INDUSTRIAL DIAMONDS

By a Special Contributor

Diamond, pure carbon, is the hardest naturally-occurring mineral and this, together with the high refractive index that gives diamond its remarkable brilliance, has meant that diamond is unsurpassed as a gem. However, in addition to hardness and high refractive index, diamond has a number of other physical properties, including the highest thermal conductivity of any mineral, and high electrical resistivity. Hence, in addition to its gem qualities, diamond has a number of important industrial applications. It is used principally as an abrasive and although there are a number of cheaper, competing materials, diamond has proved to be superior in many applications because it cuts faster and lasts longer.

Diamonds vary from colourless to black and can be transparent, translucent or opaque. Most industrial stones are translucent or opaque, gray or brown in colour, and are normally too small, flawed and irregular in shape to be of value as gems. All natural industrial diamonds are produced as a by-product of mining for gem diamonds. They are broadly of three varieties. Ballas comprises masses of minute diamond crystals difficult to cleave. Bort is typically gray to black and massive, but the name is also applied to badly flawed, irregularly-shaped diamonds. 'Drilling bort', small rounded stones averaging 20 to the carat, are used in diamond drill bits, or crushed into abrasive grits for use in grinding wheels, or suspended in oil or water for lapping and polishing. Carbonado, a black, opaque variety of diamond with no cleavage, is suitable for use in diamond-set tools.

Less than 10% of all industrial diamonds used are natural stones, and the vast majority are produced synthetically by subjecting graphite to very high temperatures and pressures. In 1955, the US firm, General Electric Co. of Schenectady, NY, was the first company to announce the successful manufacture of synthetic diamonds. Its laboratory subjected graphite to pressures approaching 7 gigapascals and temperatures greater than 1,700°C in the presence of a metal catalyst.

Modern methods of manufacture are much the same. The graphite and catalyst (typically nickel) are subjected to extreme temperature and pressure for about one hour, with diamonds nucleating at many sites in the mixture which is then cooled and reduced to atmospheric pressure. The diamond crystals are then separated using an acid wash and graded according to size, shape and impurities. Larger diamonds are used for saws and the smaller diamonds in grinding wheels. They can also be put on a carbide substrate to produce polycrystalline diamond compacts, much used for oil-well drills. Apart from its abrasive and cutting qualities, diamond's high thermal conductivity and high electrical resistance makes it highly suited as a substrate for semiconductors, an application that is growing. The larger synthetics also have an application in bearings because diamond has very low friction.

The ability to control their quality and to customise their properties to meet specific requirements gives synthetic diamonds an advantage over natural stones. (The process is expensive, however, and large stones of gem quality are not, as yet, manufactured in any significant quantity). The industrial diamond group, Elwood® Corp. of Wisconsin, estimates that prices for synthetic diamonds range between US$0.10 and US$4.00/ct, and that the annual world market is worth around US$1,000 million.

The US is the world's largest market for industrial diamonds, and according to the United States Geological Survey (USGS) the most important industry sectors for industrial

diamond consumption last year were computer chip production, construction, machinery manufacturing, mining services (drilling), stone cutting/polishing and transport infrastructure.

The USGS estimates that world consumption of industrial diamonds last year was approximately 1,150 Mct and that mine production amounted to some 56 Mct, little changed from the preceding year. The main producers were Australia (15 Mct), Democratic Republic of Congo (14.2 Mct), Russia (11.7 Mct), South Africa (6.5 Mct) and Botswana (5 Mct). Increased demand for industrial diamonds is expected for at least the next five years but the USGS says that the increase is likely to be higher for synthetic diamonds than for natural diamonds. In the US, the most dramatic increase in usage of industrials diamond is likely to occur in the construction sector; the country is mid-way through a US$200 billion transport infrastructure programme and diamond saws are vital for cutting cement in highways construction and repair.

Last year, the US imported 299 Mct of synthetic diamonds and manufactured 408 Mct. Apparent consumption was 626 Mct. There was no US production of natural industrial diamonds but imports amounted to some 1.7 Mct and apparent consumption is estimated at 1.2 Mct.

Prices for synthetic diamonds have been declining - US imports averaged US$0.44/ct in 1998 but slipped to US$0.42 in 2000 and to US$0.31/ct in 2001 - and the USGS expects the decline to continue because of advances in production technology and the growing number of low-cost producers in China and Russia. Prices for natural industrial diamonds imported into the US show considerable fluctuation from year to year, with an average of US$4.47/ct last year comparing with US$5.31 in 2000, US$4.61 in 1999, US$3.92 in 1998 and US$7.69/ct in 1997.