Hiden Reference: AP0322
Hiden Product: EQP Mass and Energy Analyser

Composition and species evolution in a laser-induced $LuMnO_3$ plasma

Multiferroics, materials comprising two or more ferroic properties, such as ferromagnetism, ferroelectricity or ferroelasticity in the same phase, are very promising systems for future applications in computing or sensing. These materials would allow the design of new digital storage devices thereby combining the advantages of long lived magnetic storage with easy accessibility and robustness of electronic storage technology. Still, materials combing both properties useful for applications are scarce. To better adapt multiferroicity, thin film growth introduces new parameters such as strain, allowing the tuning of the respective materials properties. For a targeted growth control mass spectrometry as well as emission spectroscopy is utilized to investigate the plasma during the growth by pulsed laser deposition.

Rare-earth manganates ($ReMnO_3$) with an orthorhombic structure are very interesting multiferroics since the electrical polarization is induced by changes of the crystalline structure and magnetic ordering. As a result, the coupling between magnetism and electrical polarization is strong. Orthorhombic $LuMnO_3$ (LMO) thin films were grown from a sintered, ceramic LMO target by pulsed laser deposition. To correlate ablation conditions like fluence, background pressure or substrate-target distance to the film growth, the composition of the laser induced plasma was investigated by mass spectrometry using a Hiden Analytical EQP Quadrupole Mass Spectrometer complemented by optical emission spectroscopy (see Fig. 1).

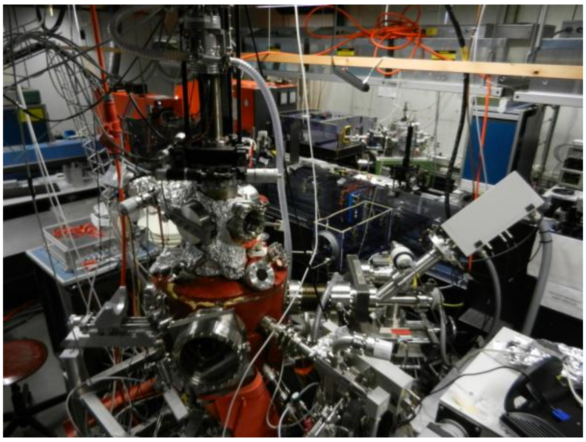

Fig. 1: Photo of the UHV chamber.

The plasma composition was investigated for three different background conditions, vacuum, 1×10^{-2} mbar O_2 and 1×10^{-2} mbar N_2O. In particular, the amount of metal species (Lu, Mn) and their oxides (O_x, LuO_x, MnO_x) and how the relative intensities change under varying background conditions was of interest. The mass spectrometer was used in different modes to observe positively ionized species as well as neutrals using the integrated ionizer. In Fig. 2 the neutral and positive species for the three background conditions are shown in the top and bottom rows, respectively. A clear increase of oxidized species is observed for both oxidizing backgrounds, compared to vacuum LuO^+/Lu^+ changes from 1:200 to 4:1 in O_2 and 9:1 in N_2O.

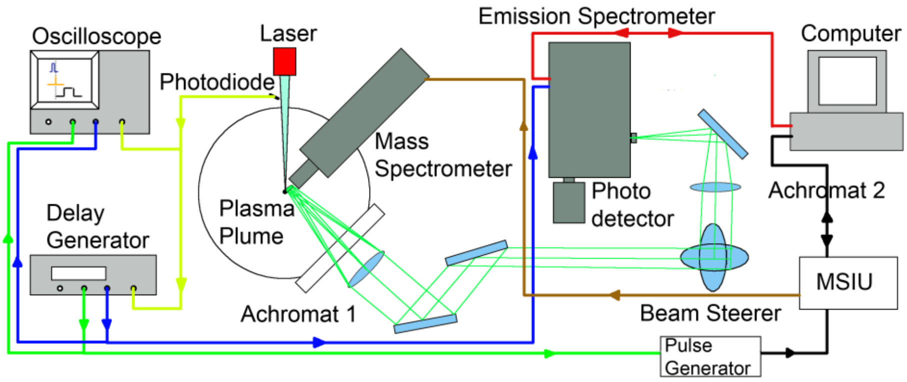

Fig. 2: Setup of the UHV chamber showing the analytical stages for mass spectrometry and emission spectroscopy.

In order to observe the expansion of the plasma species spatially and time resolved, optical emission spectroscopy was utilized as a complementary method simultaneously with mass spectrometry. The emitted plasma radiation was measured as a function of time, space and wavelength. Changes in relative intensities between Lu and LuO lines over time show a distinct behaviour when comparing vacuum conditions with an oxidizing background gas. While the initial expansion of plasma species for all background conditions is similar, the behaviour changes at later times when the interactions between species from the target and the background become dominant. In oxidizing backgrounds, the relative intensities increase towards metal-oxide species agreeing well with observations from mass spectrometry.

The combined spectroscopic and spectrometry results show the importance of a background gas for the ablation of oxides. There are clear indications from these measurements that the oxidation of metals to MeO_x species in the background is the dominating factor to incorporate oxygen directly into the growing thin film.

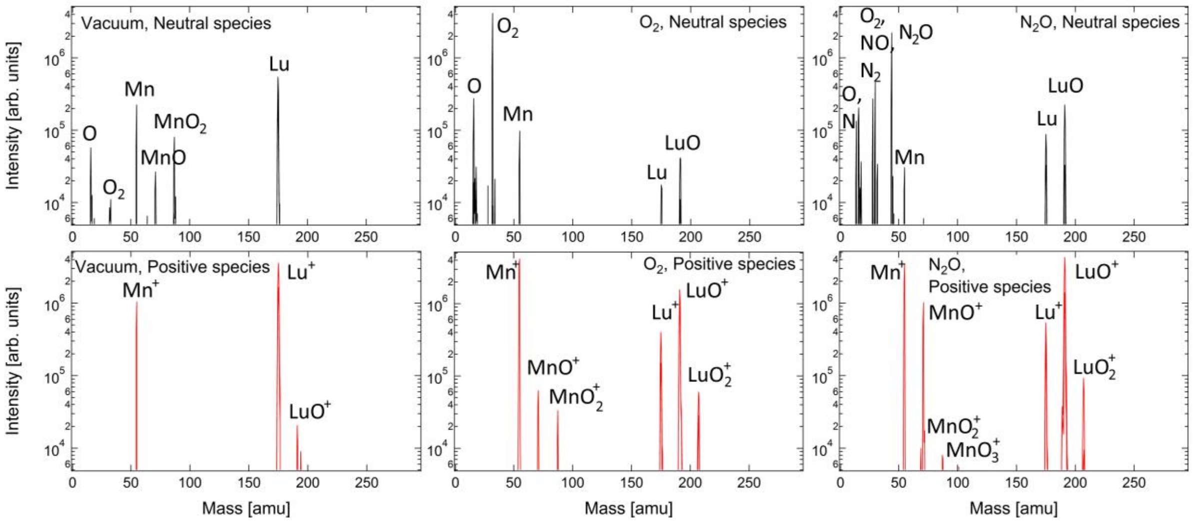

Fig. 3: Distribution of masses as taken from mass spectrometry for different background conditions: from left to right: vacuum, $1x10^{-2}$ mbar O_2, $1x10^{-2}$ mbar N_2O. The top row shows neutral species, the bottom row positive ions.

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Hiden Product:

EQP Mass and Energy Analyser

Follow the link to the product catalogue on our website for further information
http://www.hidenanalytical.com/index.php/en/product-catalog/51-plasma-characterisation/82-eqp-mass-and-energy-analyser-for-plasma-diagnostics