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Multi-electrode probe optimization for characterization of magnetic tunnel junction stacks

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CAPRES A/S COPENHAGEN APPLIED RESEARCH

DTU Nanotech
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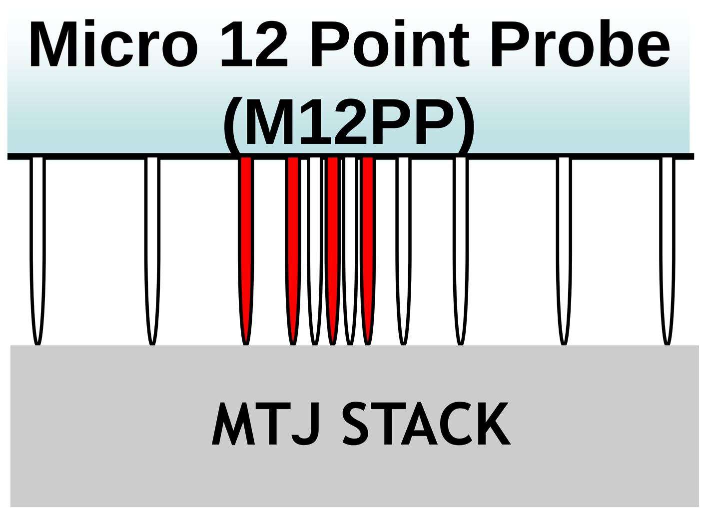
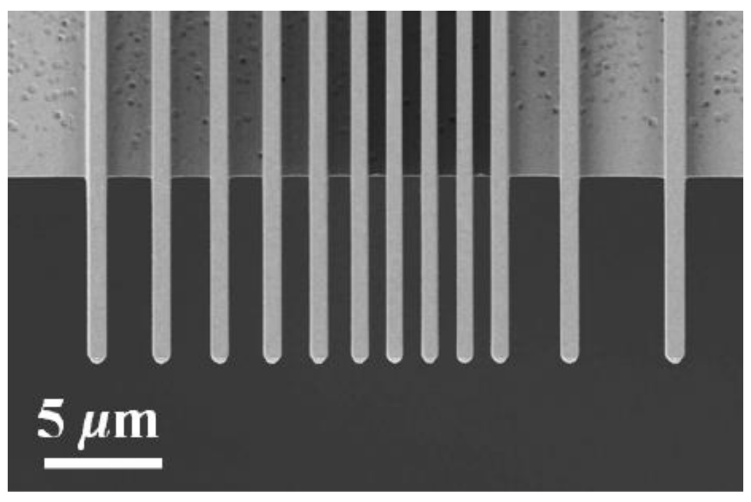
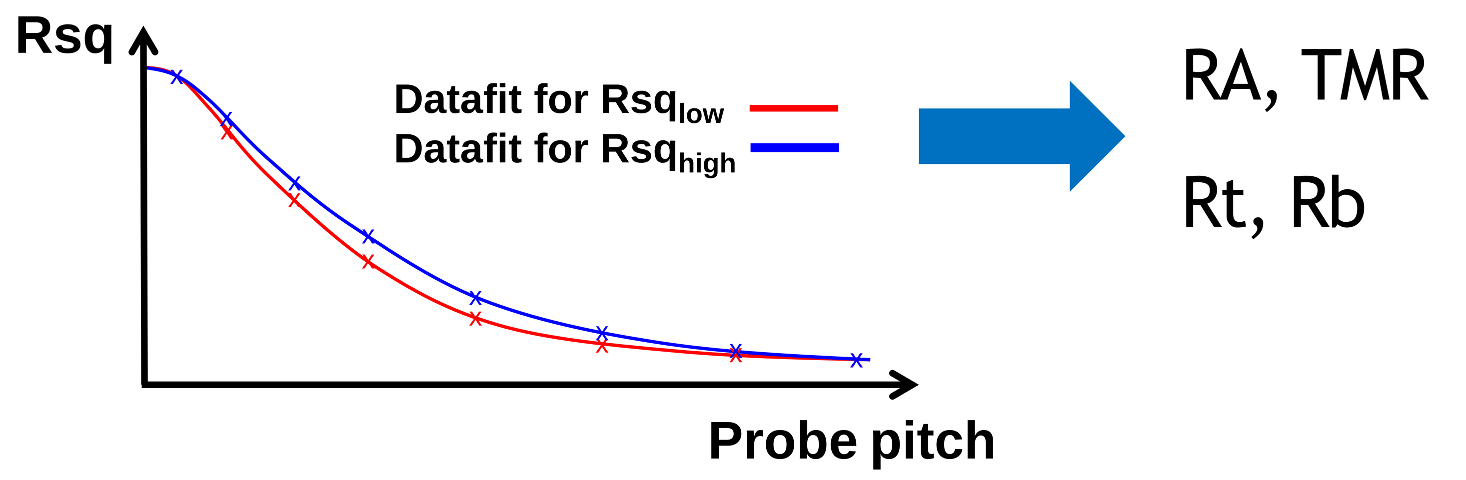
One of the most important metrologies extensively used world-wide for evaluation of Magnetic Tunnel junction (MTJ) stacks is the current-in-plane tunneling (CIPT) technique[1]. The CIPT method has been of fundamental importance in the development of MRAM technology in the past decade[2]. Until now, the design of multi-electrode probes and choice of sub-probes have been based on a best guess practice. In this study, we perform a numerical optimization of the geometrical design of multi-electrode probes as well as optimal choice of subprobes. A drastic improvement in the measurement precision for the resistance-area product and the TMR is achieved.

CIPT working principle







CURRENT PROCEDURE: 8 sheet resistance measurements using 8 micro 4 point subprobes (M4P subprobes) corresponding to 8 different electrode pitches, regardless of the sample

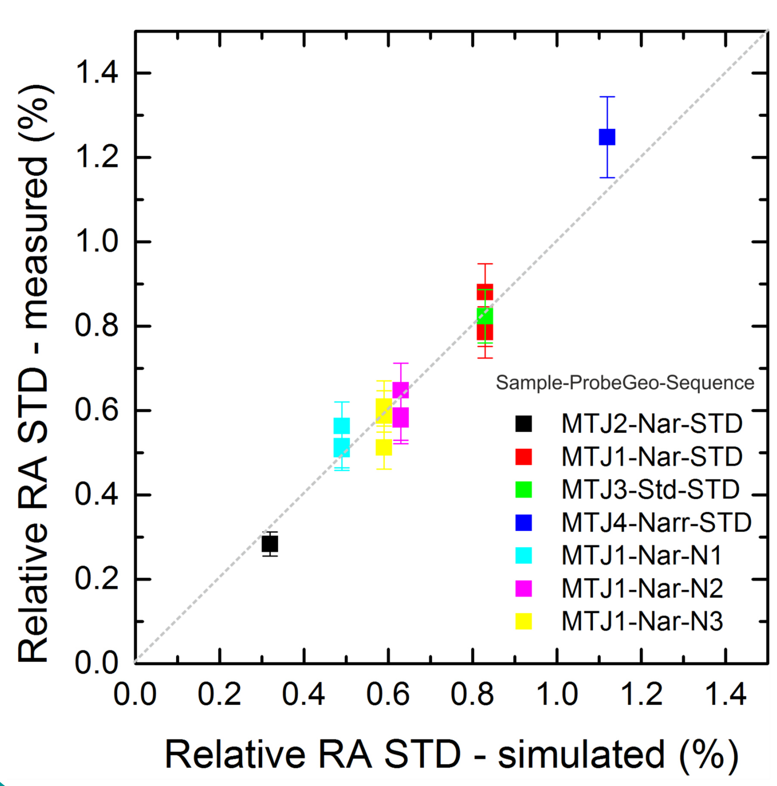
OPEN QUESTIONS:

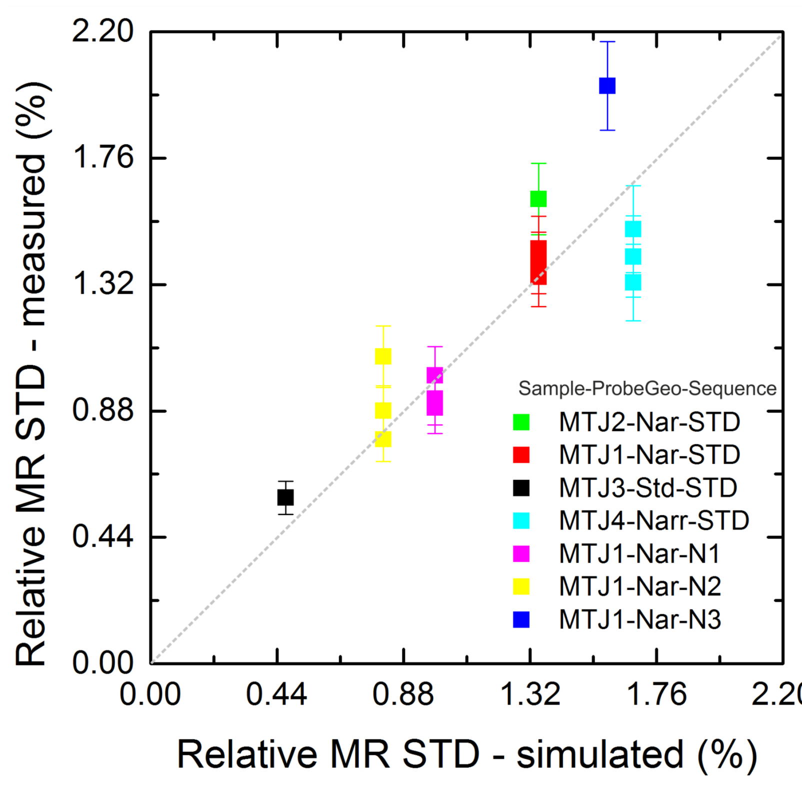
495 M4P subprobes can be formed in a M12PP, are we using the ones that gurantee the highest precision on RA and TMR for each MTJ sample?

Is it possible to optimize the relative positions of the electrodes for specific MTJ samples to maximize the precision on RA and TMR?

Measurement Precision prediction

By modeling the main noise sources of the CIPT measurement the precision, intended as the relative standard deviation (STD) on RA and MR, can be **PREDICTED** with a software tool. 4 different MTJ stacks and different probe geometries were tested.

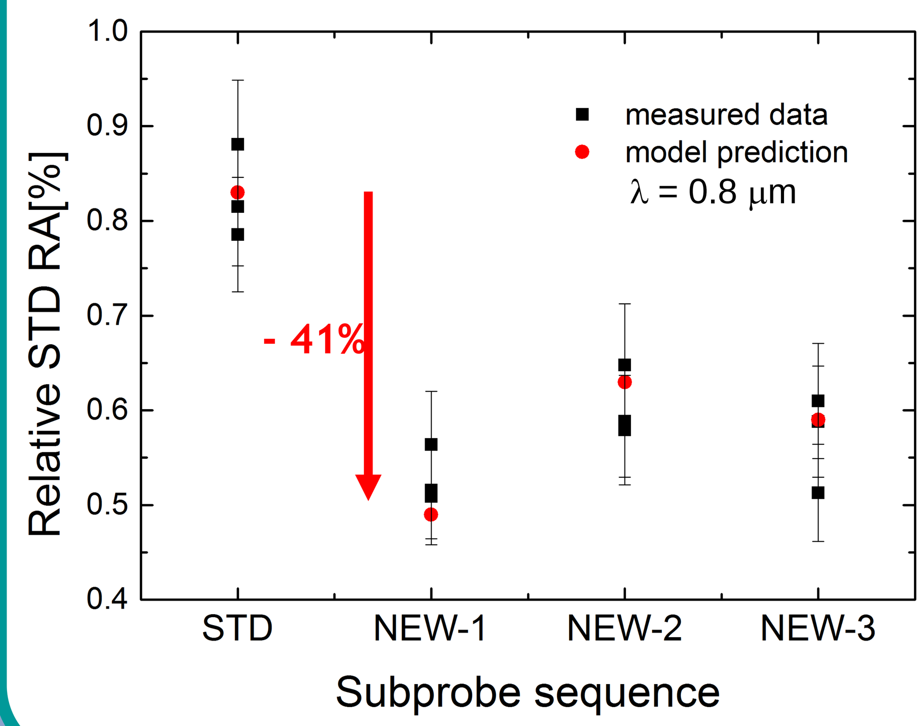


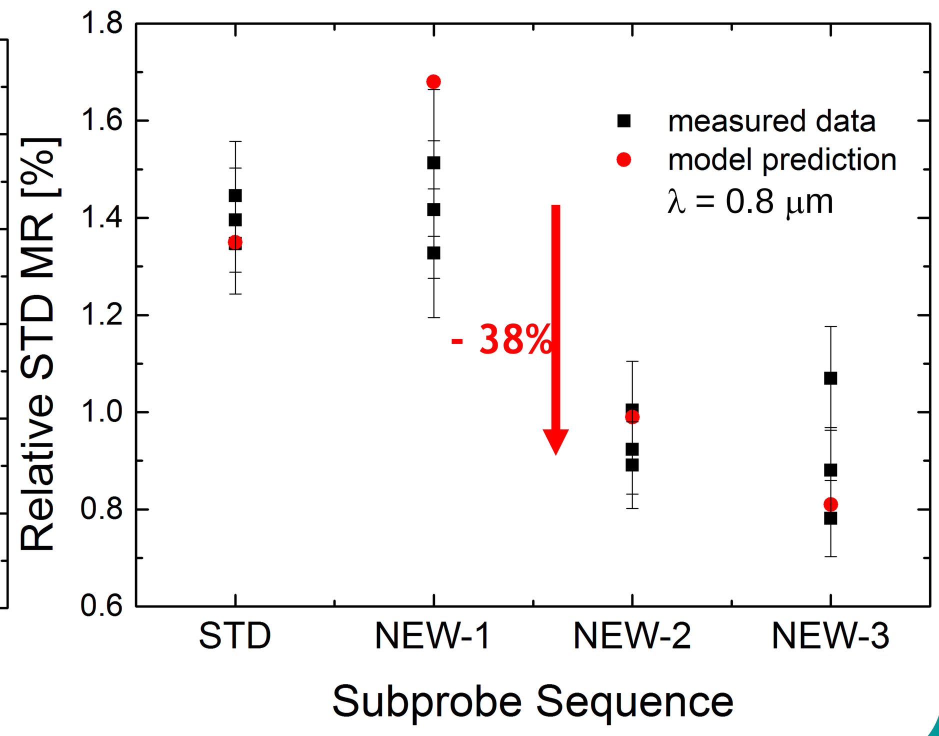


M4P Subprobe sequence Optimization

Currently for every MTJ sample the same M4P subprobe sequence is used (STD sequence), with a electrode picth ranging from 1.5 to 8.25 μm for a total of 8 M4P subprobes.

OPTIMIZATION: The optimization software is able to test thousands of subprobe sequences to identify the sequences that maximize the precision on RA and/or MR, given a specific MTJ sample.

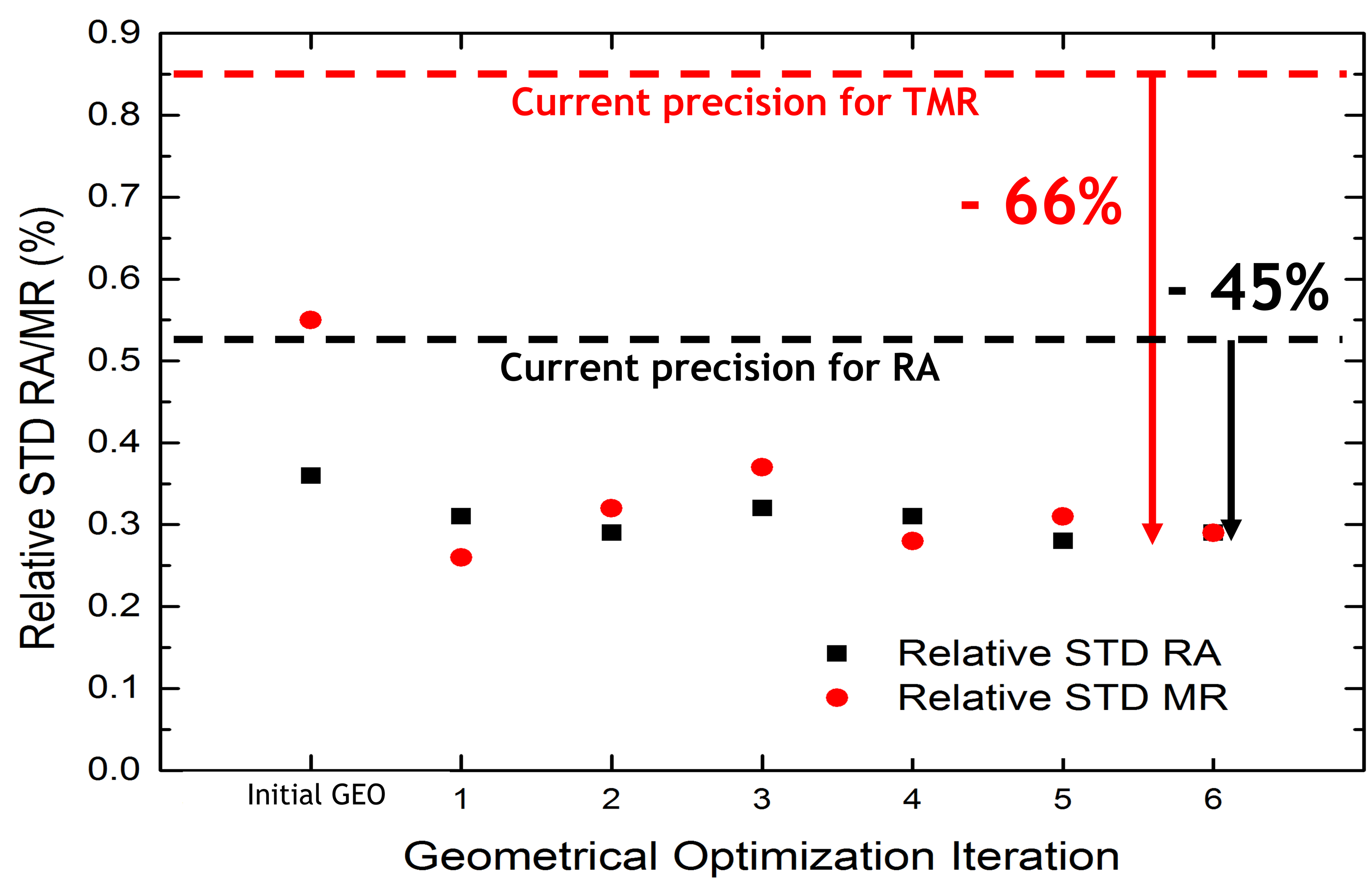




Electrode position Optimization

Currently for every MTJ sample the same M4P subprobe sequence is used for a fixed M12PP geometry.

OPTIMIZATION: combining the optimization of the subprobe sequence and the optimization of the electrode positions an improvement up to 3 times can be achieved on the measurement precision of TMR and RA (for λ = 0.68 μm).



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[2] Kjaer, D., Hansen, O., Henrichsen, H. H., Chenchen, J. W., Noergaard, K., Nielsen, P. F., and Petersen, D. H. (2015) *Measurement Science and Technology*, *26*(4), 045602.