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Review of the doctoral dissertation of Jakub Jasinski, MSc entitled "Control of Excitonic Properties in Transition Metal Dichalcogenide based Structures"

The doctoral dissertation of Jakub Jasinski, MSc addresses a highly relevant research area concerning atomically thin structures of transition metal dichalcogenides (TMDs). This topic is compelling not only due to its fundamental research implications but also because of its promising applications in transparent, flexible optoelectronics.

In my opinion, the advanced experimental research conducted as part of this doctoral project has yielded significant new results. The thesis focuses on the possibility of controlling exciton properties by using specific characteristics of these materials and by applying external perturbations, such as stresses and electric fields, to specially prepared layered nanostructures. This work required the development of complex nanostructures, facilitated through extensive scientific collaboration with renowned research laboratories. I am confident that the doctoral dissertation of Jakub Jasinski, MSc fully deserves admission to public defense, as I will justify in detail later in the review.

The dissertation follows the classic format typical of doctoral research, comprising six chapters and, together with appendices and a comprehensive bibliography, spans 162 pages. The text is well-edited, making it engaging and accessible to readers. The figures are well-prepared and effectively illustrate key results.

Chapter 1 introduces the basic properties of transition metal dichalcogenides. It is important to highlight the substantial effort the Doctoral Candidate invested in studying and carefully selecting relevant literature. This section will be beneficial not only for understanding the results presented in the dissertation, but also as a very good overview of the topic for students and researchers in the field of 2D materials.

Chapter 2 covers the experimental techniques employed in the dissertation (light reflectivity, photoluminescence, luminescence excitation, Raman spectroscopy, and tight polarization techniques) and describes the experimental setups used for optical and electrical measurements. It also includes details on the preparation of layered nanostructures, which are essential for the PhD project. This is a well-crafted section, supported by an appropriate bibliography.

Chapter 3 investigates the effect of uniaxial stresses on the emission associated with charged exciton recombination in MoS_2 monolayers. Uniaxial stress was applied using GaAs nanomembranes onto which an MoS_2 layer was deposited. The stress distribution within the MoS_2 monolayers was correlated with their optical properties, showing that Raman and exciton reflectivity measurements yielded consistent strain values resulting from the interaction of the MoS_2 monolayer with the GaAs nanomembranes. The most notable result in Chapter 3 is the observed lifting of charged exciton degeneracy which resulted in polarization anisotropy of the charged exciton emission. This unexpected finding was attributed to the polaronic Fermi nature of excitons in the TMD, a fascinating result supported by theoretical calculations. I agree with the Doctoral Candidate that strain-induced linear polarization could be used in various device applications.

Chapter 4 presents an in-depth study of valley polarization in two structures: the WSe_2 monolayer and the $WSe_2/(BA)_2PbI_4$ heterostructure. In both cases, the observed valley polarization was convincingly attributed to a coherent, resonant transfer of excitons between valleys via Dexter-type mechanisms under circularly polarized excitation. The findings indicate that efficient spin transfer from TMDs to other 2D materials is achievable. The results demonstrate the candidate's strong experimental skills and ability to work effectively with theoretical groups.

Chapter 5 focuses on tuning excitonic properties using structures that allow efficient electrical gating of $MoSe_2$ bilayers. The main result in this chapter is the observation of quadrupole exciton states, supported by theoretical calculations. These calculations suggest that the properties of quadrupolar excitonic states can be effectively modulated by an external electrical bias. This result emphasizes the importance of coupling mechanisms such as charge carrier tunneling and dipolar exchange coupling in understanding excitonic behavior in $MoSe_2$ bilayers. The observed tunability of excitonic properties highlights the potential of TMD bilayers as a platform for studying many-body phenomena under electric field control. I believe this is the dissertation's most significant result, laying a foundation for further research into exciton interactions within many-body systems. I would be interested to hear the Doctoral Candidate's perspective on the possibility of achieving exciton condensation in layered TMD structures.

It is worth noting that some of the results of the doctoral research have already been published, and Jakub Jasiński, MSc is the first author of these articles. The publications include: "Strain induced lifting of the charged exciton degeneracy in monolayer MoS2 on a GaAs nanomembrane" in 2D Materials 9, 045006 (2022), and "Control of The Valley Polarization of Monolayer WSe2 by Dexter-like Coupling" in 2D Materials 11(2), 025007 (2024). A third article, "Quadrupolar Excitons in Natural MoSe2 Bilayers," is currently under review, published as arXiv:2407.18040 [cond-mat.mes-hall] (2024). These are high-quality publications. The first article has been already cited six times, indicating a strong reception within the scientific community.

In addition to these three papers directly related to the dissertation, Jakub Jasiński, MSc has published two additional articles in renowned journals. Jointly, his publications have been cited 12 times (excluding self-citations), resulting in an H-index of 3 - a good achievement, given that the publications span only 2021-2024.

It is also worth noting that Jakub Jasiński, MSc presented his PhD-related findings in oral presentations - three times at the Flatlands - Beyond Graphene conference (2022, 2023, 2024) and once at the International School & Conference on the Physics of Semiconductors "Jaszowiec 2022." Additionally, he presented five posters at international conferences, demonstrating that his work has been well-regarded by the scientific community. Jakub Jasiński, MSc has an in-depth knowledge of the literature, evidenced by the extensive bibliography of over 300 items, comprising original articles published in specialized scientific journals and carefully selected to support the thesis.

In conclusion, I believe this dissertation offers an original solution to a scientific problem and demonstrates Jakub Jasinski's broad theoretical understanding in the physical sciences. The candidate skillfully applies advanced experimental techniques and effectively utilizes various methods for data analysis, interpreting results based on established theoretical models. In my opinion, he has reached the level of a mature scientist, capable of conducting independent scientific work.

In view of the above, I request that Jakub Jasiński, MSc, be admitted to the public defense of his doctoral dissertation. Given the quality of the experimental results and their in-depth theoretical analysis, I believe that the dissertation fully deserves distinction.