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“POWER SoC With Integrated PassivEs”

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“Magnetics on Silicon process transfer report”

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2. Introduction

This report details the Tyndall ‘Magnetics on Silicon’ process. The ‘Magnetics on silicon’ process was developed for fabrication of micro-inductor and micro-transformer structures. The process is currently employed to fabricate ‘elongated spiral’ or ‘racetrack’ device structures. The top view and the cross-section of the racetrack magnetic structure are shown in figure below.

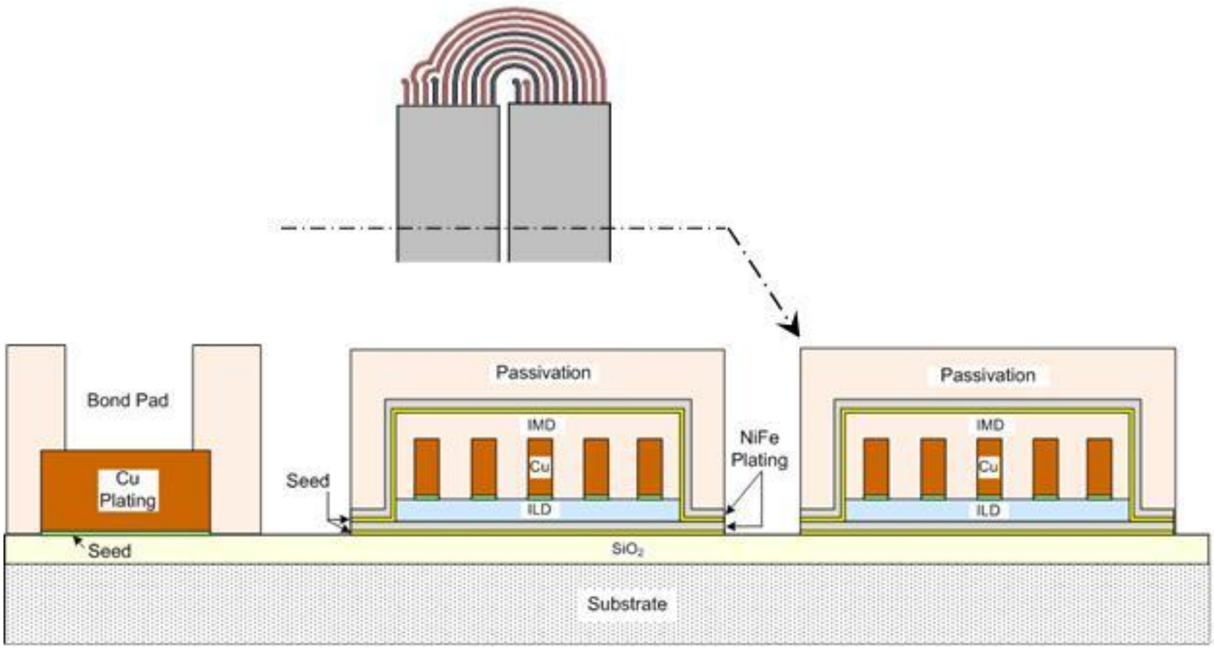


Figure 1. Top view and cross-section of the Magnetic structure (ILD- Inter layer dielectric, IMD- Inter metal dielectric)

This is a 5 mask process, with 3 metal layers (2 magnetic and 1 conductor) and two insulation layers (Inter layer dielectric and Inter metal dielectric). The conductor layer is sandwiched between two magnetic layers. Two different dielectrics are used for passivation of the bottom magnetic core-conductor and conductor-top magnetic core.

This report is part of process transfer task between Tyndall National Institute and Infineon, Regensburg.

3. Magnetics on silicon process technology

3.1 Magnetics on silicon process flow

The Tyndall Magnetics on silicon process is a 5 mask with 20 process steps. A flow chart of all the steps involved in shown in Figure 2.

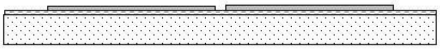
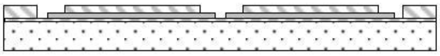
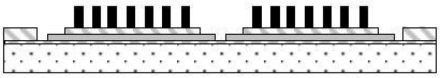
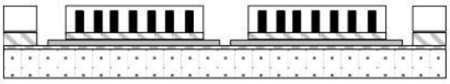
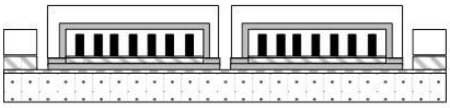
Mask Layer	*Processing steps*	*Equipment*
Layer 1: NiFe Bottom Core 	1. Sputter bottom core seed layer	Nordiko 4000 Series Sputterer
	2. Electroplate NiFe bottom magnetic core	Custom Plating Bath
	3. Photolithgraphy for bottom core	DNS/Screen track EV 420 Contact Aligner
	4. Etch NiFe	Wetbench Bath
	5. Etch seed layer	Wetbench Bath
	6. Strip photoresist	Wetbench Bath
Layer 2: ILD 	7. ILD polymer deposition 8. ILD photolithograpy	DNS/Screen track EV 420 Contact Aligner
Layer 3: Copper Coils 	9. Sputter bottom core seed layer	Nordiko 4000 Series
	10. Photolithography Metal1 Cu Coil	DNS/Screen track EV 420 Contact Aligner
	11. Electroplate coil copper	Schlotter SG1 Plating Bath
	12. Strip photoresist	Wetbench Bath
	13. Etch seed layers	Wetbench Bath
Mask Layer	*Processing steps*	*Equipment*
Layer 4: IMD 	14. IMD deposition	DNS/Screen track
	15. IMD photolithography	EV 420 Contact Aligner
Layer 5: NiFe Top Core 	16. Sputter top core seed layer	Nordiko 4000 Series
	17. Electroplate NiFe top magnetic core	Custom Plating Bath
	18. Passivation photolithography	DNS/Screen track / EV 420 Contact Aligner
	19. Etch NiFe top core	Wetbench Bath
	20. Etch top core seed layer	Wetbench Bath

Figure 2. Flow chart of steps in Tyndall ‘Magnetics on Silicon’ process

The rest of report discusses the different materials and processes employed in the fabrication of racetrack micro-inductor structures. The next section discusses the magnetic material deposition and processing as bottom and top core layers.

3.2 $Ni_{45}Fe_{55}$ magnetic core material

The Tyndall racetrack micro-inductor structure employs $Ni_{45}Fe_{55}$ as a core material. The magnetic and physical properties of $Ni_{45}Fe_{55}$ thin films are shown in Table 1.

Property	Value
Saturation, B_{sat}	1.44 T
Coercivity, H_c	80 A/m
Resistivity, r	45 µΩ.cm
Anisotropy, H_k	800 A/m

Table 1. Summary of magnetic and physical properties of $Ni_{45}Fe_{55}$ thin film

These properties suggest $Ni_{45}Fe_{55}$ with relatively higher resistivity, anisotropy field and high flux density is an ideal core material for high frequency inductor structures. The magnetic core is deposited using a pulse-reverse plating technique. The details of the plating technique have previously reported in [1]. A uniaxial anisotropy is induced within the magnetic film during deposition, by plating in presence of magnetic field. The BH loops showing the easy and hard axis measurements on anisotropic $Ni_{45}Fe_{55}$ thin films are shown in Figure 3.

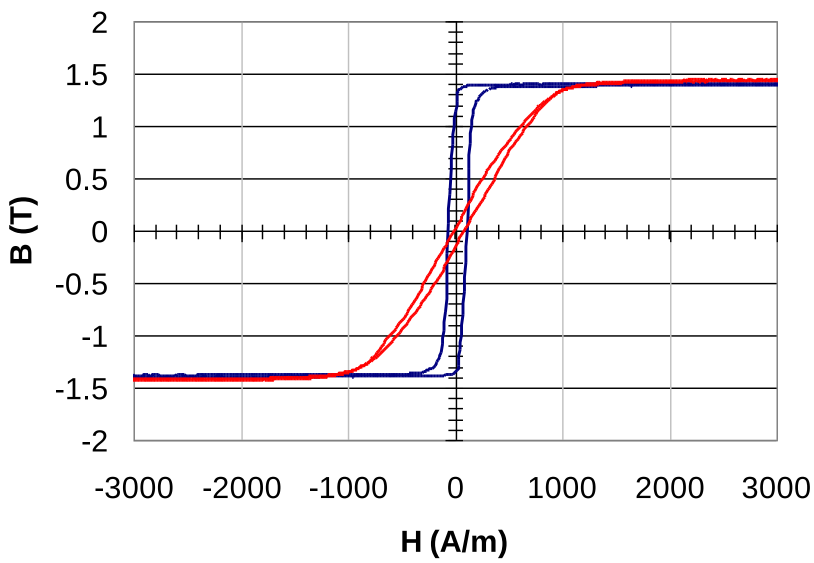


Figure 3. BH loops for $Ni_{45}Fe_{55}$ easy and hard axis measurements

3.3 Inter layer dielectric and Inter metal dielectric

The Tyndall magnetics on silicon process employs BCB 46 as Inter Layer Dielectric (ILD). It provides insulation between bottom magnetic core and copper conductor tracks. BCB is a photo-sensitive negative resist which can be patterned using lithography. Su-8 50 is employed as an Inter Metal Dielectric (IMD), to insulate copper conductor tracks and top magnetic core. As BCB, Su-8 is also a photo sensitive negative resist which is patterned using lithography. Figure 4 shows below the different dielectrics in the test inductor structure.

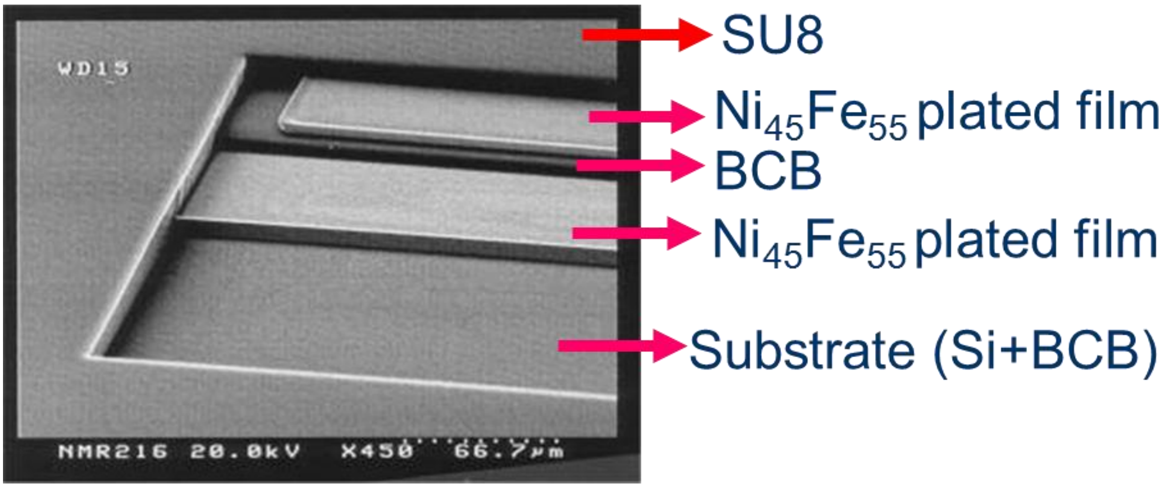


Figure 4. Different dielectrics in the racetrack inductor structure

3.4 Copper conductor deposition

Copper is used as conductor in the micro-inductor structure. Copper is deposited using direct current electroplating technique. Copper tracks are realised by plating within resist tracks, after which the resist is cleared and conducting seed layer is etched away. High aspect ratio copper structures have been deposited using the Tyndall process technology. Aspect ratios of 1:2.5 have demonstrated previously. Figure 5 shows the cross-section and top view of a fully fabricated Tyndall micro-inductor structure.

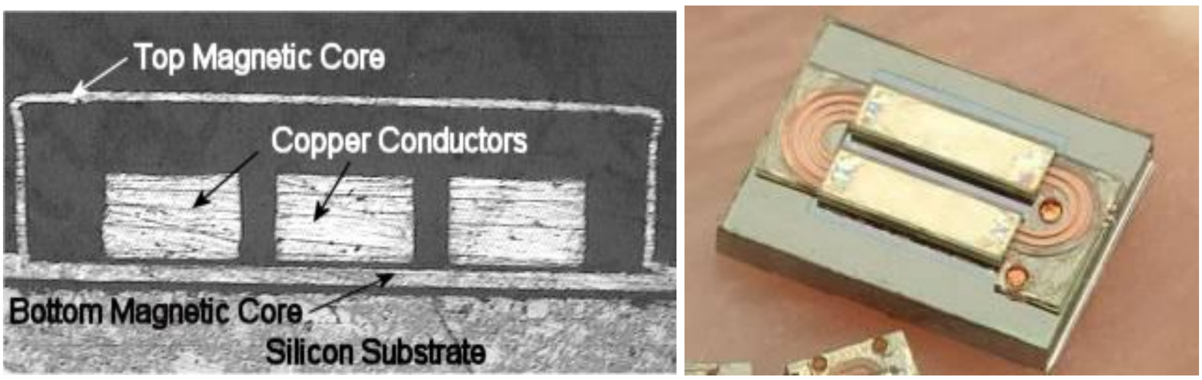


Figure 5. Cross-section of Tyndall racetrack micro-inductor structure

4. Conclusions

This report details the Tyndall ‘Magnetics on silicon’ process technology. The report is part of the Tyndall-Infineon process transfer task within work package 3. The Tyndall magnetics on silicon process is a 5-mask layer technique. The racetrack micro-inductor structure includes copper conductor sandwiched between two $Ni_{45}Fe_{55}$ magnetic cores. BCB and Su-8 are employed as Inter Layer Dielectric (ILD) and Inter Metal Dielectric (IMD). Figure 6 shows fully fabricated 4-inch wafer with different micro-inductor structures.

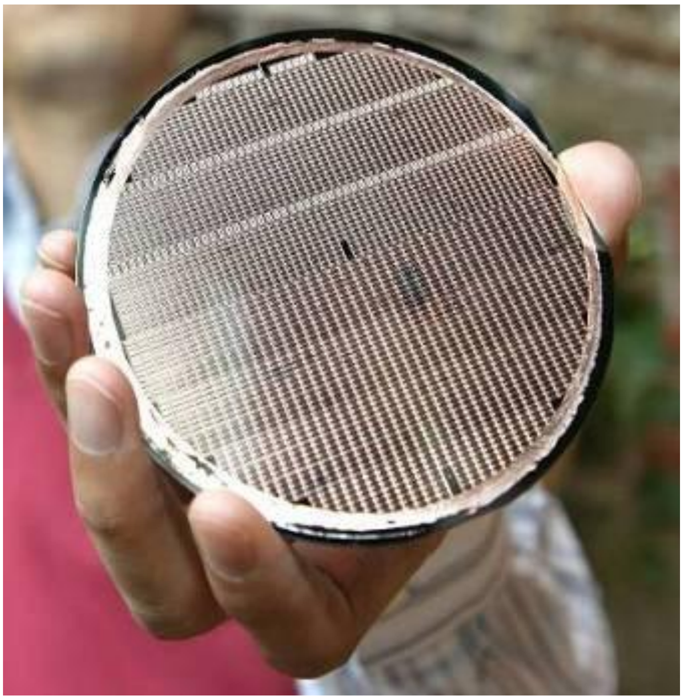


Figure 6. Fully fabricated micro-inductor structures on a 4-inch wafer

[1] S. Roy et al, *Journal of Magnetism Magnetic Materials*, **290-291**, 1347 (2005)