# Transition metal dihalides – van der Waals magnetic semiconductors for the superconducting spintronics and quantum technologies

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A progress in the development of the superconducting qubits achieved in the last decade marked important milestones like demonstration of the commercial quantum processors with tens of nodes [1]. A most common architecture of these qubits was superconducting transmon that proved to be a reliable scheme suitable for intermediate-size systems [1]. Nevertheless, scaling up of the quantum processors requires improvement of the qubit's performance that stimulates investigation of the alternative architectures. A number of competing qubit's architectures were developed, including the semiconductor spin qubits [2] and more recently the superconducting Andreev spin qubit [3,4]. In contrast to the original idea of the Andreev spin qubit [5], where spin splitting is achieved due to the spin-orbit interaction, using of superconductor — magnetic semiconductor interfaces for implementing single-qubit operations in spin qubits was found to be more advantageous. For instance, Al/EuS bilayers were proposed for using in Andreev spin qubits to complement or even substitute the use of spin-orbit interaction [6].

A number of magnetic semiconductors suitable for creating exchange coupling in the heterostructures with superconductors is limited because majority of these compounds are antiferromagnets. In this work we present our results of investigation of the transition metal dihalides ($NiCl_2$, $NiBr_2$, $FeCl_2$ and $FeBr_2$) grown on the superconducting $NbSe_2$ substrate. We will show that these materials demonstrate collinear or non-collinear ferromagnetic ordering in the limit of a single or a few atomic layers thick films, although in bulk form they are antiferromagnets [7]. Following our previous work [8] we used a number of advanced spectroscopic and microscopic techniques to perform detailed characterization of the electronic and magnetic properties of these materials [9, 10]. Obtained results will be discussed in the context of implementation of the hybrid magnetic semiconductor -- superconductor devices for superconducting spintronics and quantum technologies.

## References

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