the compound AuIn₂. Our results³ have confirmed that thin film interdiffusion occurs at room temperature in the Au–Ga system. The present paper concerns the structure of the compounds formed when films of Au and In of various thicknesses are evaporated on top of one another.

2. EXPERIMENTAL

Thin gold and indium films were prepared by evaporation *in vacuo* in an NRC 3117 unit. The pressure in the unit was 1×10^{-6} Torr and the substrate was 35 cm from the source. The gold and indium were evaporated sequentially from separate tungsten boats onto unheated glass substrates. The layer thicknesses were controlled using a Sloan DTM 200 digital thickness monitor, or were measured after deposition by means of a Talystep unit. The compounds formed were identified with an X-ray diffractometer. The AuIn₂ compound was identified on the basis of the relevant ASTM card, and the Au₇In₃ compound was identified using the results from ref. 4. No X-ray patterns for Au₄In, Au₇In, Au₃In and AuIn compounds were found in the available literature. Therefore our own standards were prepared by fusing the corresponding stoichiometric amounts of Au and In in a sealed quartz tube.

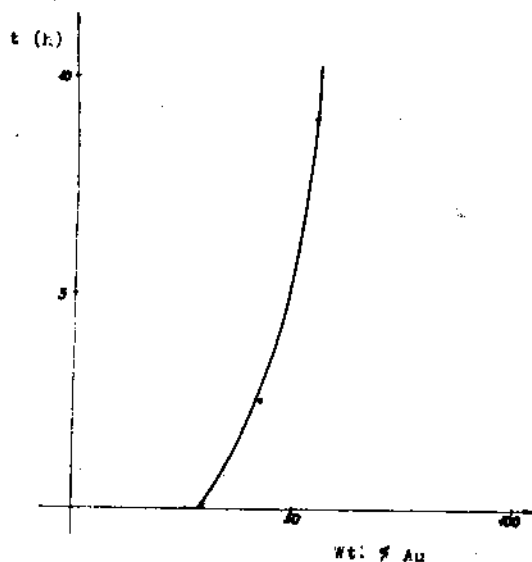


Fig. 1. Time taken for the complete disappearance of the gold colour as a function of the Au content in the layer.

TABLE I

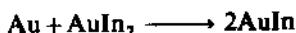
ELEMENTS AND COMPOUNDS IDENTIFIED IN THE FILMS BY X-RAY DIFFRACTION

Wt. % In	1st day	4th day	7th day	15th day	4 months	6 months	9 months
76							
70	In				In		In
57	AuIn ₂				AuIn ₂		AuIn ₂
53							
45	AuIn ₂				AuIn ₂		AuIn ₂
36	Au						
29	AuIn ₂		AuIn	AuIn			AuIn
23	AuIn						
20							
15	Au AuIn ₂	Au AuIn			Au Au ₇ In ₃ Au ₆ In	Au Au ₇ In ₃ Au ₄ In	
7	Au				Au	Au	
5.2	AuIn Au ₇ In ₃				Au ₄ In	Au ₄ In	
3.6							
3.4	Au				Au	Au	

3. RESULTS AND DISCUSSION

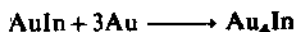
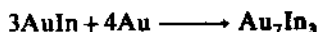
The thicknesses of the evaporated gold layers were in the range 200–1600 Å, whilst the In films were 56–3000 Å thick. From the measured thicknesses of the Au and In layers, their surface area (always the same) and the known density values, the weight percentage composition was determined for all samples. Variation of the conditions of preparation yielded films with a wide range of In content (3.6–76%). Thin Au and In films deposited sequentially diffuse very quickly at room temperature. The interdiffusion can be observed visually as a loss of gold colour. The time taken for the gold colour to disappear completely depends on the percentage of Au in the layer, as shown in Fig. 1. In layers of higher Au content (60–80%) the Au colour disappeared within a few days, but in the layers with 80–97% Au the Au colour did not disappear even after nine months.

Interdiffusion at room temperature leads to the formation of binary intermetallic compounds of Au and In. Which compound will be formed depends on the composition of the layer and on the duration of the diffusion (Table I). If the layer contains more than 65% In the compound $AuIn_2$ is formed, together with some free In, and it remains stable even nine months after its formation. When the layer contains 53–45% In, only the $AuIn_2$ compound is formed, and again it remains stable even after nine months. In layers containing 36–23% In, the compounds $AuIn_2$ and $AuIn$ with excess of Au are formed during the first day. Over several following days the compound $AuIn_2$ reacts progressively with the Au until it completely disappears and only the $AuIn$ compound, presumably formed by the reaction

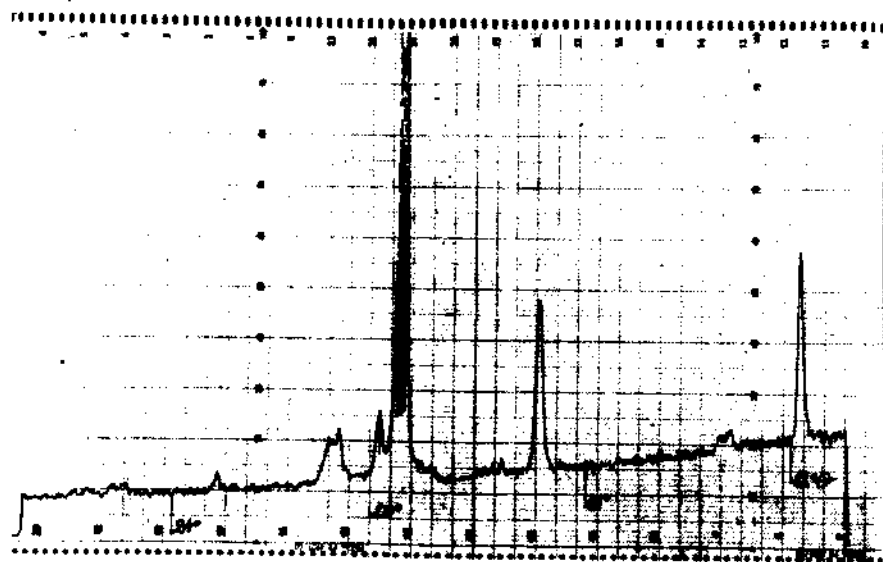


remains stable for at least nine months.

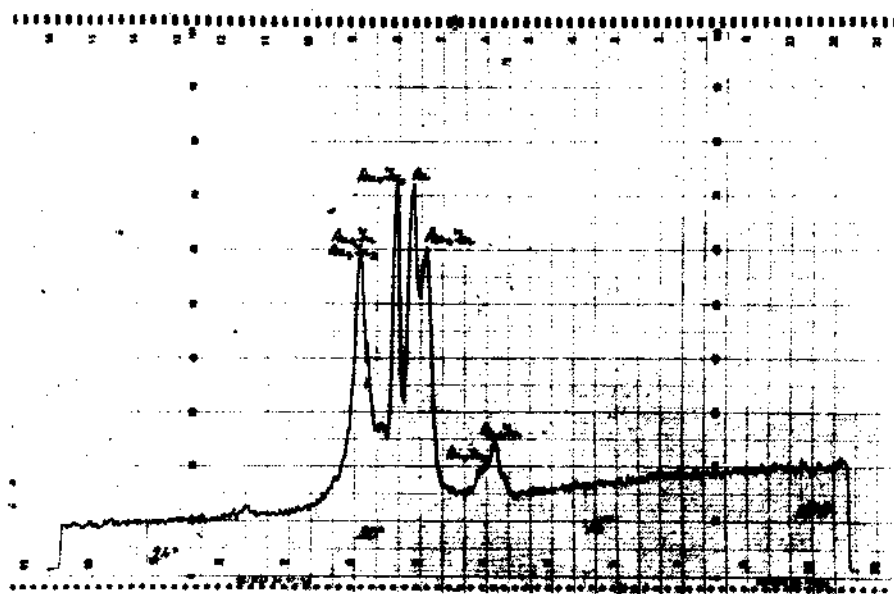
If the layer contains 20–15% In, $AuIn_2$ is formed with excess of Au. Over the first four days the $AuIn_2$ reacts with the Au to form $AuIn$. The excess Au reacts further with the $AuIn$ leading to the formation of Au_7In_3 and Au_4In :



In layers containing 7–5.2% In, the compounds $AuIn$ and Au_7In_3 are formed with excess of Au. After several months a structural transformation can be observed: there is a decrease in Au content, a complete disappearance of $AuIn$ and Au_7In_3 and the formation of Au_4In . Further reactions with Au do not lead to the formation of a compound of higher Au content (Au_7In) because this compound is stable only at higher temperatures⁵. The layer with 3.4% In contains only Au, probably because In is in solid solution with the Au⁶. The X-ray patterns of the compounds identified in layers with 36% In and 20% In are presented in Figs. 2(a) and 2(b) respectively. The compounds formed (Table I) are in accordance with the Au–In equilibrium diagram⁵ (Fig. 3). Au_3In and Au_7In were not identified at room temperature; this is in agreement with the equilibrium diagram according to which these compounds are stable only at temperatures above 400°C.



(a)



(b)

Fig. 2. X-ray patterns of AuIn layers with (a) 36% In (AuIn compound) and (b) 20% In taken four months after evaporation.

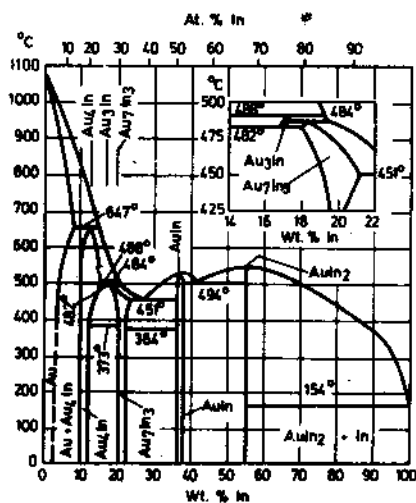


Fig. 3. Equilibrium diagram of the Au-In system according to ref. 5.

4. CONCLUSION

Thin film interdiffusion of Au and In occurs at room temperature and the compounds $AuIn_2$, $AuIn$, Au_7In_3 and Au_3In can be formed. Which compound will be formed depends on the Au:In ratio in the layer and on the diffusion time. If more than 45% In is present, the compound $AuIn_2$ is formed immediately and remains stable even after nine months. If the indium content is less than 45%, compounds with higher In content are formed first but these react with the excess free gold to form compounds of lower In content.

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