

METASTABLE Gd-Ag ALLOY THIN FILMS

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The work reported here concerns measurements on Gd-Ag alloys prepared by the vapour quench technique. Materials formed in this way have been extensively studied by Mader (1) who found that if the atomic radii ratios of the two constituent elements were less than 1.10 a crystalline structure was obtained, whereas above 1.10 an amorphous structure was formed. These amorphous alloys are only stable below approximately 0.3 of the average melting point of the constituent elements.

Experimental

Samples prepared by the co-evaporation of the two metals on to substrates at room temperatures, 78 K and 4.2 K were analysed by X-ray fluorescence. Their composition was found to be within a few per cent of the expected value. Studies by X-ray diffraction and microprobe analysis, before and after annealing, have enabled the distribution and arrangement of the silver and gadolinium atoms to be investigated. Finally E.S.R. X-band measurements on the alloy samples were made at temperatures between 4.2 K and 360 K.

Results

A summary of the properties of the alloys is shown in Tables I and II. E.S.R. studies of the vapour quenched alloys show that the resonance line width is a minimum at the Curie temperature (2) and this has enabled the Curie temperature of different alloy structures to be

TABLE I

Summary of Properties of Alloys prepared at 4.2 K and 78 K

Alloy At. % Gd	Curie temp °K	g-factor	Crystal Structure
100	310 ± 10	1.95 ± 0.01	
96	270 ± 10	1.97 ± 0.01	
94	180 ± 20	1.98 ± 0.01	
90	45 ± 10	1.98 ± 0.01	
87	72 ± 10	2.01 ± 0.01	
85*	140 ± 10	1.99 ± 0.01	
84	150 ± 10	1.96 ± 0.01	
79	165 ± 20	1.96 ± 0.01	
76	200 ± 20	1.96 ± 0.01	
53	335 ± 10	2.02 ± 0.02	
46*	~350	1.98 ± 0.01	
23*	350 ± 10	1.98 ± 0.01	

*Deposition at 78 K

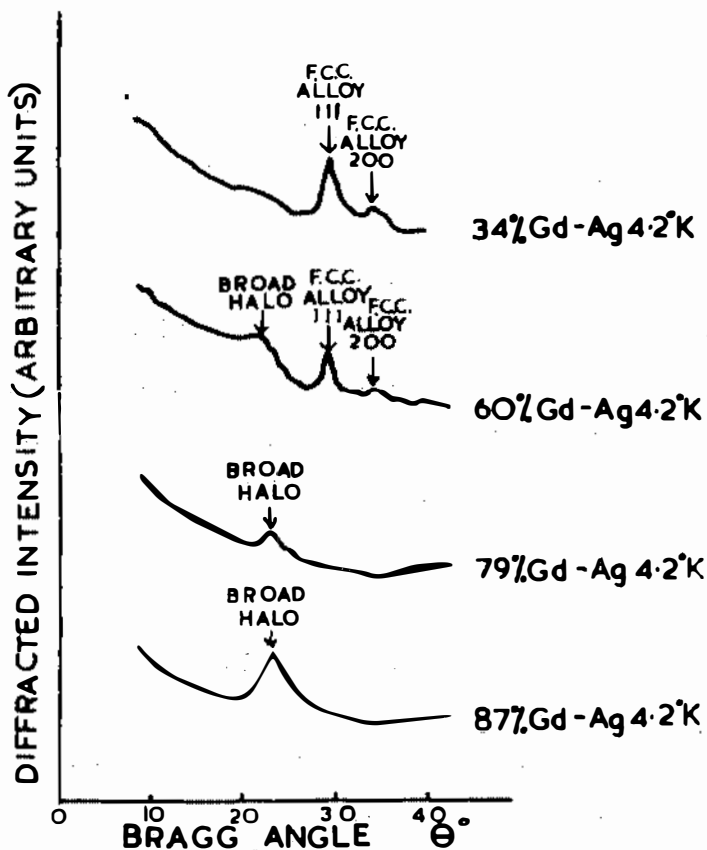
TABLE II

Summary of Properties of Alloys prepared at Room Temperatures

Alloy At. % Gd	Curie temp °K	g-factor	Crystal Structure
100	310 ± 10	1.98 ± 0.01	Amorphous
94	285 ± 10	1.96 ± 0.01	Amorphous
89	275 ± 10	1.97 ± 0.01	Amorphous
80	110 ± 10	1.96 ± 0.01	
66	115 ± 10	1.95 ± 0.01	F.C.C.
59	110 ± 10	1.95 ± 0.01	F.C.C.
45	85 ± 15	2.00 ± 0.01	F.C.C.

Fig. 1

Microdensitometer Curves of X-Ray
Diffraction Photographs of Gd-Ag



ascertained. Results show that for samples prepared at 4.2 K and 78 K the Curie temperature falls from 310 K for pure Gd to a minimum value of 45 K for a 90 at. % Gd alloy increasing to a temperature above that for pure Gd in more dilute alloys. For room temperature deposited samples the Curie temperature falls from that of pure gadolinium to 110 K at 80 at. % Gd and remains at this value for compositions down to 45 at. % Gd.

It would appear that the E.S.R. data is a sensitive measure of

change in structure and the sharp change in Curie temperature for low temperature deposited samples is typical of what might be expected if a structure change occurred.

Microdensitometer curves of X-ray diffraction photographs (Figure 1) show that alloys produced at low temperature with a high Gd content are amorphous becoming crystalline tending to form an f.c.c. structure for samples with less than 66 at. % Gd.

Microprobe analysis of samples before and after annealing show that although the atoms can be considered randomly dispersed initially, annealing causes some aggregation which becomes pronounced on samples annealed at 200°C. This effect does not appear significant when low temperature deposited samples are raised to room temperature. The metastable nature of the alloys is evident from the structure change on annealing.

Discussion

In both low temperature and room temperature deposited samples the change in Curie temperature with decreasing Gd content suggests that the Gd atoms are dispersed by the silver, ie. the fall in Curie temperature confirms the formation of alloy samples. The behaviour of low temperature and room temperature deposited samples differ in that (1) the fall in Curie temperature is more pronounced in the former and (2) below 90 at. % Gd the Curie temperature of the low temperature deposited samples increases whilst that of the room temperature deposited samples remains constant. It would appear that for room temperature deposited samples the Gd environment does not change appreciably below 90 at. % Gd and that this could result from a tendency for the Gd atoms to cluster. For the low temperature deposited samples there are a number of observations which indicate

the possibility of a different structure below 90 at. % Gd. These observations are :

- 1) The change in Curie temperature
- 2) The change in character of the resonance line width and g factor with composition.

When these observations are coupled with the X-ray diffraction data the possibility of a structure change becomes feasible.

Microprobe analysis and X-ray diffraction studies show that all alloys can be considered metastable below room temperature but around 200°C there is evidence of the appearance of a two phase structure.

References

1. Mader S., J. Vac. Sci. Tech. 2, 35 1965.
2. Harris A. M., Popplewell J. and Tebble R. S. Proc. Phys. Soc. 88, 679, 1966.

DISCUSSION :

- R.D. Doherty : Why does the Curie temperature rise again with more than about 10 at% silver for alloys evaporated onto the cold substrate?
- J. Popplewell : The Curie temperature is determined by the strength of the ferromagnetic exchange interaction. Since a structure change is observed on reducing the gadolinium content of the alloy, this change may be responsible for the increases in the Curie temperature since it is known that the ferromagnetic exchange coupling is sensitive to changes in the structure and any associated change in the conduction electron concentration.
- B.K. Chakraverty : The reason for the increase of T_c after the minimum could be simply due to increased s-f interaction, as happens with Gd in Eu.
- J. Popplewell : The value of the Curie temperature in all alloys studied arises through s-f interactions. It is rather a question of what causes the ferromagnetic exchange interaction to increase.