7 Physical Classification of Diamond

The physical classification of diamond is based on the optical absorption of nitrogen, boron and hydrogen-related defects and paramagnetic absorption of single substitutional nitrogen. The first classification of diamonds into types I and II based on the peculiarities of their optical absorption was given by Robertson et al. (1934). The first definite classification of the modern type was given by Dyer et al. (1965a).

A different classification of diamonds based on their physical properties, morphology and mineralogy is given by Orlov (1973); Kurdumov et al. (1994); and Beskrovanov (1985).

7.1 Type I

Type I comprises diamonds in which impurity-related optical and paramagnetic absorption are dominated by nitrogen defects. Historically type I diamonds were those which were transparent to 300 nm (Robertson et al. 1934). In general, the impurity content of natural type I diamonds is more varied compared to that of type II diamonds (Bienemann-Kuespert et al. 1967). The most evident difference between type I and II diamonds comes from IR absorption spectra, which are considered to be the main criteria for this differentiation (Robertson et al. 1934).

About 98% of natural diamonds contain nitrogen with concentrations detectable in optical absorption (Field 1992). 74% of them have a nitrogen content high enough to be definitely classified as type I (Bienemann-Kuespert et al. 1967). Nitrogen is regularly present in natural diamonds at levels as high as 200 to 4000 ppm (Kaiser and Bond 1959; Lang 1977; Palyanov et al. 1997a). In extreme type I diamonds the nitrogen concentration attains a value of 0.25 atom% (Kaiser and Bond 1959; Kurdumov et al. 1994). Usually nitrogen in type I natural diamonds is not distributed uniformly. It forms areas of increased concentration, or may even gather in clusters of about 10 atoms (Berman et al. 1975).

7.1.1 Type Ia

Type Ia comprises type I diamonds, which do not show absorption due to single substitutional nitrogen atoms. Nitrogen impurities are present in type Ia diamonds as nonparamagnetic aggregates. The typical nitrogen concentration in natural type Ia diamonds is about 500 ppm (Field 1992). In high-nitrogen type Ia diamonds the
nitrogen concentration may be as high as 3000 ppm (Nazare and Neves 2001). To be of pure type Ia diamond should contain single substitutional nitrogen atoms in concentrations below $10^{16}$ cm$^{-3}$ (Brozel et al. 1978).

**Type IaA (type Ia in some publications)** comprises type Ia diamonds containing predominantly the A-aggregates of nitrogen. The discovery of the A, B and B' defects in infrared absorption was reported for the first time by Sutherland et al. (1954). Typically type IaA natural diamonds contain 500 ppm of nitrogen in the form of A-aggregates and 0.01 to 0.1 ppm of dispersed nitrogen atoms (Field 1992; Evans and Qi 1982b). Characteristic optical features of type IaA diamonds are the UV absorption continuum at wavelengths below 330 nm and the IR absorption peaks at wavelengths of 7.8, 8.3, 9.1 and 20.8 μm. The H3 center is commonly observed in type IaA diamonds (Kurdumov et al. 1994; Plotnikova 1990). Most gem-quality natural diamonds contain nitrogen predominantly in the form of A-aggregates and are classified as type IaA (Davies 1977c) (Fig. 3.22).

**Type IaB (type III or intermediate type in some publications)** comprises type Ia diamonds containing nitrogen predominantly in the form of B-aggregates (Clark et al. 1956a; Clark et al. 1956c). Very small amounts of type Ia diamonds are of true type IaB (Field 1992). Characteristic optical features of type IaB diamonds are the IR absorption peaks at 7.5, 8.5, 9.1 and 12.8 μm and UV optical centers N9 and N10. The absorption coefficient of the B-aggregates of nitrogen in type IaB diamonds attains a value of 30 cm$^{-1}$ (Kluev et al. 1982). The H4 and S2 centers are commonly observed in type IaB diamonds (Kurdumov et al. 1994; Plotnikova 1990; Ilyin et al. 1970). Type III is characterized by an additional criterion: the nitrogen concentration in type III diamonds should not exceed $10^{19}$ cm$^{-3}$ (Kluev et al. 1972a) (Fig. 3.27).

**Type IaB'** comprises diamonds containing B'-defects (platelets). The concentration the B'-defects in type IaB' diamonds may attain a value up to $10^{15}$ cm$^{-3}$ (Kluev et al. 1982). Characteristic optical features of type IaB' diamonds are the absorption continuum at wavelengths below 330 nm, the peaks at 0.267, 0.283, 7.3, 7.5, 7.8, 8.5 and 9.1 μm as well as the N3 center (Kurdumov et al. 1994; Plotnikova 1990). The B'-defects are a notable feature in most natural type Ia diamonds (Lang 1977).

**Type IaB' regular** comprises diamonds with a relatively high content of B'-defects, the absorption intensity of which correlates well with that of the B-aggregates of nitrogen (Collins 1997).

**Type IaB' irregular** comprises diamonds with a low content of B'-aggregates, the absorption intensity of which is considerably weaker relative to the absorption of the B-aggregates of nitrogen (Collins 1997).

**Type IaB without B'** has been proposed as a separate type for those type IaB diamonds which contain no platelets (Beckman et al. 1994; Woods et al. 1993b).

### 7.1.2 Type Ib

Type Ib comprises type I diamonds, which contain paramagnetic single substitutional nitrogen atoms as the dominating defects. Type Ib diamonds were