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Polycrystalline Ni_3Al-based intermetallic alloys have overcome their room temperature brittleness problem with a small amount of boron addition [1-3]. Because of their unique strength-temperature relationship and good oxidation resistance at high temperatures, research efforts have been concentrated extensively on the structural applications at elevated temperatures [4]. In this paper we show that ductile Ni_3Al-B alloys also exhibit remarkable mechanical properties at cryogenic temperatures.

The nominal composition of the alloy studied is given in Table 1. The equivalent aluminum concentration, defined as the total atomic percents of Al and other elements that substitute for Al, is designed to be 23.8% since the boron ductilization in Ni_3Al intermetallics occurs most effectively with a substoichiometric composition [5]. The boron addition is set at 0.25 at.%.

One 8 kg. heat was prepared by vacuum induction melting using high purity raw materials. The ingot was remelted and atomized into powders by argon atomization. Screened powders of -140 mesh were canned, evacuated, and sealed in vacuum. The consolidation was carried out by hot isostatic pressing (HIP) at 1150°C/100 MPa for two hours. The alloy, designated as T144, was then cold rolled 20%, followed by annealing at 1000°C for one hour.

Alloy T144 has a fully recrystallized, equiaxed grain structure after the annealing treatment; the grain size is ASTM 10 (10 - 15 μm) as seen in Figure 1. The alloy consists predominately of the $L1_2$ type ordered phase with only a trace amount of secondary phase particles detected.

Table 2 lists the measured tensile properties at different temperatures. Alloy T144 in the annealed condition shows 40% elongation at room temperature, with necking observed after the alloy reaches its ultimate tensile strength. This excellent ductility is retained through the cryogenic temperature regime down to liquid helium temperature (4°K). Unlike other intermetallic alloys, ductile Ni_3Al-B alloys does not show a ductile-brittle transition at some low temperature.

Both yield and tensile strengths are found to increase with decreasing temperature. This observation is contradictory to previous data. The positive temperature dependence of flow stress in polycrystalline Ni_3Al has been reported to extend to liquid nitrogen temperature (-196°C) [6]. The difference in behavior is due to the fine grain structure of the present P/M Ni_3Al-B based alloys which is expected to generate a grain size strengthening effect at low temperatures. As a result of two strengthening mechanisms, the anomalous thermal effect and the regular grain size effect, alloy T144 shows a yield strength minimum around room temperature. On the other hand, a significant increase in tensile strength with decreasing temperature is directly associated with the change of strain hardening rate. The stage II strain hardening rate for annealed T144 alloy was measured to be 4800 MPa at room temperature; 6960 MPa at liquid nitrogen; and 7310 MPa at liquid helium.

Table 2 also lists the measured properties of cold worked alloy T144 without annealing. The alloy develops a very high strength after 20% cold rolling. The high strain hardening rate allows the ductile Ni_3Al-B alloys to be strengthened effectively through a small amount of cold work. This aspect of Ni_3Al has received little attention in the past because of the brittleness at low temperature. The cold-worked specimen of this study shows necking during tensile testing and maintains a ductility of more than 10% elongation at room temperature and at liquid nitrogen temperature.

In summary, cryogenic tensile properties of ductile Ni_3Al-B type intermetallic alloys have been investigated in an experimental P/M alloy, T144. Excellent tensile ductility was observed from room temperature to liquid helium temperature (4°K). Both yield and tensile strengths, as well as the strain hardening rate, increase with decreasing temperature. The high strength imparted by cold working at room temperature does not impair cryogenic ductility.

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Table 1 Chemical Composition of P/M T144 Alloy (wt.%).

Ni	Co	Al	Hf	Mo	Nb	Zr	B
bal.	11.5	11.5	1.75	1.00	0.50	0.05	0.05

Table 2 Low Temperature Tensile Properties of P/M T144 Alloy.

Testing Temperature °K	Yield Strength MPa	Tensile Strength MPa	Final Elongation %
		Annealed	
673	690	1351	42
298	575	1441	40
77	641	1757	38
4	660	1929	40
	682	1915	37
		Cold Worked	
298	1585	1745	12
77	1758	2086	14

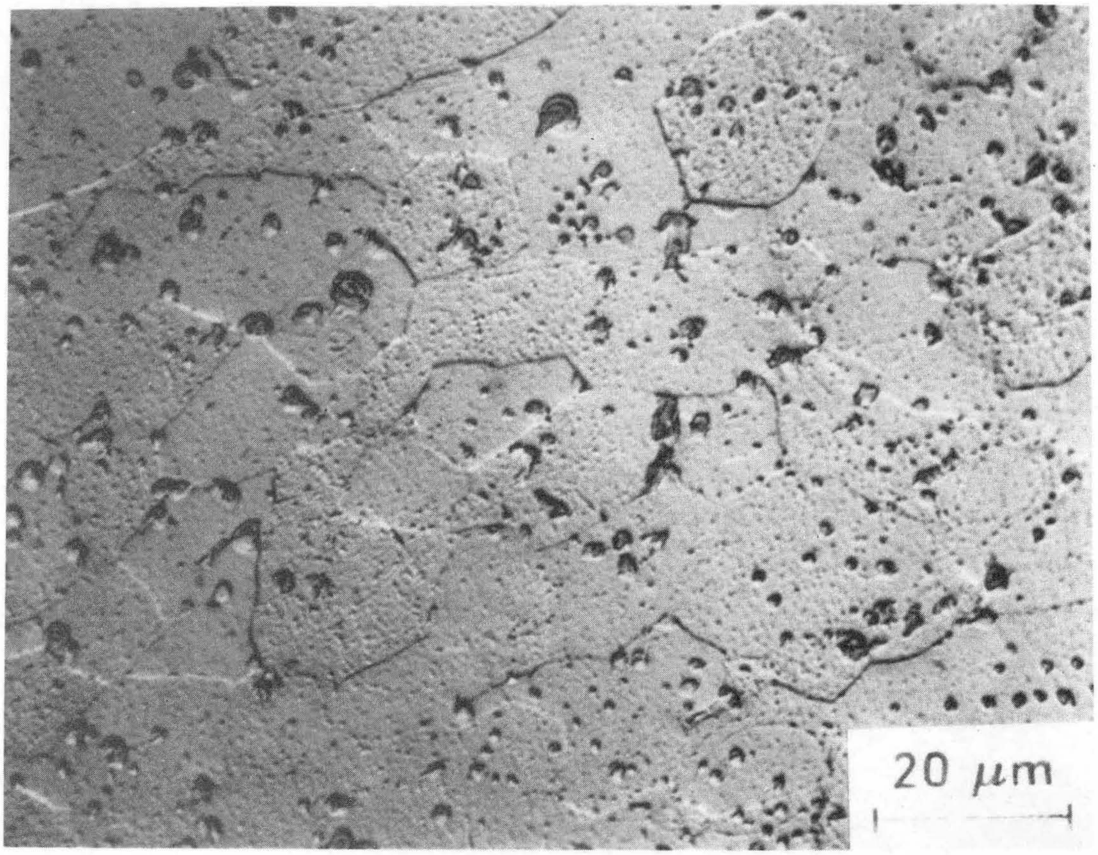

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Figure 1. Metallography of annealed P/M T144 alloy.

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