Study reactive ion etching- transformer coupled plasma (RIE-TCP) mode for patterning of MgZnO alloys, used for computing and memory applications

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Magnesium Zinc Oxide (MgZnO) is a novel metal alloy considered for advanced memory applications. When used as a dielectricum in transistors in dynamic random-access memory (DRAM) [1] or core elements in resistive random-access memory (RRAM) [2], MgZnO exhibits the potential to display high $I_{on/off} > 10^6$ [3], high mobility> 40 cm^2/VS [4], and low processing temperature [1]. Therefore, minimal damage-inducing patterning of the alloy for use in electrical nanoscale devices is needed.

During the etching process, MgZnO film may be chemically and physically damaged, impacting its electrical performance. Changes in chemical composition and diffusion of etchants into the material are some types of chemical damages observed during etching. These can impact carrier mobility within the material. Physical damage consists of modified roughness, profile distortion, and redeposition on the pattern sidewalls. These are all critical issues because carrier transport in transistor channels is significantly affected by interface roughness between the channel and gate insulator [5]. The etch process developed should preserve the chemical composition and roughness in MgZnO and provide good selectivity when patterning other layers of the stack and hard mask (HM). There are three methods for dry etching consisting of physical, chemical, and physical-chemical mechanisms [6]. Pure physical etching is not selective and pure chemical etching can be isotropic. Reactive ion etching (RIE) is used in this study to generate an etching mechanism that can provide an optimal combination of chemical and physical etching [6].

In this work, we carried out the etch investigation of MgZnO film using an RIE-transformer coupled plasma (TCP) system. 10 nm MgZnO films are deposited on a 50 nm SiO_2 layer/Si substrate (Fig. 1). The impact of different gas mixing ratios, RF power, DC substrate bias, and process pressure are studied. In this study, the RIE window that consists of optimal chemistry, voltage, power, and pressure with selectivity and less changing of roughness was found for etching MgZnO. The etching of MgZnO thin films is carried out using $Cl_2/CH_4/Ar$ mixture. Cl_2 increases chemical reactivity by creating $MgCl_2$ [7] and $ZnCl_2$ [8] by-products that remove from the surface sooner than Mg-O and Zn-O bonds due to less boiling point. Moreover, the addition of CH_4 produces organometallic volatile etch by-product – $Zn(CH_3)_2$ (boiling point: 46°C) [8]. Therefore, MgZnO is to be etched partly by physical and chemical mechanisms. These hypotheses are studied in detail by carrying out in-depth X-ray photoelectron spectroscopy (XPS) based composition analysis on MgZnO surfaces subjected to the RIE window (Fig. 2). Based on the results Zn gets etched faster than Mg in MgZnO and etching of Mg is more physical and Zn is more chemical by the RIE window. These investigations should enable a more systematic patterning study of MgZnO-based features at different scaled dimensions and densities.

References

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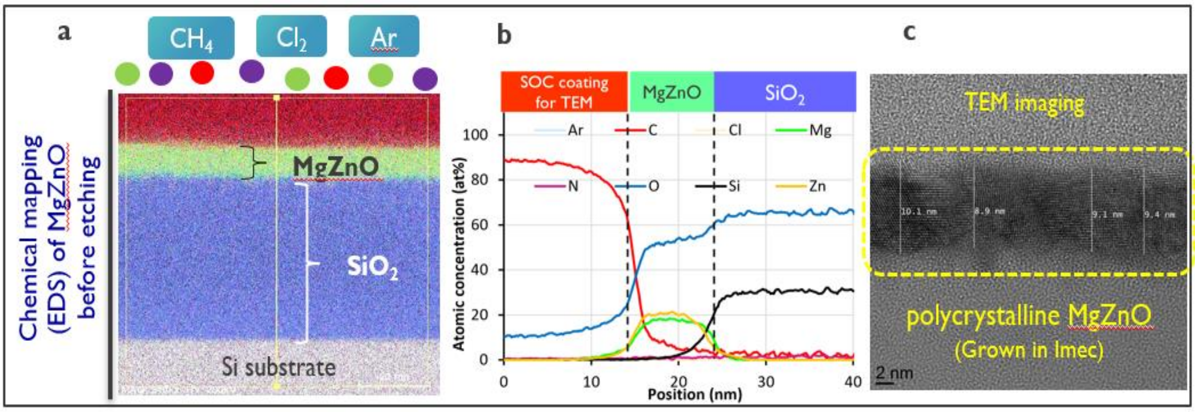
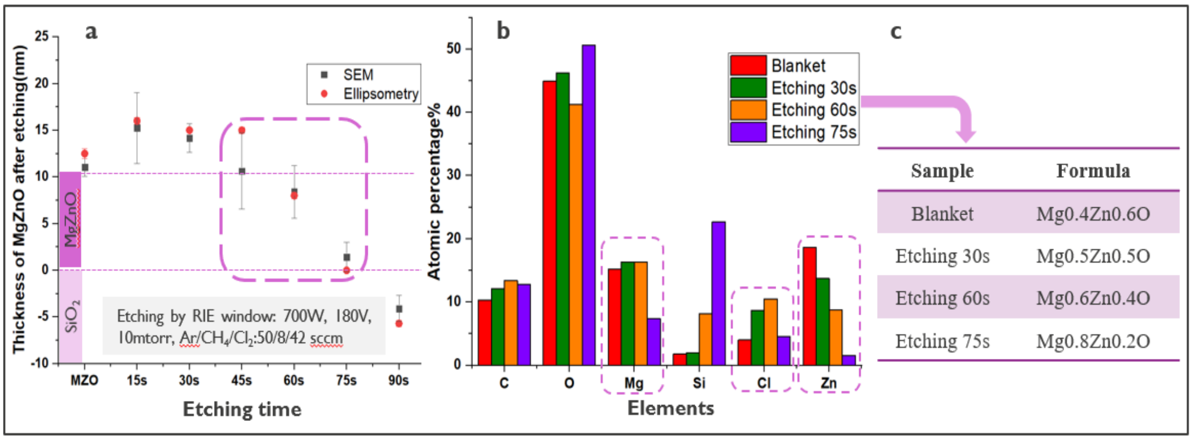


Figure 1: a) Structure of MgZnO stack with etching chemistry, b) Atomic concentration, and, c) Crystally structure of MgZnO layer



Sample	Formula
Blanket	Mg0.4Zn0.6O
Etching 30s	Mg0.5Zn0.5O
Etching 60s	Mg0.6Zn0.4O
Etching 75s	Mg0.8Zn0.2O

Figure 2: [a) Thickness of MgZnO layer, b) Changing the atomic percentage of Mg, Zn, C, O, Cl, and Si, c) The formula of modified layer] after etching with RIE window in the 30s, 60s, 75s.