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E. S. R. STUDIES OF AMORPHOUS Gd-Ag ALLOY THIN FILMS

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Résumé. — Les lames minces de l'alliage Gd-Ag ont été produites par l'évaporation simultanée de Gd et Ag sur des substrats à 4.2 °K, 78 °K et à la température ambiante. Pour les lames déposées à basse température, la température de Curie déterminée à partir des études E. S. R. montre un minimum de 45 °K à 90 at. % Gd. Pour les lames déposées à la température ambiante, la température de Curie diminue à mesure que la quantité de Gd diminue. Les résultats sont compatibles avec un changement de structure à environ 90 at. % Gd.

Abstract. — Gd-Ag alloy thin films have been produced by the simultaneous evaporation of Gd and Ag on to substrates at 4.2 °K, 78 °K and room temperature. For low temperature deposited films the Curie temperature as determined from E. S. R. studies shows a minimum of 45 °K at 90 at. % Gd. For room temperature deposited films the Curie temperature decreases with decrease in Gd content. The results are consistent with a change in structure at about 90 at. % Gd.

I. Introduction. — The work reported here concerns measurements on alloys prepared by the vapour quench technique. This technique has been used extensively by Mader [1]. Using this method the solubility of trivalent gadolinium in monovalent silver has been extended beyond the previously reported maximum of 0.8 at. % gadolinium [2]. Hence measurements of the effect of (a) the electron concentration and (b) the atomic packing, on g-shift and resonance line widths can be examined without being restricted to very dilute alloys.

II. Experimental Method. — Alloys are formed by dropping a powdered mixture of Gd and Ag on to a molybdenum filament at 2000 °C. The vapour is condensed on to a «Formvar» coated substrate which for low temperature depositions is made of copper, cooled with either liquid helium or liquid nitrogen. The composition of the alloys was found by using X-ray fluorescence analysis. The films, removed from the substrate by dissolving the «Formvar» coating with chloroform, were coated on to a quartz fibre for X-ray diffraction studies or on to a copper sample holder for E. S. R. studies.

The E. S. R. spectrometer is an X-band reflection instrument using a modulation frequency of 100 kHz. The cavity may be maintained at any temperature between 360 °K and 4.2 °K.

III. Results. — E. S. R. measurements were taken as the sample was cooled from the paramagnetic to the ferromagnetic region. The resonance line width is found to decrease with temperature to a minimum in the region of the Curie temperature. Observations by other workers [3] on the line widths taken in both ferromagnetic and paramagnetic states on Gd-Y and Gd-Lu show similar minima in the region of the Curie temperature. The line width DH, the half power-half width of the pure absorption curve has been obtained from the resonance line using an analysis due to Peter et al. [4]. Figure 1 shows DH plotted against temperature for an 87 at. % Gd alloy (continuous line) and a 96 at. % Gd alloy (dashed line), both deposited at 4.2 °K. The addition of 10 at. % silver to gadolinium lowers the Curie temperature from 310 °K to 45 °K thus indicating that silver has been dispersed. Figure 2 shows the variation of the Curie temperature with composition for samples produced on low temperature (continuous line) and room temperature (dashed line) substrates. It can be seen that the variation in Curie temperature with composition is determined by the substrate temperature.

The following empirical relationship for the variation of paramagnetic line width with temperature is given below:

$$DH = m[T - T_c] + (\rho - T_o)$$

where $m$ is the gradient and has the value of the Korringa slope within experimental error. For alloys
deposited at low temperature \( \varphi = 350 \, ^\circ \text{K} \) in the composition range 90 to 100 at. \% Gd in Ag and \( \varphi = 560 \, ^\circ \text{K} \) for those compositions below 90 at. \% Gd. X-ray diffraction photographs from both room temperature and low temperature deposited samples show broad diffuse haloes in the range 66-100 at. \% Gd-Ag. According to Hilsch [5] this is characteristic of photographs from amorphous materials. The structure observed below 66 at. \% Gd can be assigned to a f. c. c. structure.

For depositions at liquid helium temperature the \( g \) factors are found to vary from 1.95 \( \pm \) 0.01 for pure Gd to 2.01 \( \pm \) 0.01 for an 87 at. \% Gd-Ag alloy falling to 1.96 \( \pm \) 0.01 for alloys containing less than 84 at. \% Gd. For samples deposited at room temperature the \( g \) factor falls gradually from a value of 1.98 \( \pm \) 0.01 for pure Gd to 1.95 \( \pm \) 0.01 at 50 at. \% Gd. These \( g \) factors are within the same range as those reported by Harris et al. [3].

IV. Discussion. — For alloys containing more than 90 at. \% Gd, the Curie temperature falls as the proportion of Gd is reduced and this can be considered to arise from the dilution effect of the silver atoms. This explanation could apply to both room temperature deposited samples and those deposited at low temperature. The reasons behind the fall in Curie temperature are not clear but could arise either from tight packing of the gadolinium atoms about the Ag atoms (studies on gadolinium show fall in Curie temperature with increased pressure [6]) or a dilution effect similar to that observed in solid solutions with yttrium and lutetium [3].

For samples deposited at room temperature but containing less than 80 at. \% Gd the constant Curie temperatures suggest that the Gd environment remains essentially unchanged with increasing silver content. This behaviour might be expected in room temperature prepared samples if there is a tendency for the Gd atoms to cluster. The size of these clusters would then seem to be independent of the overall composition.

At 90 at. \% Gd there is evidence to suggest that there is some change of structure in the alloy prepared at low temperatures namely (1) the sharp change in Curie temperature (2) the abrupt change in \( g \) factor (3) the sharp increase in the temperature independent part \( \varphi \) of the resonance line width below 90 at. \% Gd. X-ray diffraction data on these samples shows the presence of an amorphous structure above 66 at. \% Gd but in more dilute solutions there is a transition to some crystalline state.

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References