A new set-up for in-situ probing of irradiation effects in materials and electronic devices

M. Peres[1], F. Rocha[1] , L.C. Alves[1,3], M. Felizardo[1], N. Catarino[1,2], C. Cruz[1,2], E. Alves,[1,2], K. Lorenz[1,2]

[1]Instituto Superior Técnico (IST), Campus Tecnológico e Nuclear, Estrada Nacional 10, P-2695-066 Bobadela LRS, Portugal
[2]IPFN, IST, Portugal
[3]C[2]TN, IST, Portugal
*marcoperes@ctn.ist.utl.pt

Introduction

The micro-probe facility installed at the Van de Graaff accelerator at C²TN/IST permits simultaneous in-situ measurements of:

- **Rutherford Backscattering Spectrometry (RBS),**
- **Particle Induced X-ray Emission (PIXE),**
- **Iono-Luminescence (IL),**
- **Electrical characterization (EC).**

Combinations of all these characterization techniques make this setup a powerful tool to characterize and modify different materials with spatial resolution using proton and α-particle beams up to 2.2 MeV.

RBS

- Composition with lateral and depth resolution,
- Some information on morphology.

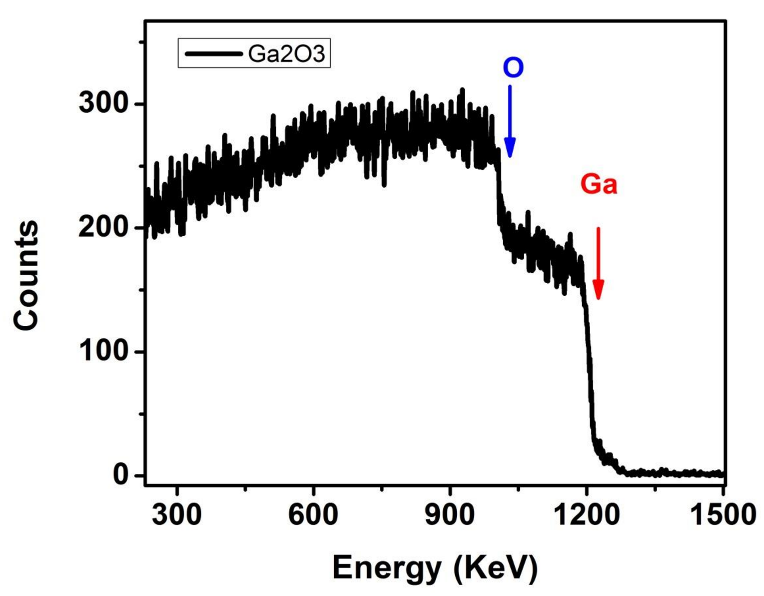

Fig. 1: Typical Ga_2O_3 RBS spectrum obtained with the μ-probe with protons of 2 MeV.

Experimental Setup

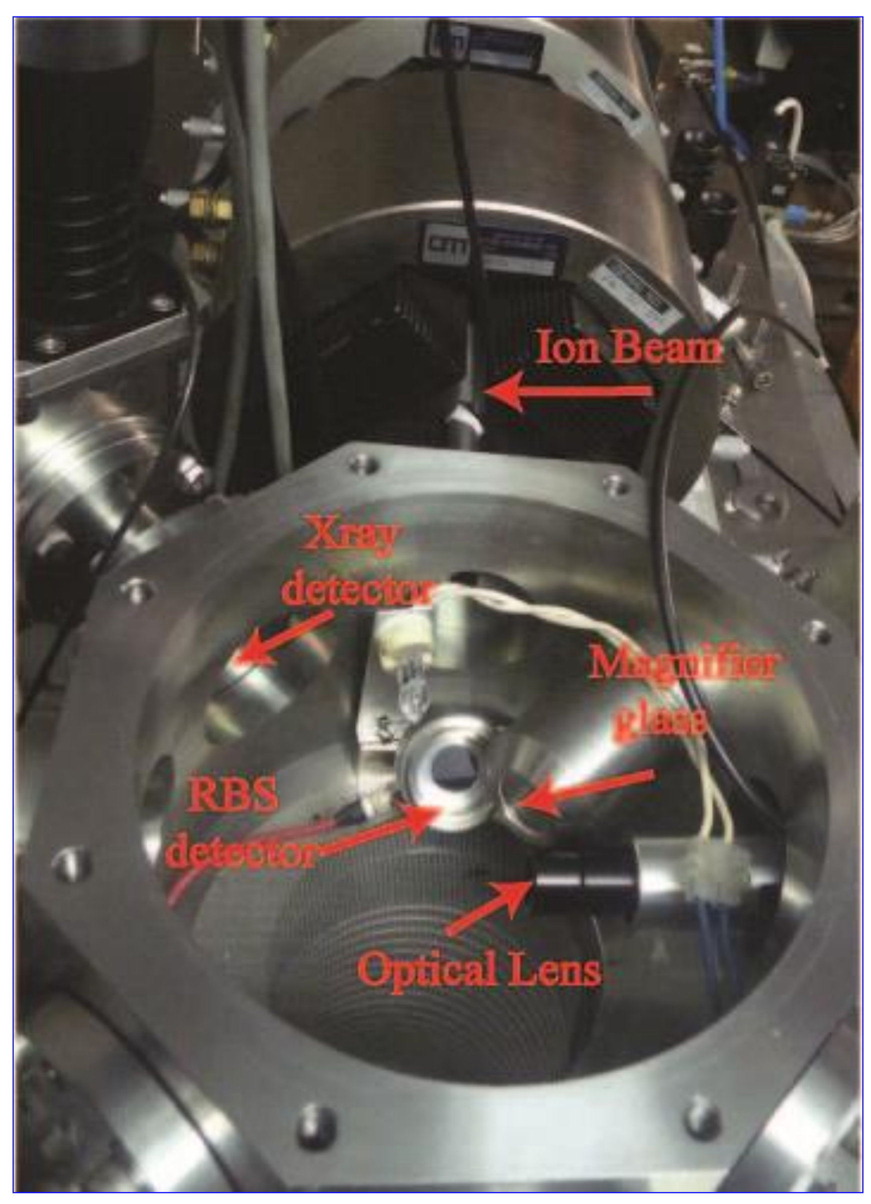

Fig. 5: Chamber where the μ-probe is installed. The different detectors used to perform RBS, PIXE and IL are identified.

PIXE

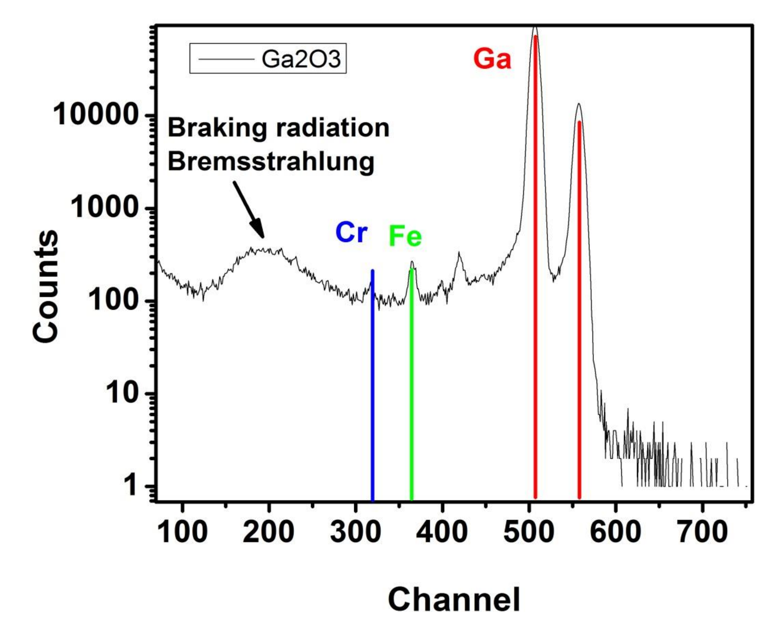

Fig. 2: PIXE spectrum of Ga_2O_3 bulk sample obtained with protons of 2 MeV.

- Composition and trace elements with lateral resolution.

Electrical characterization (EC)

Fig. 4: Set-up with a cryostat that allows to do studies combining IL, RBS, PIXE and EC in a range of temperatures between ~70 K and Room Temperature.

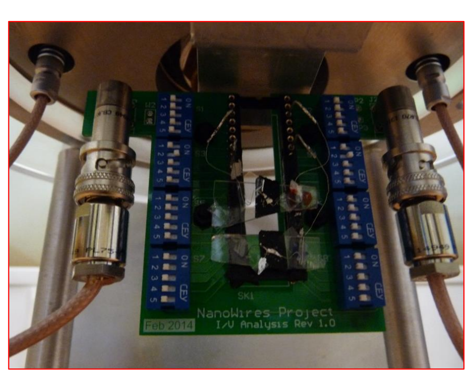

Fig. 3: Sample holder to do electrical characterization between 70K and RT.

- I-V curves and their dependence with the fluence and beam energy can be studied and correlated with the defects created during the irradiation.

Ionoluminescence (IL)

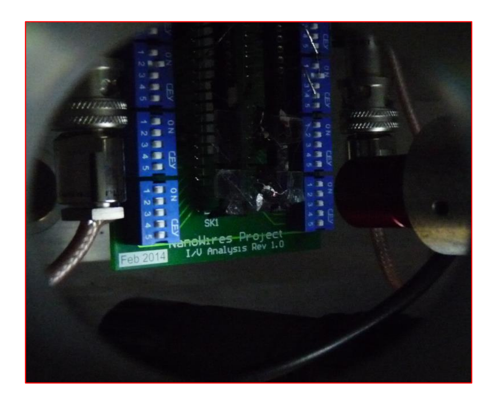

Fig. 6: Sample holder and optical lens used to do IL

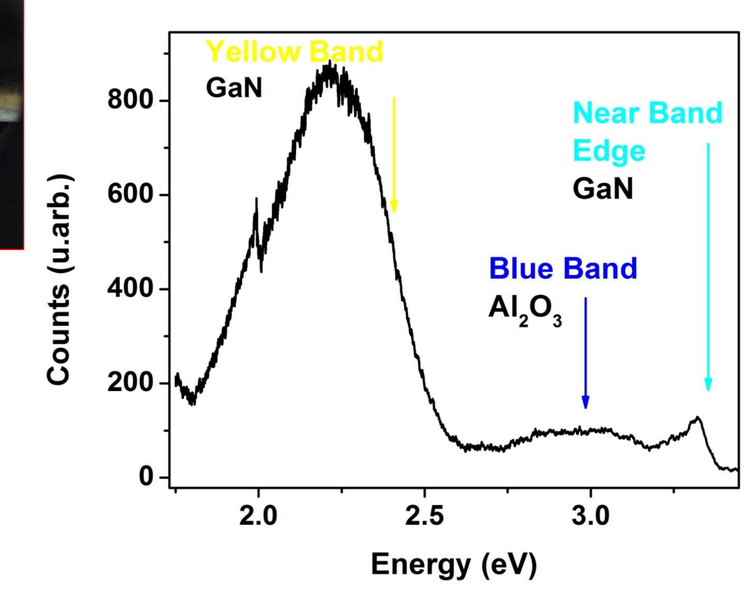

Fig. 7: IL spectrum obtained at RT with a proton beam of 2 MeV in a GaN thin film grown on Al_2O_3.

Case studies

GaN- Irradiation

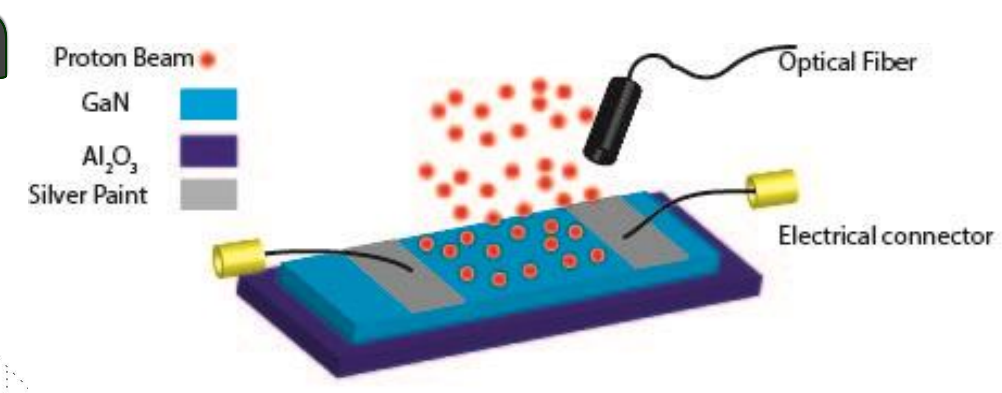

Fig. 8: GaN device schematic representation.

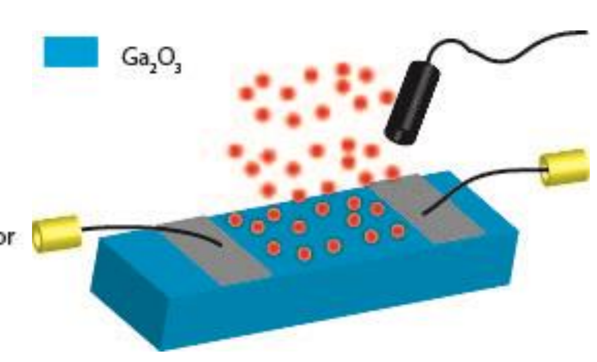

Fig. 9: Ga_2O_3 device schematic representation.

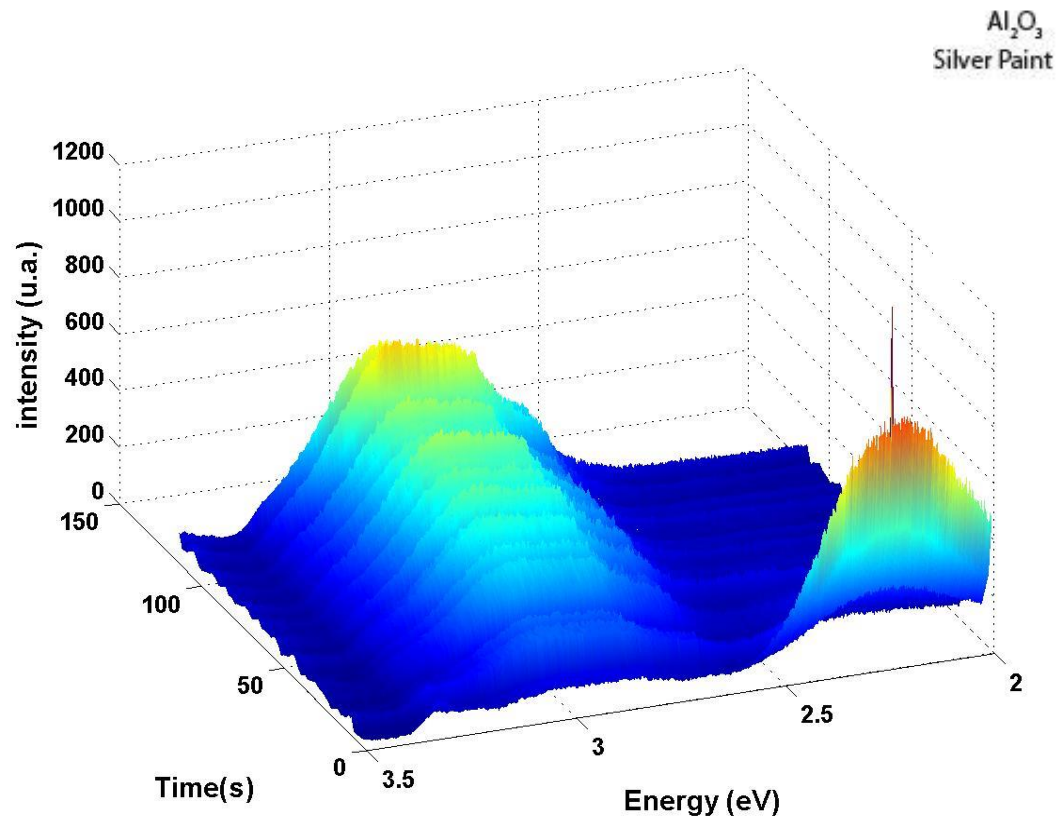

Fig. 10: IL as a function of the irradiation time.

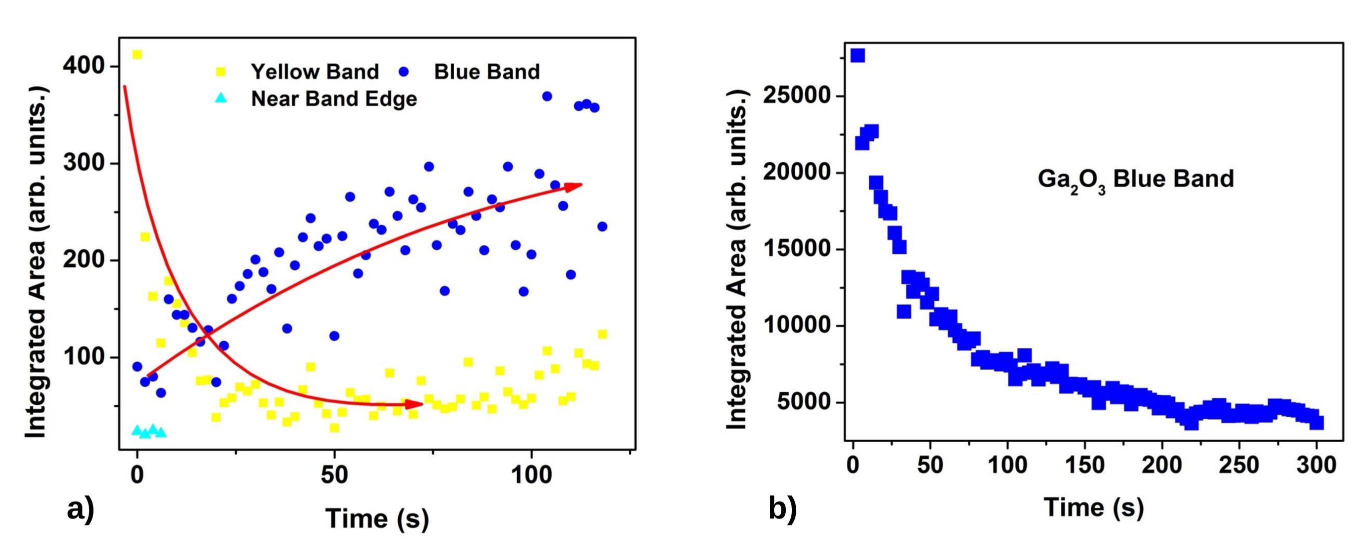

Fig. 11: Integrated area as function of the irradiation time a) GaN b) Ga_2O_3.

Ga_2O_3-Irradiation

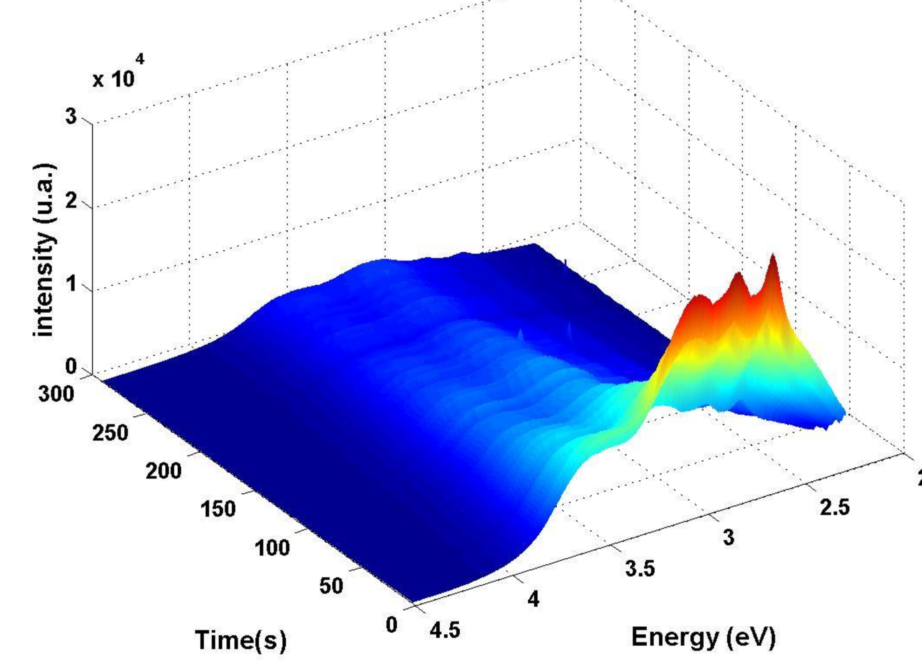

Fig. 12: IL as a function of the irradiation time

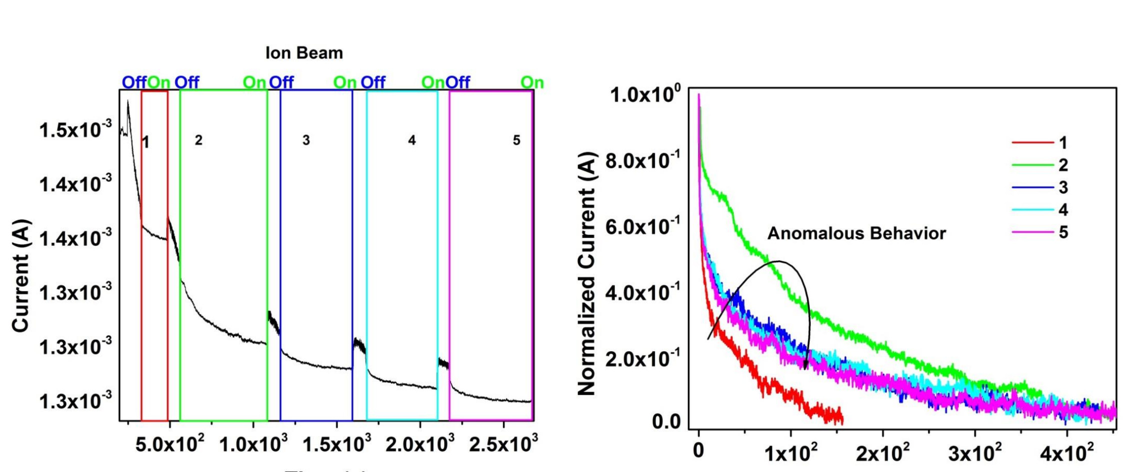

Fig.13: a) Changes of the conductivity measured in real time during the irradiation.
b) Normalized conductivity evolution after stopping (off) the irradiation.

- For both samples, the Persistent Ionoconductivity (PIC) increases with the irradiation time, although for GaN we can see an anomalous behavior.
- The electrical measurements in real-time during the irradiation show a distinct behavior for the GaN thin film and for the bulk Ga_2O_3. These distinct behaviors are associated to the different roles of the defects created during the irradiation in both materials.
- The IL technique shows a clear decrease of the luminescence with the irradiation time. This decrease is considerably faster in the case of the GaN sample. This behavior is associated to different defects created during the irradiation.

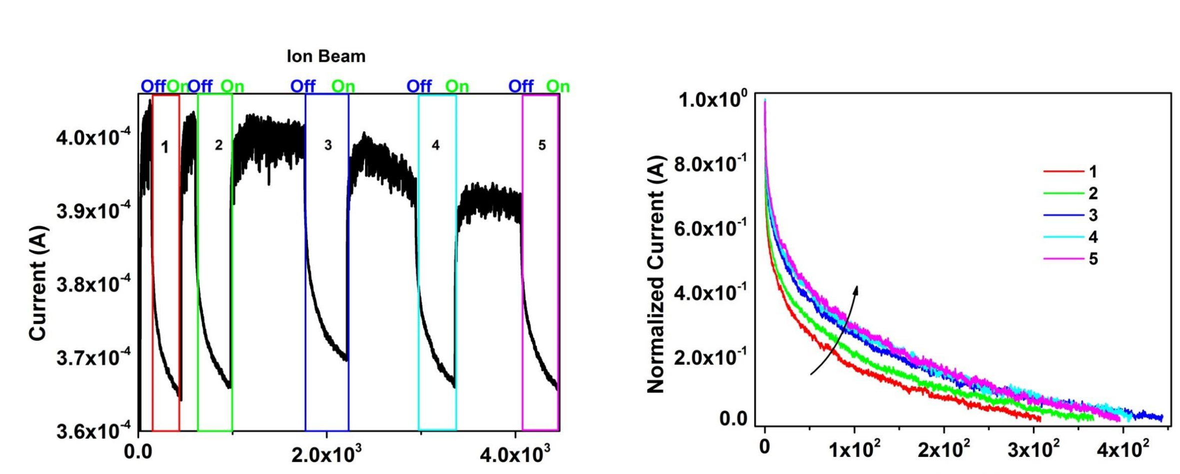

Fig.14: a) Changes on the conductivity measured in real time during the irradiation.
b) Normalized conductivity evolution after stopping (off) the irradiation.

Acknowledgments

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