Production of Metal Carbides using Thermax®

Thermax® N990/N991 Ultra Pure grade thermal carbon blacks, produced by Cancarb Limited, are well-known as the highest purity form of amorphous carbon available in both pellet (N990) and powder (N991) form. Thermal carbon blacks are produced by the thermal decomposition of high purity methane feedstock and are characterized by low surface area, low ash and moisture content, and extremely low levels of sulphur and other impurities. These properties have provided Thermax with wide acceptance in the metal carbide industry as the preferred carbon source for carburizing hard metals.

Thermax N990/N991 Ultra Pure products provide:

- Highest carbon purity which enhances carbide yield and minimizes impurities in the final hard metal product.
- Lowest sulphur levels which allow carbide tool producers to manufacture premium micro-grained products.
- Lowest ash levels and low grit levels minimizing the final metal carbide porosity and enhancing density.
- Nanometer scale particles that permit a reaction efficiency that cannot be matched by the coarser grain carbon sources such as graphite.
- Availibility in pellet or powder form to conform to particular processing requirements.
- Soft and uniform pellets for ease of mixing and blending and for achieving optimal dispersion.
- High bulk density compared to other forms of carbon black.
- Very uniform lot-to-lot properties for demanding quality control requirements.

Hard metals, also known as cemented carbides, are a class of materials comprised of hard refractory metal carbide particles that are cemented together with a softer metallic binder, usually cobalt or nickel. As a result of their composition and microstructure, they have a good combination of hardness and toughness that makes them well suited for use as tools for metal cutting, metal forming, mining, rock drilling, road constructions, and many other similar applications.

The most common industrial carbide production process involves dry mixing precise amounts of refractory metal powders with either carbon black or graphite powders in a ball mill or high-energy mixer. These powder mixtures are placed in graphite containers and heated in a reducing atmosphere to temperatures between 1100°C and 2000°C to form refractory metal carbide powders.

The hard phase composition commonly consists of tungsten carbide (WC) particles having a specified average particle size, size distribution, and carbon level. Several other carbides including TiC, TaC, NbC, Cr_3C_2, VC, and ZrC rely on Thermax N990/N991 Ultra Pure to achieve superior final properties. Additions of other carbide powders to WC carbides are sometimes used to enhance properties needed for specific applications. As can be seen in Table 1, in comparison to graphite, Thermax N990/N991 Ultra Pure contains low levels of elemental impurities which may be detrimental to production and final product properties.

Table 1. Elemental impurities of carbon sources for metal carbide production. Graphite impurities were taken as the median value of the samples found in the reference.[1]

Element (ppm)	Thermax® N990/N991 UP	Natural Graphite	Synthetic Graphite
Aluminum	<1	20	3.5
Antimony	<0.5	<0.5	<0.5
Arsenic	<1	<0.1	<0.1
Bismuth	<0.5	<0.1	<0.1
Boron	<1	0.87	1.4
Cadmium	<0.5	<0.1	<0.1
Calcium	<2	10	30
Chlorine	<6	11	8.4
Chromium	<0.5	<0.5	2.4
Copper	<1	2.5	0.65
Gallium	<0.5	<0.1	<0.1
Iron	5	25	47
Lead	<1	<0.5	<0.5
Lithium	<0.5	<0.01	0.24
Magnesium	<0.5	7.2	3.2
Manganese	<0.5	0.38	1.1
Mercury	2	<0.5	<0.5
Nickel	<0.5	0.51	3
Phosphorus	3	0.51	1.6
Potassium	<1	0.66	0.62
Silicon	20	330	54
Sodium	10	5.5	6.9
Sulphur	<10	60	58
Tin	<0.5	<0.5	<0.5
Titanium	<0.5	5.4	5.5
Vanadium	<0.5	0.45	6.7
Zinc	<0.5	0.4	0.3

The quality of finished carbide product varies depending on the process and on the quality of raw starting materials. High quality metal carbides require the best refractory powders to achieve consistent and favourable properties. It has been shown that the level of impurity in the finished carbide is determined entirely by the purity of the hard phase and the carbon source.[2] Elements like

[1] Trammell, Michael P, & Pappano, Peter J. *Analysis of Natural Graphite, Synthetic Graphite, and Thermosetting Resin Candidates for Use in Fuel Compact Matrix*. United States.

[2] Krstic, V. D. (1992). Production of Fine, High-Purity Beta Silicon Carbide Powders. *Journal of the American Ceramic Society, 75*(1), 170-174.

S, Ca, Na, P, Si, and Al that are present in the raw materials remain in the finished WC powders, ultimately causing degraded hard metal properties. Thermax N990/N991 Ultra Pure is the highest purity amorphous carbon achieved by using high quality natural gas feedstock.

The thermal process yields spherical/ellipsoidal carbon particles with an average diameter of 280 nm as can be seen in Figure 1. The smaller particle size of Thermax as compared to graphite allows for a larger surface area for the carburization to occur, resulting in faster reaction times. In the case of N990 Ultra Pure, soft pellets, averaging 0.5 mm in diameter, are produced that flow easily and create minimal dusting. The ash content specification for Ultra Pure grades is about 30% of current commerical synthetic graphite grades recommended for hard metal carburization. The combination of these physical characteristics, low moisture content, and high chemical purity make Thermax N990/N991 Ultra Pure the ideal choice for commercial production of refractory metal carbide powders that are required for modern hard metal applications.

During the carburization reaction, many of the impurities present in the carbon and metal powders are removed from the WC powder via evaporation. Since the degree of purification increases with increasing carburizing temperature, finer WC powders typically have higher impurity levels than coarser powders produced from the same starting materials. Thermax N990/N991 Ultra Pure is the largest particle size carbon black and is capable of producing metal carbides with extremely low impurity levels.

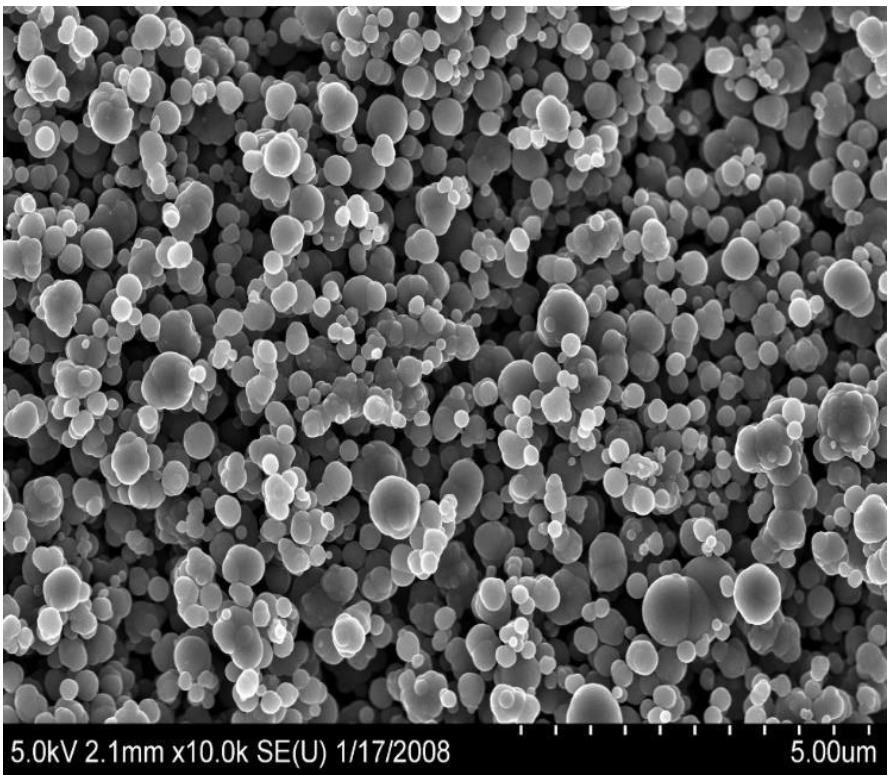

Figure 1. SEM image of N990 Ultra Pure showing spherical particle shape and approximate particle size.

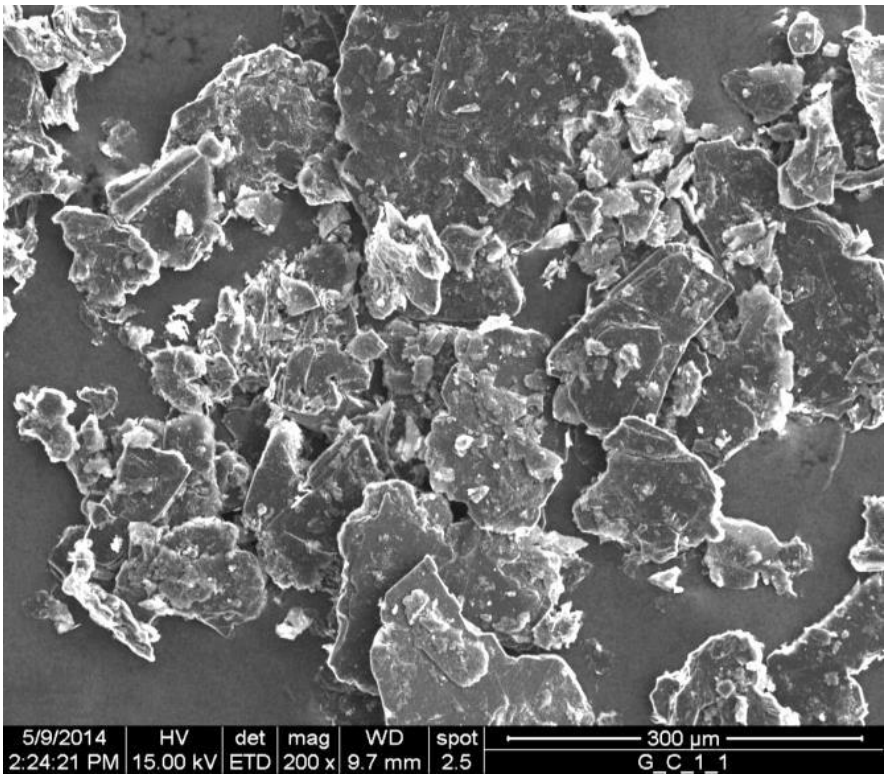

Figure 2. SEM image of graphite demonstrating particle shape

Table 2. Thermax Ultra Pure specifications

Test Description	Units	ASTM Reference	Thermax N990 Ultra Pure
Sieve Residue		D1514	
325 Mesh, max.	% (ppm)		0.0015 (15)
Magnetics on 325 Mesh, max.	% (ppm)		0.0005 (5)
Ash Content, max.	%	D1506	0.02
Nitrogen Surface Area	m^2/g	D6556	7.0-12.0
Heat Loss, max.	%	D1509	0.1
Total Sulfur, max.	% (ppm)		0.006 (60)
Fines Content, as shipped, max.	%	D1508	8.0
Pellet Hardness, 14 x 18 mesh		D5230	
Average, max.			30
High, average of 3 highest, max.			50