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Nitride, carbonitride and nitrocarbide inclusions in lower-mantle diamonds: A key to the balance of nitrogen in the Earth

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A few years ago a series of iron carbides Fe3C, Fe2C, Fe7C3 and Fe23C6 (haxonite) containing up to 7.3-9.1 at.% N (N/(N+C) = 0.19-0.27) was identified as inclusions in diamonds from the Juina area, Brazil in association with native iron and graphite (Kaminsky and Wirth, 2011). Subsequently nitrocarbides and carbonitrides Fe3(C,N) and Fe9(C,N)4 (nitroyarlongite) containing 12.8-18.42 at.% N (N/(N+C) = 0.37-0.60) were identified in a lower-mantle microxenolith in association with ferropericlase and two post-spinel oxides Mg-Cr-Fe-O (CT phase; Mg-xieite) and Ca-Cr-O (new mineral) with an orthorhombic structure (Kaminsky et al., 2015).
Recently pure nitrides Fe3N with a trigonal structure P312 and Fe2N with an orthorhombic structure Pbcn were identified among mineral inclusions from diamonds in the same area. They have admixtures of Cr (0.68-1.8 at.%), Ni (0.35-0.93 at.%) and Mn (0-1.22 at.%). Fe2N contains also an admixture of 5.1-7.6 at.% Si. The nitrides associate with nitroyarlongite Fe9(N0.8C0.2)4 and iron carbide Fe7C3, which contain nanocrystals of moissanite, hexagonal 6H polytype of SiC. Fe7C3 crystallizes, in the Fe-C system, the first in association with diamond at pressures starting from 130 GPa, i.e. within the lowermost mantle, the D[U+02BA] layer. Native iron and a series of nitride-carbonitride-nitrocarbide-carbides associated with Fe7C3 form as a result of infiltration of the Fe-Ni melt from the outer core into the lowermost mantle. This melt contains up to 10 % light elements, such as C, N, O and Si, which may be the source of nitrides-carbides.
The existence of nitrides in the lower mantle helps to solve the problem of ‘missing nitrogen’ in the Earth’s nitrogen balance and consider the Earth’s core as the major reservoir of nitrogen. According to calculations, the total amount of nitrogen in the Earth’s core is 9,705 $\times$ 1021 grams, and in the mantle $\sim$500 $\times$ 1021 grams (95 % and 4.5 % of the total amount of nitrogen respectively). In such a case the average concentration of nitrogen in the Earth is $\sim$1,710 ppm, which is similar to the concentration of nitrogen in chondrites.

References

1. Kaminsky, F. V., Wirth, R. (2011) Iron carbide inclusions in lower-mantle diamond from Juina, Brazil. Canadian Mineralogist 49(2), 555-572.
2. Kaminsky, F. V., Wirth, R., Schreiber, A. (2015) A microinclusion of lower-mantle rock and some other lower-mantle inclusions in diamond. Canadian Mineralogist 53(1), 83-104.