6.17 3D coplanar waveguide design using organic isolation layers

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Improvement of non-volatile data storage media like magnetic random access memories (MRAM) is of elementary importance for future data storage. For achieving ultrafast switching in the GHz range it is necessary to investigate single domain elements with a well defined Stoner-like magnetization reversal behavior. Recent publications [1, 2] report on ellipsoidally shaped synthetic antiferromagnet (SAF) elements used as the active switching part in MRAM cells. Switching was initiated by two orthogonally oriented, time delayed in-plane magnetic field pulses being aligned at an angle of ±45° with respect to the in-plane magnetic easy axis of the element. The main disadvantages of this concept are the low switching speed and the necessity for a pre-read step prior to the writing process. An improvement of the switching concept for precession-dominated switching of SAF elements could recently be demonstrated by simulations [3, 4] allowing for ultrafast switching and a direct writing scheme without pre-read. To investigate this precession-dominated switching process experimentally by means of time-resolved magneto-optical Kerr effect microscopy, a double layer structure of high quality crossed coplanar waveguide (CPW) structures is required to apply the suggested two independent magnetic field pulses. For achieving ultrafast rise time field pulses, a bandwidth of the CPW in the GHz range is required. This report addresses the development and preparation of such CPW structures by using the photosensitive polymer Cyclotene 4024-40TM (hereafter referred to as BCB, Dow Chemical) as electric insulation layer. This polymer guarantees for good electrical insulation (volume resistivity $\rho \simeq 1 \cdot 10^{19} \Omega m$ [5]) as well as an extremely high surface planarization (about 90% [6, 7]), which is an essential requirement for the quality of the applied field pulses and for the magnetic properties of the SAF element. We demonstrate the fabrication of a BCB based CPW multilayer stack feasible for such applications.

The newly developed crossed CPW design consists of six different layers, three conducting lines, two BCB insulation layers and, on top, the magnetic thin film element. The setup is shown schematically in Fig. 1.

In this figure, the layer thickness as well as the width of the CPW lines are displayed to scale. The substrate is a B270 glass substrate (dielectric constant $\varepsilon = 7.0$). The first layer on top of the sub-

Fig. 1: Schematic cross section of the crossed CPW multilayer sample design. The film thicknesses and CPW dimensions are drawn to scale. The sample area has been enlarged by a scaling factor of five to demonstrate the position of the magnetic thin film element.

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strate is a microstructured Cu stripline, the so-called reset line produced either by using a shadow mask or by UV-photo lithography and lift-off. This reset line allows to reset the initial magnetization state of the investigated magnetic element. This is required for the stroboscopic measurement technique used for the investigation of the magnetization dynamics. The film thickness is 2µm and the width of the reset line is 100µm in the central constriction and 350µm elsewhere. The central constriction of the reset line is used to increase the output Oersted field. The second layer, which is the first BCB insulation layer, is processed by UV photolithography and lift-off where the contacts of the reset line are uncovered areas at the ends for electrical contacting. The following first coplanar waveguide CPW 1 is oriented at an angle of +45° with respect to the reset line. The second BCB insulation layer also leaves open areas for electrical contacting of CPW 1 and the reset line. CPW 2 is then positioned on top of this second insulation layer and oriented at an angle of −45° with respect to the reset line, i.e., the coplanar waveguides are orthogonal to each other. The film thickness of the CPWs is 500nm and the impedance is 50Ω. Finally, on top of the whole setup, a magnetic thin film element is prepared in the central area of the CPW cross (see Fig. 2) by means of electron beam lithography and lift-off.

Fig. 2 shows an optical micrograph of the central structure region. The sampling area is 10×10µm², defined by the squared width of the central signal lines of the CPWs.

The micropatterning of the conduction lines (i.e., the reset line and CPWs) is carried out by UV-photo lithography using a negative lift-off process. The resist used is AZ 5214-E (Clariant). In order to pattern the reset line a pre-treatment with the adhesion promotor hexamethyldisilazane (HMDS) is required prior to the resist coating. After spin-coating the resist and several other steps including soft bake and UV-exposures, the resist is finally developed in AZ 400K (Clariant) and in deionized water. After depositing the Cu by electron beam evaporation the lift-off is carried out in acetone.

The signal processing of the CPWs is extremely sensitive to the planarity of the structure. Any edges due to underlined microstructure cause reflection losses and thus additional noise. This high degree of planarity cannot be achieved by standard insulators used so far and made it necessary to develop a multilayer BCB process which yields the highly insulating, structurable and planar films. Figure 3 shows a typical result achieved after processing. Shown is a secondary electron micrograph of the cross section of a BCB multilayer sample including a Cu CPW. The planarization of the CPW with the BCB is very good as no surface profile caused by the CPW can be observed. Furthermore, good adhesion between the different BCB layers is achieved as no interface can be

Fig. 2: Optical micrograph of the crossed CPW design (top view). The reset line and both CPWs are visible whereas the BCB insulation layers are transparent.
Experimental Results

detected between the two BCB layers. These qualities guarantee for good insulation and very good high frequency characteristics.

The elliptical magnetic thin film element (dimensions: $2 \times 1 \mu m^2$) is prepared on top of CPW 2 by means of electron beam lithography, and oriented orthogonally to the reset line.

To demonstrate the quality of the device, the transmission characteristics of the CPWs is measured with the experimental setup shown in Fig. 4. The sample is mounted in the center on top of a post and contacted with special spring contacts providing three parallel arranged needle-contacts. These so-called picoprobes® (GGB Industries, Inc.) are fixed in holders with integrated $x$-, $y$- and $z$-positioning stages enabling an exact adjustment of the uncovered contacts ends of the CPWs.

The transmission characteristic is measured in the range of 200MHz up to 15GHz using a scalar network analyzer. According to the 3dB criterion the bandwidth is larger than 10GHz. These measurement prove the good quality of the CPWs and prove the waveguide design presented here is feasible for the measuring of ultrafast magnetization reversal processes as requested in [3, 4].
In conclusion, the applicability of polymer insulation layers in a 3D crossed CPW design for ultrafast magnetization measurements was demonstrated. It is possible to integrate BCB into a multilayer sample structure, which allows for high electrical insulation and high surface planarization. The micropatterned CPWs have a bandwidth larger than 10GHz according to the 3dB criterion which is of fundamental importance for the field pulse quality. This new technique has considerable potential for further application in the processing of 3D sample structures.

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References