Study for the Design of Eddy Current Microsensor Arrays for Non Destructive Testing Applications

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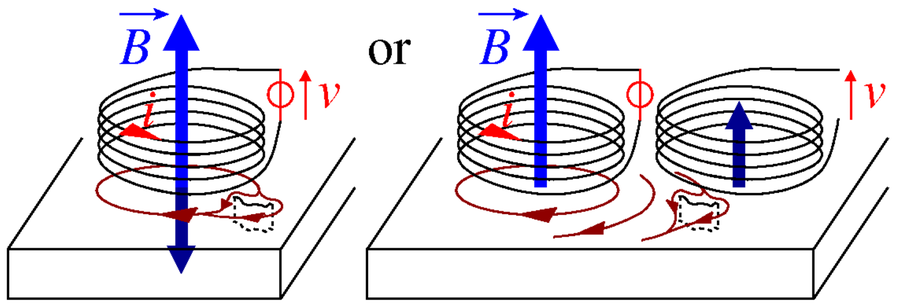
EC Measurements

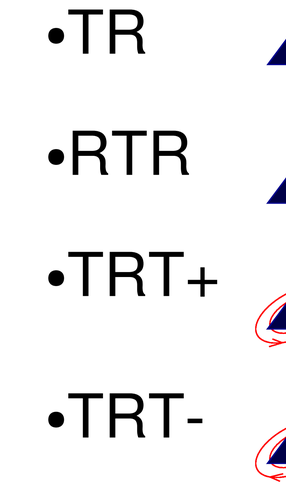


Double functions, transmission and reception, on a single coil

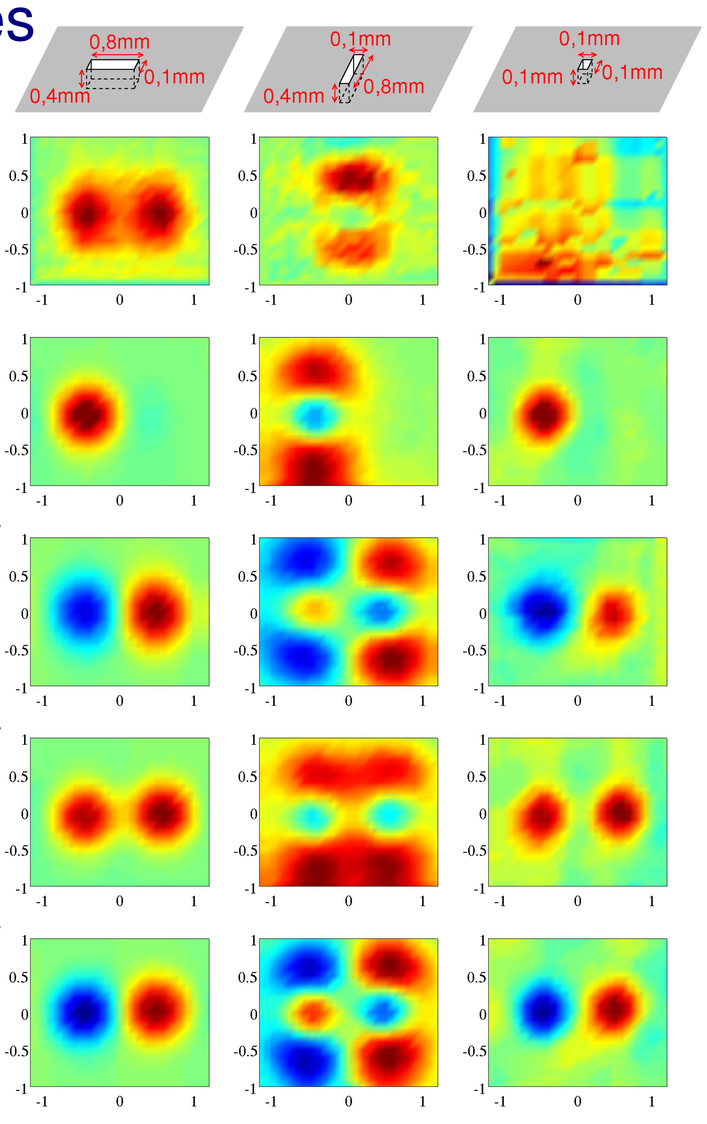
Separate functions: transmission on one coil and reception on the other coil

Transmit/Receive Strategies

- T/R — Signal is the coil impedance
- TR — Separate functions, Absolute measurement
- RTR — R voltages are subtracted, Differential measurement
- TRT+ — Magnetic fluxes are added, Superposition of two TR, Absolute measurement
- TRT- — Magnetic fluxes are subtracted, Superposition of two shifted TR, Differential measurement



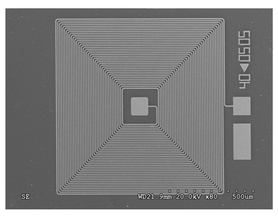
EC Images

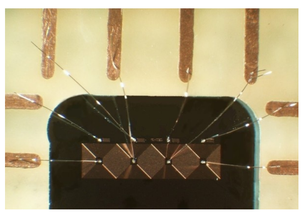


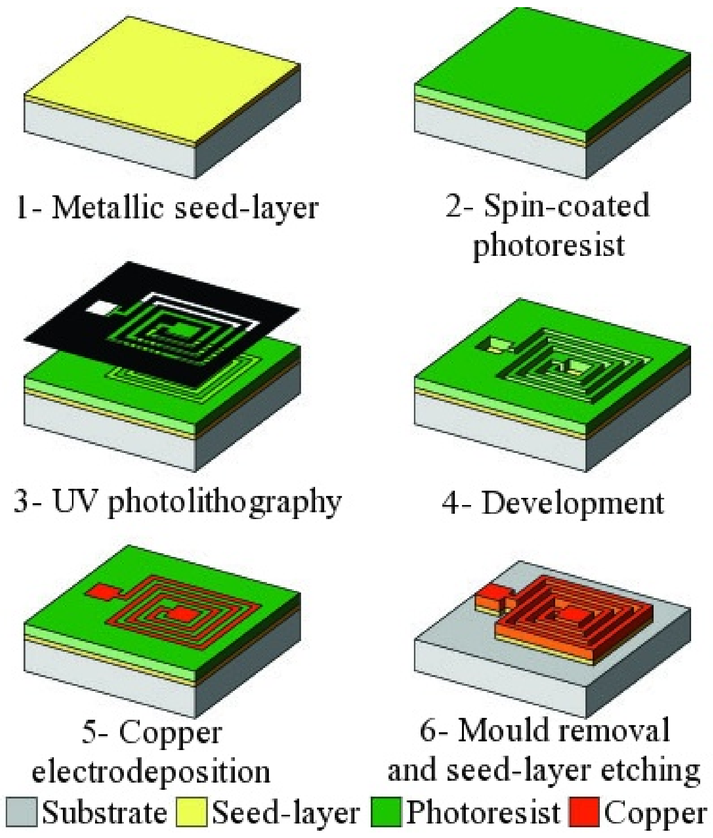
Microcoil Fabrication Process

- Silicon substrate
- Copper micromoulding
- Dimensions of the tracks:
  - 8 µm in thickness
  - 5 µm in width
  - 5 µm in spacing
- 1x1 mm², square
- 1±0,1 µH, 55±1 Ω

- Substrate is glued to an epoxy board and microcoils are microbonded with 25 µm diameter aluminium wire.

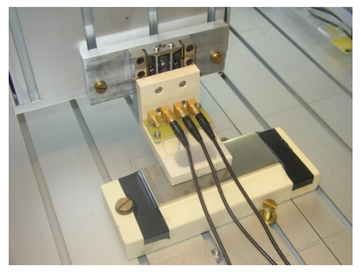






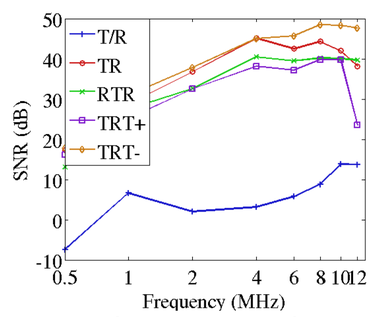
Experimental Set-up

- Nickel based alloy mockup ($\mu = 4\pi\ 10^{-7}$ H m^{-1} ; $\sigma = 0.76$ MS m^{-1})
- 30 surface breaking rectilinear notches
  - 5 lengths (0.1 mm, 0.2 mm, 0.4 mm, 0.6 mm, 0.8 mm)
  - 3 depths (0.1 mm, 0.2 mm, 0.4 mm)
  - 1 width (0.1 mm)
  - 2 orientations: perpendicular and parallel to the main orientation of the sensor array
- PC-controlled 3-axis robot; scan of surface with 0.1 mm step
- Several frequencies, from 500 kHz to 12 MHz

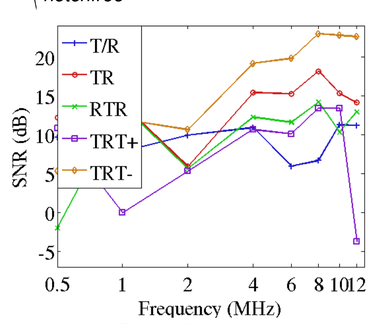


Results: SNR computation

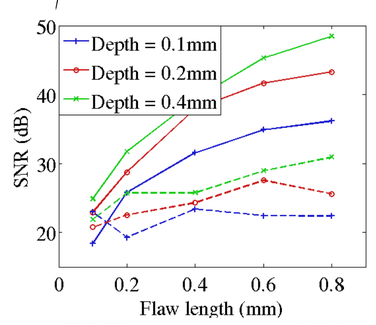
$$SNR = 10 \log\left(\frac{\sum_{notch} \left|Z(x,y) - Z_{mean}^{2}\right|}{\sum_{notchfree} \left|Z(x,y) - Z_{mean}^{2}\right|} \frac{n_{notchfree}}{n_{notch}}\right)$$



Largest notch
0.8x0.1x0.4 mm³



Smallest notch
0.1x0.1x0.1 mm³



TRT- strategy, 8MHz
parallel notches in solid line
perpendicular notches in dashed line

- TRT- strategy is far more efficient than the others
- At 8 MHz, all strategies except T/R give a SNR higher than 13 dB for the smallest notch
- Parallel notches are better detected than perpendicular ones since EC flow is perpendicular to the main array orientation

Conclusion

- An elementary array of 3 coils in line is studied. The performances of 5 different measurement strategies are compared in the field of eddy current non destructive testing applications.
- The best strategy (TRT-) is characterized: all notches, even as small as 0.1x0.1x0.1 mm³, are detected with a SNR higher than 20 dB.
- Further works will focus on 2-D microsensor arrays using the TRT- strategy, implemented in different orientations in order to maximize the sensitivity regardless of the notch orientation.