THE ELASTIC CONSTANTS OF NICKEL–COPPER ALLOY SINGLE CRYSTALS*

S. G. EPSTEIN† and O. N. CARLSON‡

The elastic constants of single crystals of the nickel–copper alloy system were determined by an ultrasonic pulse-echo technique. The elastic constants are proportional to the nickel concentration up to 70 at. % nickel at room temperature. Above this concentration where the alloys are ferromagnetic at ambient temperatures a slight positive deviation from linearity is observed in the elastic constant versus composition curves. The ΔE-effect was observed in all of the ferromagnetic nickel-rich alloys.

LES CONSTANTES ELASTIQUES DE MONOCRISTAUX D'ALLIAGES NICKEL–CUIVRE

Les auteurs ont déterminé les constantes élastiques de monocristaux d'alliages du système nickel–cuivre, en utilisant la technique de l'impulsion ultrasonore et de l'écho. Les constantes élastiques sont proportionnelles à la teneur en nickel jusqu'à 70 % at., à la température ambiante. Au-dessus de cette concentration, pour laquelle les alliages sont ferromagnétiques à la température ambiante, on observe une légère déviation positive par rapport à la loi linéaire dans les courbes constante élastique–composition. L'effet ΔE a été observé dans les alliages riches en nickel et ferromagnétiques.

DIE ELASTISCHEN KONSTANTEN VON EINKRISTALLEN DER NICKEL–KUPFER–LEGIERUNGEN

Die elastischen Konstanten von Einkristallen des Legierungs-systems Nickel–Kupfer wurden mit einer Puls-Echo Ultraschallmethode bestimmt. Die elastischen Konstanten sind bei Raumtemperatur proportional zur Nickelkonzentration bis herauf zu 70 At.—% Nickel. Oberhalb dieser Konzentration, wo die Legierungen bei Raumtemperatur ferromagnetisch sind, beobachtet man bei der Auftragung der elastischen Konstanten gegen die Zusammensetzung eine leichte positive Abweichung von der Linearität. Der ΔE-Effekt wurde in allen ferromagnetischen nickelreichen Legierungen beobachtet.

INTRODUCTION

While elastic constants have been measured for many pure metals, there exists a scarcity of data in the scientific literature on alloy single crystals.[1] At the time this study was undertaken, the authors were aware of no reported complete sets of elastic constants obtained for single crystals with compositions encompassing an entire alloy system.

The elastic constants of copper single crystals have been measured by Goens[2] by a composite oscillator technique and by Lazarus,[3] Overton and Gaffney,[4] and Schmunk and Smith,[5] all of whom used an ultrasonic pulse-echo method. The elastic constants of nickel single crystals have been measured by Honda and Shirakawa,[6] Yamamoto,[7] Bozorth *et al.*,[8] Neighbours *et al.*,[9] Levy and Truell,[10] de Klerk and Musgrave,[11] and Alers *et al.*[12] employing various techniques. There is generally good agreement in the results of these investigations for copper but the nickel values show considerable differences. This is probably due, at least in part, to the different techniques employed and to variations in the domain distributions in unmagnetized nickel crystals.[8]

Previous to this investigation Shirakawa and Numakura,[13] determined Young's moduli for the principal crystallographic orientations in nickel–copper alloy single crystals and Schmunk and Smith studied the effects of small additions of nickel on some of the elastic constants of copper using the pulse-echo technique. Very recently Sakurai *et al.*[14] published results of their study of the elastic constants of Ni–Fe and Ni–Cu alloys over a wide composition range. They incorporated the data of the above mentioned investigations in their treatment of the Ni–Cu case from which they observed a linear variation in elastic constants with composition. These results were interpreted in terms of the central and pair-like interactions between atoms. The present study attempts to provide a complete description of the dependence of the room temperature elastic constants on composition across the nickel–copper alloy system.

EXPERIMENTAL PROCEDURES

Single crystals of nickel and copper and of Ni–Cu alloys in the composition range of 6 to 84 at.% Cu

* Received September 28, 1964. Contribution No. 1585. Work was performed in the Ames Laboratory of the U.S. Atomic Energy Commission.

† Institute for Atomic Research, Iowa State University, Ames, Iowa and Brookhaven National Laboratory, Upton, New York.

‡ Institute for Atomic Research and Department of Metallurgy, Iowa State University, Ames Iowa.