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In-situ and in-operando magnetic resonance spectroscopy

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Nuclear magnetic resonance (NMR) and electron spin resonance (ESR) both offer an excellent specificity thanks to the nuclear/electron spin acting as a nanoscopic probe inside the sample of interest. NMR and ESR are largely complementary because NMR is mostly used on diamagnetic samples whereas ESR is arguably the only method that – at least in principle – allows for a direct detection of paramagnetic species, which play a crucial role in a large number of disciplines including biological systems, energy materials and catalytic reactions. However, due to the much greater operating frequencies of ESR compared to NMR in the tens of GHz, current ESR instrumentation is relatively cumbersome to use and requires significant user knowledge and interaction, limiting the use of ESR to a relatively small user circle. To tackle this problem, our research team has recently proposed the so-called voltage controlled oscillator (VCO) based ESR-on-a-chip detection approach that allows for the realization of compact, easy-to-use and affordable ESR detection platforms [1], [2].

In this invited talk, we will first review the start-of-the art in in-situ and in-operando magnetic resonance hardware, before we will discuss the great potential of combining MEMS-like manufacturing processes with integrated circuit-based readouts for the realization of compact and affordable, yet high performance MR systems. Here, we will focus on the possibility of realizing compact, versatile hardware platforms that can target upcoming MR markets such as personalized medicine and in-situ reaction monitoring for industry 4.0 applications.

In the last part of the talk, we will discuss the possibilities arising from combining miniaturized ESR- and NMR-on-a-chip detectors in compact, chip-scale dynamic nuclear polarization (DNP) experiments, which can eventually allow for the realization of portable, low-cost DNP-enhanced NMR spectrometers, potentially opening up entirely new markets for MR spectroscopy.

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1. Handwerker et al., *ISSCC 2016 Digest of Technical Papers*, p. 476-478
2. Chu et al., *ISSCC 2018 Digest of Technical Papers*, p. 354-356, 2018.