The Challenging Growth of High Crystal Quality Cu_2O: A Novel p-type Metal Oxide Semiconductor for the Observation of Giant Rydberg Excitons

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Abstract

Cuprous oxide (Cu_2O) is a p-type metal-oxide semiconductor that has a fundamental, direct energy bandgap of 2.1 eV. It has been suggested to be suitable as a solar cell absorber for a long time but so far device efficiencies have been limited to less than 10% [1]. Cu_2O has also been shown to be suitable for water splitting [2] and CO_2 reduction [2 3,4]. In addition, Cu_2O is an archetype for the study of excitons that were observed for the first time in this novel p-type metal oxide semiconductor in 1956. Consequently, Cu_2O is still an active topic of ongoing investigation that attracted even more attention after the observation of giant Rydberg excitons with principal quantum numbers up to n = 25 by Kazimierczuk *et al.* [5] as well as exciton-polaritons in a $SiO_2/Ta_2O_5/Cu_2O/Ta_2O_5/SiO_2$ Fabry-Pérot cavity by Orfanakis *et al.*[6] However it is important to note that giant Rydberg excitons and polaritons have only been observed in naturally occurring crystals of Cu_2O so further efforts into the growth of high crystal quality and purity Cu_2O are required which is important from a fundamental but also technological point of view. In this talk I will describe our activities and the challenges involved with the growth of Cu_2O via the thermal oxidation of free-standing C*u* at high temperatures e.g. 1020°C under Ar: O_2 after annealing the C*u* under Ar: H_2 [7]. The Cu_2O we obtain consists of single crystal grains with mm sizes while the surface of the Cu_2O is covered by a semi-transparent layer of 10 nm C*u*O [7]. In addition, we show that the Kirkendall voids that form in the middle of the crystal due to the bifacial oxidation of Cu may be removed easily by polishing. The Cu_2O obtained in this way exhibits clean photoluminescence at 2.1 eV in excellent agreement with density function theory calculations of the electronic band structure and is currently being optimized to observe large Rydberg excitons with principal quantum numbers of $n > 10$.

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