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Intermixing in Ni/Al multilayer thin films

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Self-propagating exothermic reactions are known to occur in multilayer films with alternating layers of a transition metal and a light element. The high velocity of these reactions, associated with high heat release rate, convert these systems in a unique heat source. The possibility of tailoring such a heat source to meet the needs of a particular process is very attractive to applications such as brazing or solid-state diffusion bonding.

The solid state reactions occurring in Ni and Al multilayer thin films, produced by d.c. magnetron sputtering with bilayer thickness (period) of 5, 14 and 30 nm, were studied by differential scanning calorimetry (DSC). DSC results demonstrated that reaction temperature and heat released increase with the period of Ni/Al multilayer thin films.

X-ray diffraction of the as-deposited films only detected Al and Ni peaks, for all the periods studied; after heat treatment peaks of Al3Ni, Al3Ni2 and NiAl were observed. The phases formed during the exothermic reactions are in agreement with other studies [1]. However, the heat release values are lower than the ones reported in the literature. For a particular system, the heat evolved during the reaction depends on the atomic diffusion distance (the layer thickness) and atomic intermixing at the layers interface [2]. Intermixing is known to occur during deposition with the consequent formation of chemically diffuse interfaces that, in this system, is usually the result of the formation of NiAl. Such an interface can considerably diminish the measured heat of reaction.

Intermixing in as-deposited 5, 14 and 30 nm period films were investigated by high resolution transmission electron microscopy (HRTEM). HRTEM images (Fig. 1) of cross sections of the as-deposited films clearly display the layered structure of these films. Fast Fourier transformation (FFT) of the images display spots of the NiAl intermetallic phase, along with others from Al and Ni. For the film with 14 nm of period, selected regions (Fig. 2) of the images were analyzed using FFT and identified as Al and Ni layers, small areas of NiAl are also identified. HRTEM observations reveal that intermixing of Ni and Al atoms occurred during deposition of the films, promoting the formation of NiAl in small areas of the as-deposited samples. NiAl formation during deposition is more significant in smaller period thin films and, as a result, the heat evolved by the solid state reaction is also smaller.

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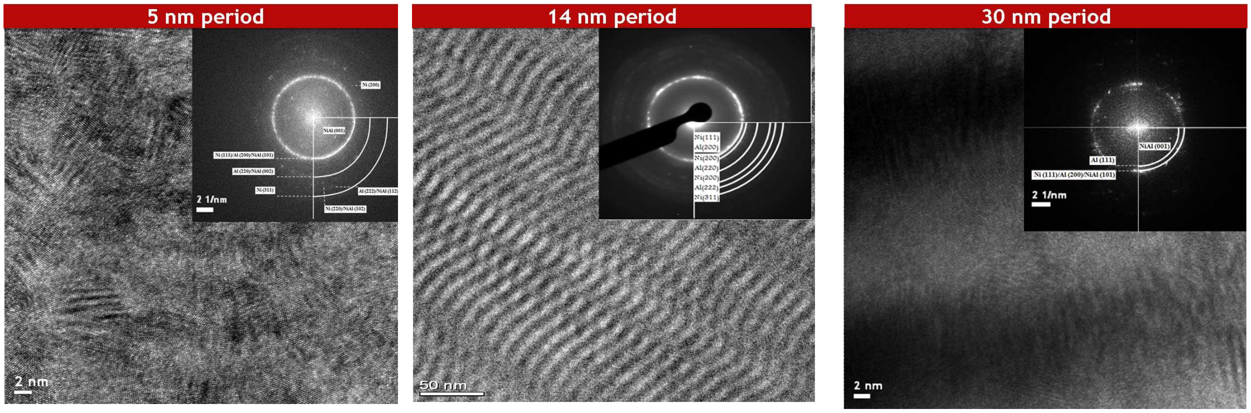

Fig. 1 – HRTEM images and corresponding FFT of Ni/Al multilayer thin films with 5, 14 and 30nm of period; spots of Al, Ni and NiAl are identified in the images.

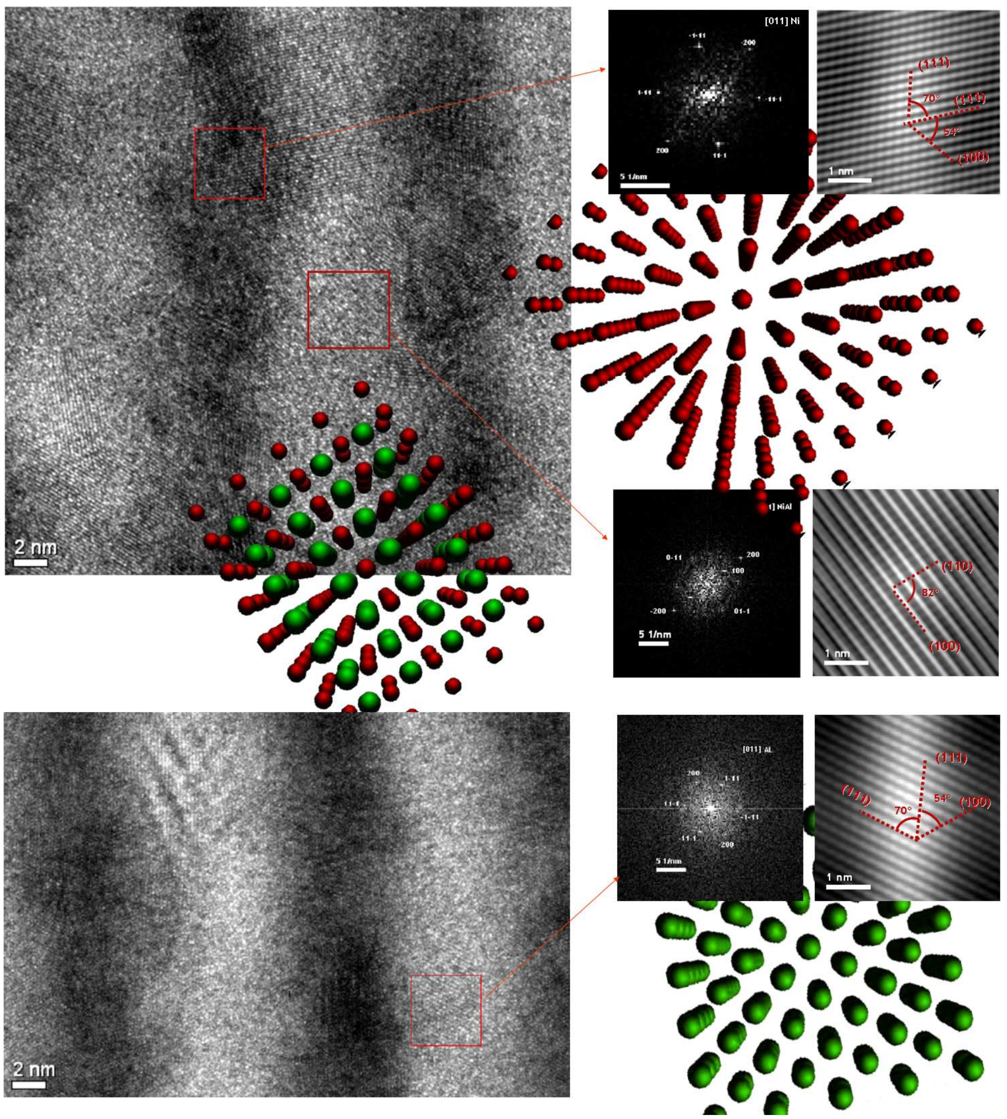

Fig. 2 – Ni/Al multilayer with 14 nm of period. HRTEM images and corresponding FFT from selected regions confirming the presence of Al and Ni layers, and small areas of NiAl.

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