APPLICATION OF JADE SAMPLES FOR HIGH-DOSE DOSIMETRY USING THE EPR TECHNIQUE

Maria Inês Teixeira[a], Adeilson P. Melo[a,b], Gilberto M.Ferraz[c] , Linda V.E.Caldas[a,*]

[a] Instituto de Pesquisas Energéticas e Nucleares/ Comissão Nacional de Energia Nuclear
Av. Prof. Lineu Prestes 2242, 05508-000, São Paulo, Brazil
[b] Centro Federal de Educação Tecnológica de Sergipe, Aracaju, Brazil
[c] Instituto de Física, Universidade de São Paulo, SP, Brazil

Running Title: Jade Samples for High Doses

PACS:
Key-words: Jade; EPR; Gamma dosimetry; High doses

* Corresponding author: Tel./fax: 55-11-3133-9716 (LindaV.E. Caldas)
E-mail addresses: miteixei@ipen.br (M.I.Teixeira), lcaldas@ipen.br (L.V.E. Caldas), gmarconf@if.usp.br (G.M.Ferraz), adeilson_pessoa_melo@yahoo.com.br (A.P. Melo)

APPLICATION OF JADE SAMPLES FOR HIGH-DOSE DOSIMETRY USING THE EPR TECHNIQUE

Maria Inês Teixeira[a], Adeilson P. Melo[a,b], Gilberto M.Ferraz[c] , Linda V.E.Caldas[a,*]

[a] Instituto de Pesquisas Energéticas e Nucleares/ Comissão Nacional de Energia Nuclear
Av. Prof. Lineu Prestes 2242, 05508-000, São Paulo, Brazil
[b] Centro Federal de Educação Tecnológica de Sergipe, Aracaju, Brazil
[c] Instituto de Física, Universidade São Paulo, SP, Brazil

Abstract

The dosimeter characteristics of jade samples were studied for application in high-dose dosimetry. Jade is the common denomination of two silicates: jadeite, and actinolite. The EPR spectra of different jade samples were obtained after irradiation with absorbed doses of 100Gy up to 20kGy. The jade samples present signals that increase with the absorbed dose (g-factors around 2.00); they can be attributed to electron centers. The EPR spectra obtained of the USA jade samples and their main dosimetric properties as reproducibility, calibration curves and energy dependence were investigated.

Key-words: Jade; EPR; Gamma dosimetry; High doses

INTRODUCTION

Jade is the common denomination of two silicates: jadeite [$NaAl(Si_2O_6)$] and actinolite [$Ca_2(Mg,Fe)_5(Si_4O_{11})_2(OH)_2$], which belong respectively to the subclasses of pyroxenes and amphiboles (Zhao et al, 1994). Green materials were acquired as jade with origin in New Zealand, Austria and USA.

The dosimetric properties of these materials were already studied using the thermoluminescence technique, showing their potential use for high-dose dosimetry (Melo et al, 2003). At the Metrology Laboratory of IPEN, São Paulo, glasses, sand and Brazilian natural stones have been studied in relation to their dosimetric properties for high-doses using different techniques (Caldas and Teixeira, 2002; Quezada and Caldas, 1999; Rocha et al, 2002; Souza et al, 2002; Teixeira et al, 2005). EPR properties received a great attention in literature; Ikeya (1993) identified the main paramagnetic defects in silicates.

In the present work jade samples were studied using the electronic paramagnetic resonance (EPR) technique to investigate the potential applications in gamma radiation dosimetry. There is no evidence in the literature about jade applications in radiation dosimetry using the EPR technique; only crystallographic aspects of synthetic samples were compared to natural ones (Deer et al, 1966).

MATERIALS AND METHODS

Jade samples originating from New Zealand (NZL), Austria (AUS) and United States of America (USA) were studied. All samples were initially cleaned, pulverized, and grain diameters between 0.074 and 0.177 mm were obtained. The samples were thermally treated at 300ºC during one hour in open atmosphere, defined for their

reutilization. The irradiation of the samples were performed using a Gamma-Cell 220 system (^{60}Co, dose rate of 3.28 kGy/h) of the Center for Radiation Technology, IPEN. The electronic paramagnetic resonance (EPR) measurements were carried out using a Bruker EMX spectrometer with a rectangular cavity (ER4102 SY), at room temperature, microwave frequency of 100 kHz and field modulation amplitude of 0.1T, and using an average sample mass of (150 ± 1)mg. This EPR spectrometer belongs to the Multi-user Group of the Institute of Physics, University of São Paulo.

RESULTS

The EPR spectra of different jade samples were obtained after irradiation with absorbed doses of 100 Gy up to 20 kGy.

Figure 1 shows the EPR spectra of the jade samples in the form of powder, treated thermally at 300°C/1h and irradiated with 5kGy of ^{60}Co. The magnetic field was varied from 500 Gauss to 6500 Gauss to obtain the whole spectra of the EPR samples, and to identify the EPR characteristic peaks of each sample (Figures 2a, 3a, 4a). These measurements were taken with a standard Mn^{2+} sample, which has six well-defined EPR peaks (Ikeya, 1993).

The EPR spectrum of each sample was obtained varying the magnetic field from 3000 Gauss to 4000 Gauss (Figures 2b, 3b, 4b), to identify the characteristic g-factor, shown in Figures 2c, 3c and 4c. The EPR spectra of jade samples AUS and NZL are similar. The difference lies in the values of the g-factor or magnetic field (Gauss). The difference between the signal intensities of the two EPR peaks is very discreet.

Moreover, the EPR spectrum of the USA jade sample presents a more complex signal than of the other two samples (AUS and NZL), and its signal is fifty times greater than that of jade AUS. The EPR spectra of all jade samples present a characteristic

signal of the Mn^{2+} ion, which is the sextet observed in the range of values of g-factor between 2.20 and 1.90. This fact can be seen in the EPR spectra presented in Figures 2a, 2b, 3a, 3b, 4a and 4b. The EPR spectrum of USA jade presents a signal that increases with the absorbed dose (g-factors around 2.00), as can be seen in Figure 4c.

The EPR spectra of the NZL and USA jade samples (Figures 3a and 4a) present also a sign whose g-factor is approximately 4.3, which corresponds to the substitucional Fe^{3+} of the Si^{4+} in tetrahedron SiO_4. This tetrahedron is distorted due to the presence of a monovalent cation in its neighborhood, to offset the imbalance caused by the electrostatic difference between the valence of ions Fe^{3+} and Si^{4+} (Marfunin, 1979).

Figures 2 and 3 show the EPR spectra of AUS and NZL jade samples, irradiated to various doses (^{60}Co); they present EPR signals that not vary with the absorbed dose. The USA jade samples showed the characteristic CO^{2-} signals at g = 2.0025 and 2.0009 (Figure 5). In this case, the EPR intensities present an increase with the absorbed dose; they may be attributed to electron centers.

Figure 6 shows the dose-response curves of USA jade samples for g⊥ and g//-factors. In the case of g⊥-factor, a sublinear behavior can be observed between 0.1 kGy and 5kGy, and then the signal decreases until 20kGy. In the case of the g//-factor, the response curve presents a sublinear behavior in the whole tested range of 0.1 kGy to 20kGy.

CONCLUSION

The EPR spectra of the USA jade samples present signals that increase with the absorbed dose (g-factors around 2.00) between 100 Gy and 5 kGy. They can be

attributed to electron centers. The results obtained indicate the possibility of use of these jade samples as radiation detectors for gamma high-doses, using the EPR technique.

ACKNOWLEDGMENTS

The authors thank Dr. Maria Teresa Lamy, Intitute of Physics/USP, for the use of the EPR system, and Conselho Nacional de Desenvolvimento Cientifico e Tecnológico (CNPq), Fundação de Apoio à Pesquisa do Estado de São Paulo (FAPESP) and Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES), Brazil, for the partial financial support.

REFERENCES

Caldas, L.V.E., Teixeira, M.I., 2002. Commercial glass for high doses using different dosimetric techniques. Radiat. Prot. Dosim. 101 (1-4), 149-152.

Deer, W. A., Howie, R. A., Zussman, J., 1966. An Introduction to the Rock Forming Minerals, Longman.

Ikeya, M., 1993. New applications of electron spin resonance – dating, dosimetry and microscopy. World Scientific: Singapore, 1st ed.

Marfunin, A.S., 1979. Spectroscopy luminescence and radiation centers in minerals. Springer Verlag: Berlin, ISBN 3-540-09070-3.

Melo, A.P., Valerio, M.E.G., Caldas, L.V. E., 2004. Thermoluminescent characteristics of mineral samples acquired as jade. Nucl. Inst. Meth. B(218), 198-201.

Quezada, V.A.C., Caldas, L.V.E., 1999. Glass detectors for dose determination in a flower irradiation process. Radiat. Prot. Dosim. 85 (1-4), 473-475.

Rocha, F.D.G., Cecatti, S.G.P., Caldas, L.V.E., 2002. Dosimetric characterization of Brazilian natural stones using the thermally stimulated exoelectron emission technique. Radiat. Prot. Dosim., 100 (1-4), 417-420.

Souza, D.N.; Lima, J.F.; Valério, M.E.G. and Caldas, L.V.E., 2002. Performance of pellets and composites of natural colourless topaz as radiation dosemeters. Radiat. Prot. Dosim. 100 (1-4), 413-416.

Teixeira, M.I.; Ferraz, G.M.; Caldas, L.V.E., 2005. Sand for high-dose dosimetry using the EPR technique. Appl. Radiat. Isot., 62, 359-363.

Zhao, Th.; Yan, X.W.; Cui, J., 1994. The physical and chemical properties of synthetic and natural jadeite for jewelry. J.Mater.Sci., 29 (6), 1514-1520.

FIGURE CAPTIONS

Figure 1: EPR spectra of jade samples (AUS, NZL USA) treated at 300°C/1h and irradiated with 5kGy (^{60}Co).

Figure 2: EPR spectra in different intervals of measurement of jade AUS irradiated with different aborbed doses of ^{60}Co.

Figure 3: EPR spectra in different intervals of measurement of jade NZL irradiated with various aborbed doses (^{60}Co).

Figure 4: EPR spectra in different intervals of measurement of jade USA irradiated with different aborbed doses of ^{60}Co.

Figure 5: g-factors for the centre CO^{2-} observed in the USA jade sample: $g\perp$ = 2,0025 e g// = 2,0009.

Figure 6: Dose-response curves of the EPR response of the USA jade sample (^{60}Co); g-factors: 2.0025 and 2.0009.

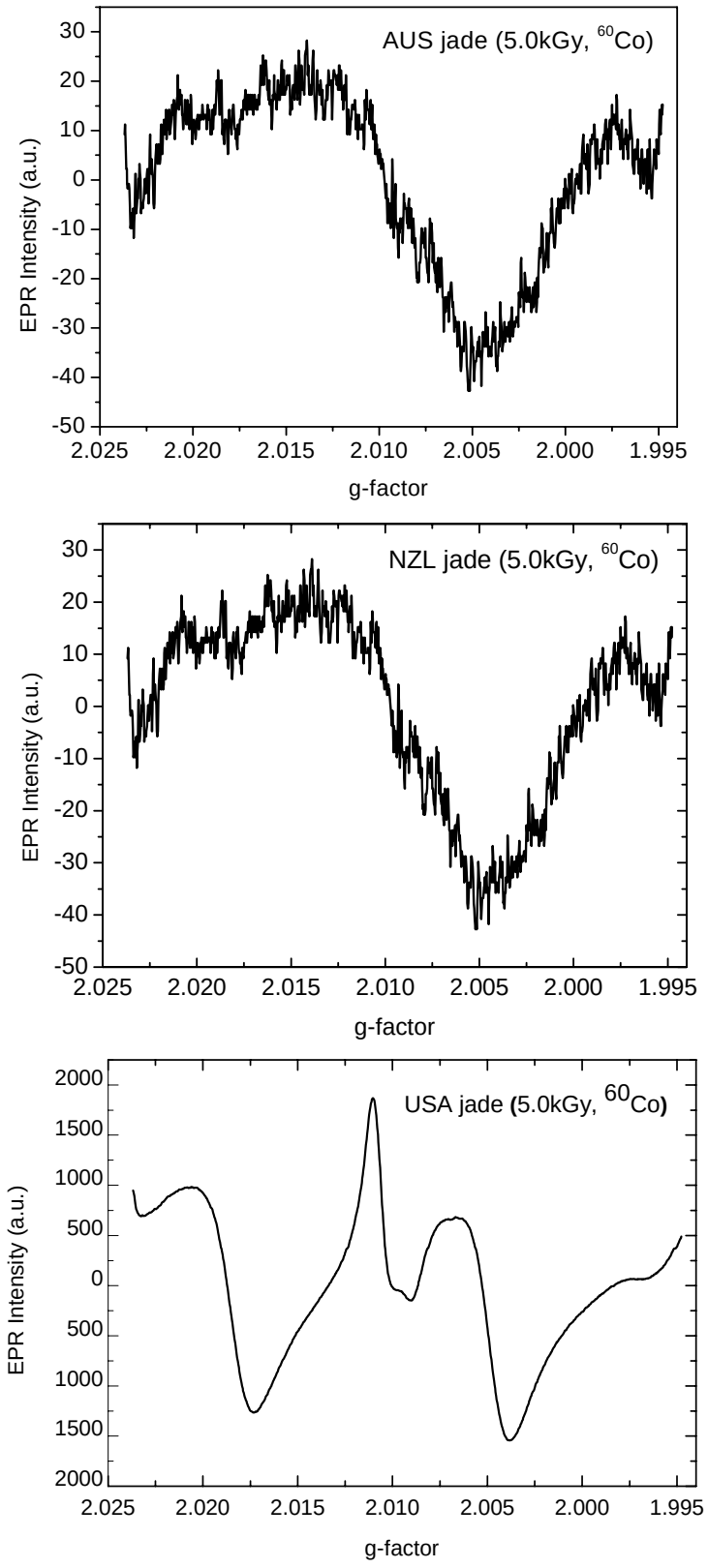

AUS jade (5.0kGy, 60Co)
EPR Intensity (a.u.)
g-factor
NZL jade (5.0kGy, 60Co)
EPR Intensity (a.u.)
g-factor
USA jade (5.0kGy, 60Co)
EPR Intensity (a.u.)
g-factor

Fig. 1

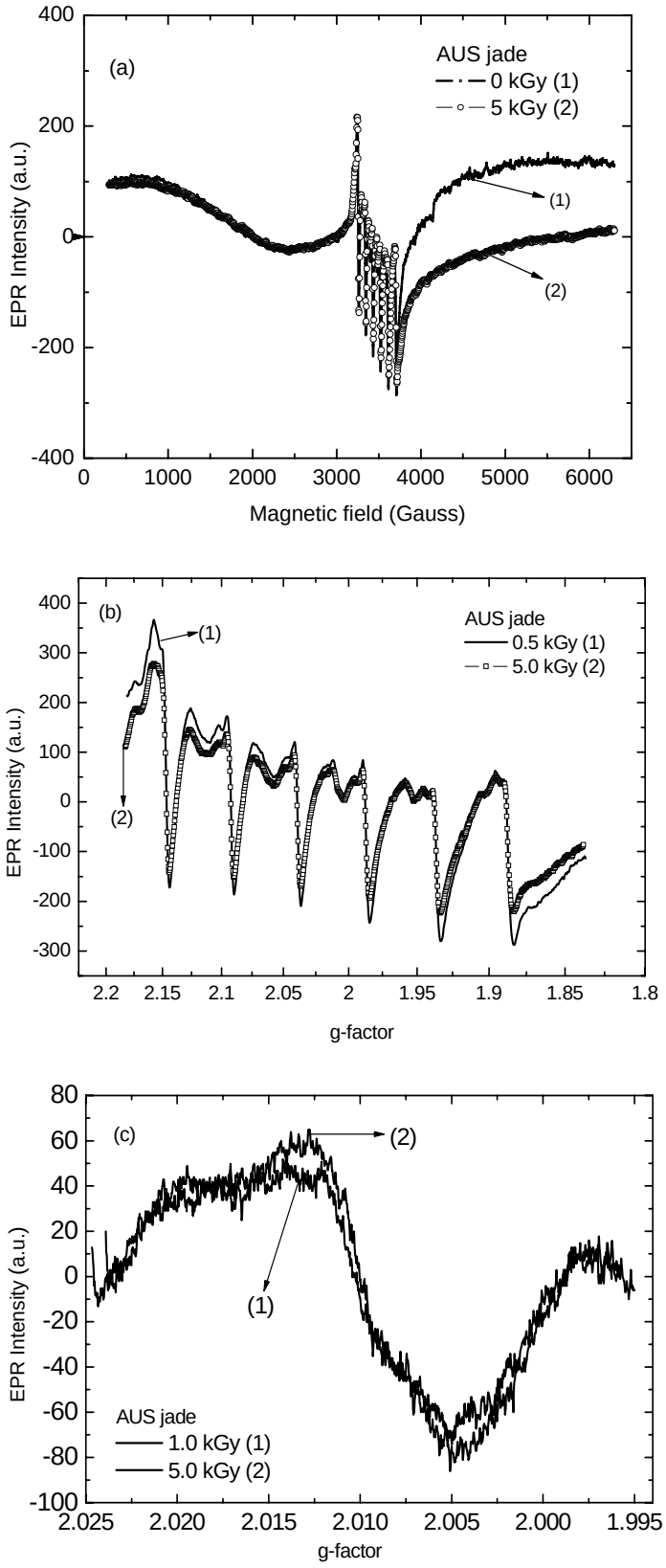
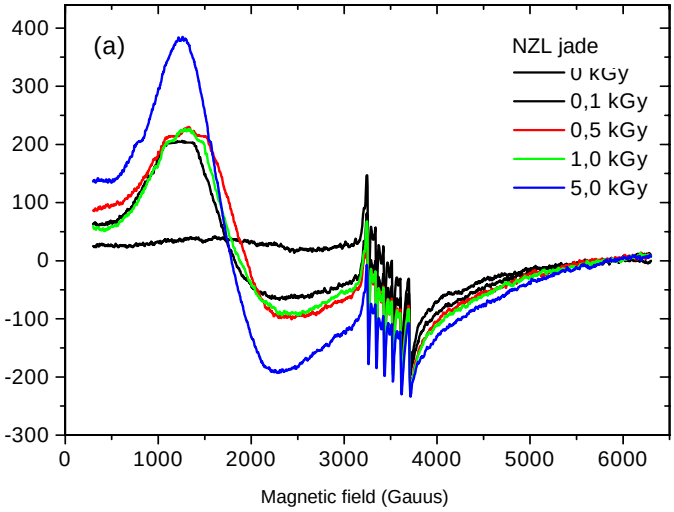
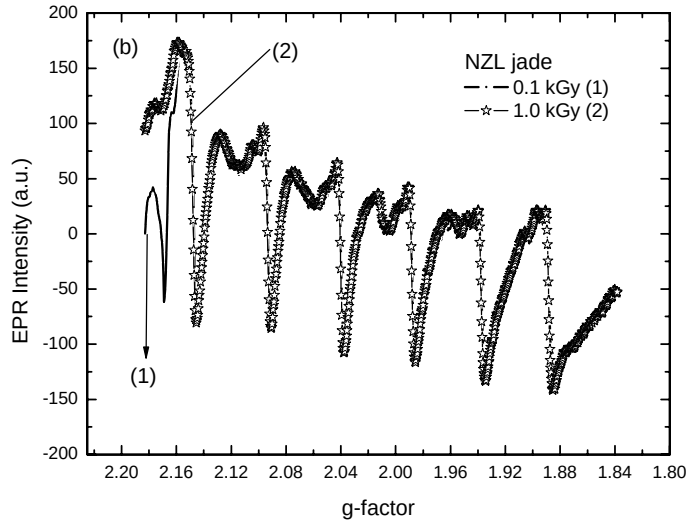

(a)
AUS jade
0 kGy (1)
5 kGy (2)
(1)
(2)
EPR Intensity (a.u.)
Magnetic field (Gauss)
(b)
AUS jade
0.5 kGy (1)
5.0 kGy (2)
(1)
(2)
EPR Intensity (a.u.)
g-factor
(c)
(2)
(1)
AUS jade
1.0 kGy (1)
5.0 kGy (2)
EPR Intensity (a.u.)
g-factor

Fig. 2


(a)
NZL jade
0 kGy
0,1 kGy
0,5 kGy
1,0 kGy
5,0 kGy
Magnetic field (Gauus)


(b)
(1)
(2)
NZL jade
0.1 kGy (1)
1.0 kGy (2)
EPR Intensity (a.u.)
g-factor

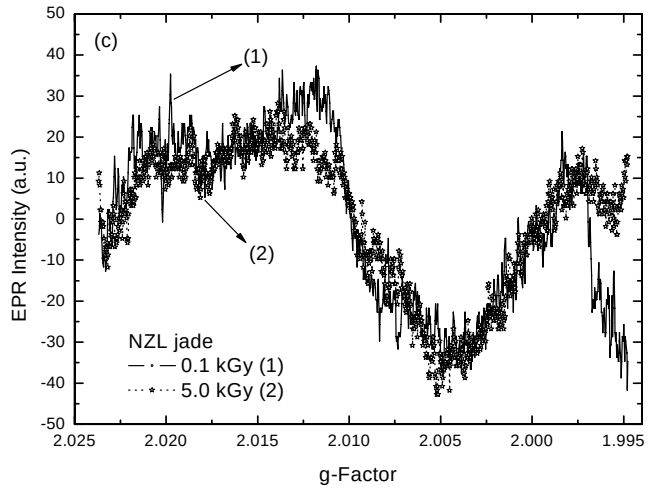
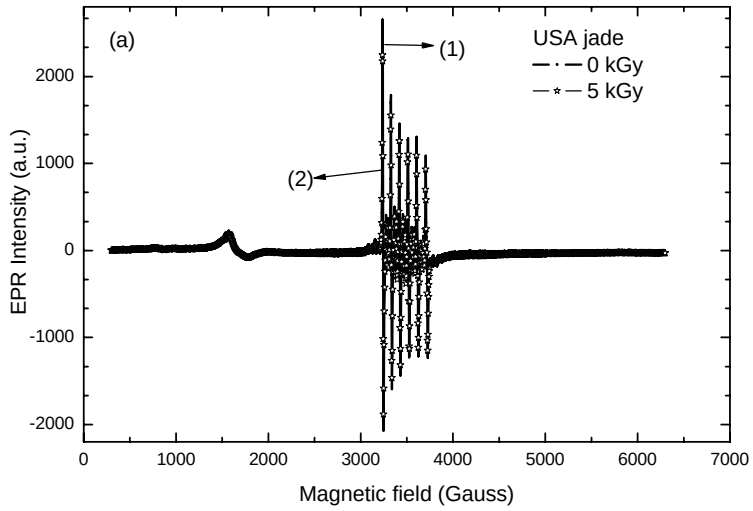
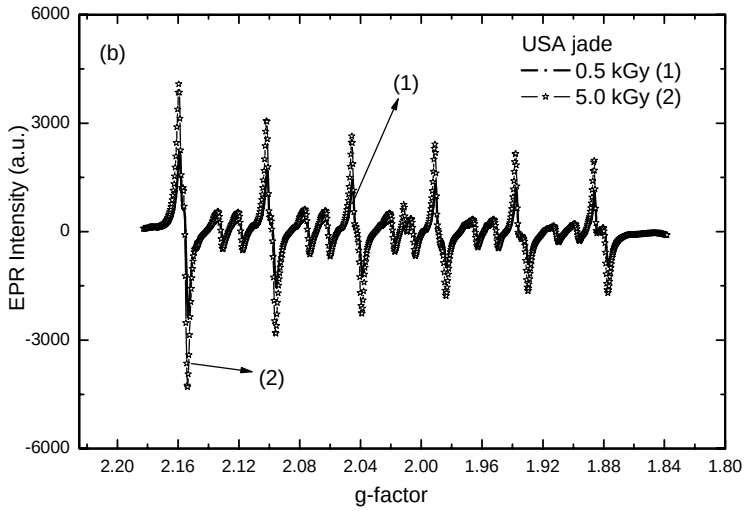

(c)
(1)
(2)
NZL jade
0.1 kGy (1)
5.0 kGy (2)
EPR Intensity (a.u.)
g-Factor

Fig. 3

Fig. 4


(a)
USA jade
0 kGy
5 kGy
(1)
(2)
EPR Intensity (a.u.)
Magnetic field (Gauss)


(b)
USA jade
0.5 kGy (1)
5.0 kGy (2)
(1)
(2)
EPR Intensity (a.u.)
g-factor

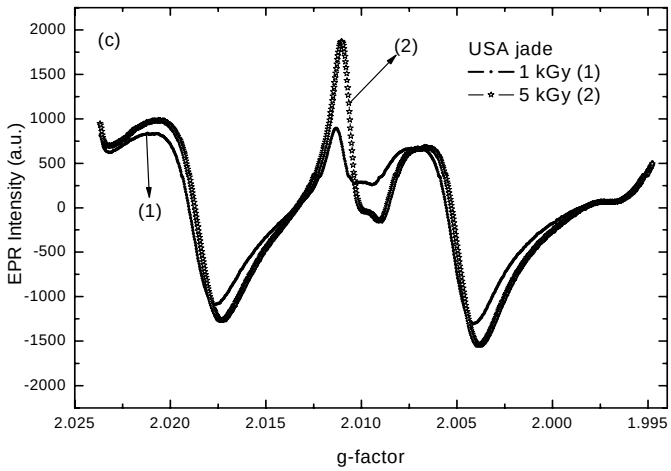

(c)
USA jade
1 kGy (1)
5 kGy (2)
(1)
(2)
EPR Intensity (a.u.)
g-factor

Fig. 4

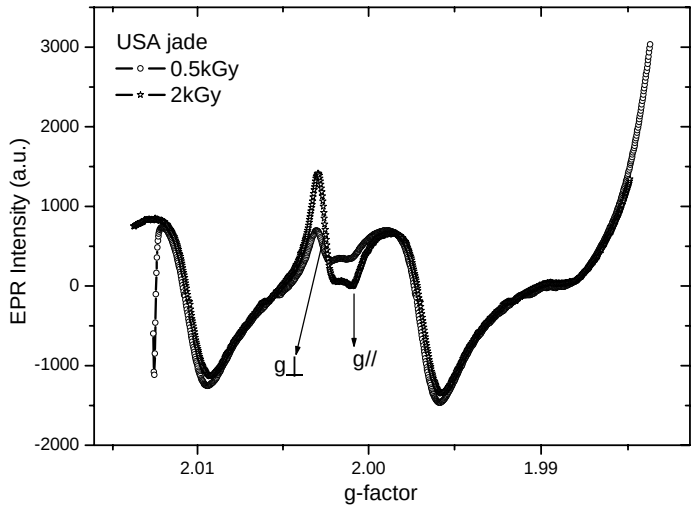
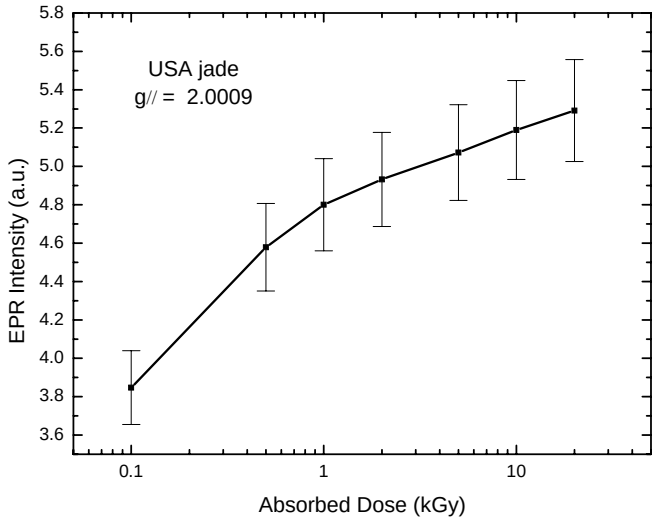

USA jade
0.5kGy
2kGy
EPR Intensity (a.u.)
3000
2000
1000
0
-1000
-2000
2.01
2.00
1.99
g-factor
g⊥
g//

Fig. 5


USA jade
g// = 2.0009
EPR Intensity (a.u.)
Absorbed Dose (kGy)
5.8
5.6
5.4
5.2
5.0
4.8
4.6
4.4
4.2
4.0
3.8
3.6
0.1
1
10

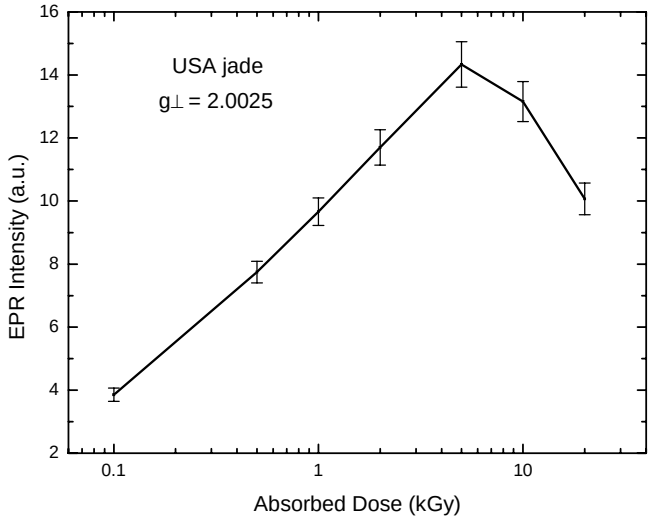

USA jade
g⊥ = 2.0025
EPR Intensity (a.u.)
Absorbed Dose (kGy)
16
14
12
10
8
6
4
2
0.1
1
10

Fig. 6