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NanoSQUID magnetometry on individual cobalt nanowires at variable temperature

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Performing magnetization studies on individual nanoparticles is a highly demanding task, especially when measurements need to be carried out under large sweeping magnetic fields or variable temperature. Yet, characterization under varying ambient conditions is paramount in order to fully understand the magnetic behavior of these objects, e.g., the formation of non-uniform states, the mechanisms leading to magnetization reversal, thermal stability or damping processes. This, in turn, is necessary for the integration of magnetic nanoparticles and nanowires (NWs) into useful devices, e.g., spin-valves, racetrack memories or magnetic tip probes. Here we show that YBa2Cu3O7 nano Superconducting QUantum Interference Devices (YBCO nanoSQUIDs) are particularly well suited for this task. For this purpose, we have successfully characterized a number of individual cobalt NWs grown by means of Focused Ion Beam Induced Deposition (FEBID) of cobalt and subsequently annealed at different temperatures in high-vacuum conditions. The resulting samples are transported to the surface of the sensor with nanometric resolution, achieving large NW-SQUID coupling. Magnetization measurements performed under sweeping magnetic fields (up to ~100 mT) and variable temperature (1.4 - 80 K) underscore the intrinsic structural and chemical differences between NWs annealed at different temperatures. As we show here, thermal annealing leads to the nucleation or vanishing of antiferromagnetic species within the NW. On the other hand, dramatic differences in the temperature-dependent magnetization switching are observed. These are attributed to significant changes in the crystalline structure and the resulting effective magnetic anisotropy of the NWs annealed at the largest temperatures. Our measurements also demonstrate the strong potential of YBCO nanoSQUIDs as ultra-sensitive and versatile nanosensors for the characterization of individual magnetic objects for different applications