Diamond & Related Materials 20 (2011) 1095–1102

Contents lists available at ScienceDirect

Diamond & Related Materials

journal homepage: www.elsevier.com/locate/diamond

Optically stimulated luminescence (OSL) and laser excited photo luminescence of electron beam treated (EBT) diamonds: Radiation sensitization and potential for tissue equivalent dosimetry

Medury D. Sastry [a,*], Mahesh P. Gaonkar [a], Yogesh C. Nagar [b,1], Sandesh N. Mane [a], Shripal N. Desai [a], H. Bagla [c], K.T. Ramachandran [a], Ashok K. Singhvi [b]

[a] Gemmological Institute of India, 304 Sukhsagar Building, N.S.Patkar Marg, Opera House, Mumbai 400 007, India
[b] Physical Research Laboratory, Navrangpura, Ahmedabad 380 009, India
[c] Department of Chemistry, K.C. College, Churchgate Mumbai 400 020, India

ARTICLE INFO

Article history:
Received 7 May 2010
Received in revised form 29 March 2011
Accepted 14 June 2011
Available online 29 June 2011

Keywords:
Diamond
BLSL
IRSL
TL
Radiation dosimetry

ABSTRACT

We report the first optically stimulated luminescence (OSL; blue light stimulated luminescence (BLSL) and infrared light stimulated luminescence (IRSL)) results on colored diamonds and present experimental evidence that electron beam treatment (EBT) increases the radiation sensitivity of diamonds to a level that makes them suitable for low level radiation dosimetry. A suite of seven samples was examined. These comprise a white, three brown and three yellow diamond pieces. The FT-IR spectra of these diamonds revealed the nature and concentration of nitrogen impurity. The white diamond was kept as a control. The brown and yellow (with varied saturation) diamonds were irradiated by a 1.7 MeV electron beam. These turned blue/dark green; three of them were then heated in vacuum in the temperature range of 850–900 °C for two hours. Heating turned the irradiated diamonds to lemon yellow, pink, and purple colors. The irradiated and unheated blue samples were designated as 2C and 2D.

The control sample, an un-irradiated white type Ia diamond, did not yield any significant IRSL/BLSL with doses up to 100 Gy. The BLSL/IRSL sensitivity of irradiated and heat treated diamonds was very poor, and depended on the heat cycle and hence were not pursued. Sample 2C exhibited significant BLSL and negligible IRSL sensitivity. Sample 2D gave an intense orange red emission under IR excitation as also responded to BLSL. The dose response of the BLSL signal in 2C suggested a minimum detectable dose of ~0.1 Gy and its use as a tissue equivalent dosimeter.

Based on supporting experiments such as laser excited photoluminescence, we suggest that the BLSL process in 2C is primarily driven by carbon vacancies, which release a mobile hole when excited by GR2 band in the blue region. BLSL intensity exhibited a maximum around 285 °C. Given that TL glow peak also occurs near this temperature and that the nitrogen–interstitial carbon (N–Ci) complex also forms at this temperature (as reported in the literature), and it appears that the e–h recombination at sites with N–Ci complex could be involved in BLSL production. Laser excited photoluminescence (PL) at wavelengths 325, 514 and 785 nm and absorption spectra in UV–Visible range gave insights into the contrasting BLSL/IRSL responses of 2C and 2D. These differences were due to differences in nitrogen impurity complexes and the concentration of carbon vacancies produced by EBT in 2C and 2D. In 2D, the presence of Ni as NE8 center (four nitrogens coordinated to Ni) giving 800 nm emission on 785 nm excitation, appeared to suppress BLSL and sensitize IRSL in the orange window.

1. Introduction

Diamond is a covalent crystal with a band gap of 5.47 eV at 300 °K. In its purest form (type IIa), diamond is colorless. Nitrogen is the most common impurity in diamonds and its concentration can be up to few hundreds ppm. In natural type Ia diamonds, the nitrogen impurity exists as a cluster of two nitrogen atoms occupying two adjacent carbon sites (A-cluster) and/or four nitrogen atoms in the neighboring sites associated with a carbon vacancy (B-cluster) and neither of these imparts any color to diamonds. However, isolated nitrogen atoms at substitution sites give yellow color to diamonds. Existence of a single nitrogen at substitution position is common for high pressure–high temperature (HPHT) treated natural diamonds and synthetic diamonds [1,2].

* Corresponding author.
E-mail address: mdsastry@yahoo.co.in (M.D. Sastry).
[1] Present address: Snow and Avalanche Study Establishment, Manali, 175103, India.

0925-9635/$ – see front matter © 2011 Elsevier B.V. All rights reserved.
doi:10.1016/j.diamond.2011.06.012