CrSBr: A New Frontier for Magneto-Exciton Control

Imagine materials so thin they're essentially two-dimensional, yet they possess fascinating properties like magnetism and light emission that we can control with unprecedented precision. This is the realm of 2D van der Waals materials, a frontier in modern physics that promises revolutionary advancements in electronics, optics, and even quantum computing. Our project dives deep into one such remarkable material: **CrSBr**, a layered semiconductor with unique magnetic properties that are intricately linked to its light-emitting behavior.

Since the groundbreaking discovery of graphene, the world of 2D materials has exploded, revealing metals, semiconductors, insulators, and superconductors, all in atomic-scale forms. A more recent, equally exciting discovery has been the realization of magnetism in these incredibly thin layers, defying long-held scientific beliefs. These 2D magnets offer a perfect playground for exploring magnetism at its most fundamental limit.

CrSBr stands out in this family. It's an antiferromagnet (meaning its tiny internal magnets align in opposing directions between layers) but, unlike many other 2D magnetic materials, it's remarkably stable in air, making it practical for real-world applications. What makes CrSBr truly special is the strong connection between its magnetic state and how it interacts with light. We can actually "read" its magnetic configuration just by looking at how it glows!

However, despite its immense potential, our understanding of CrSBr's light-emitting properties – specifically, its "excitons" (tiny packets of energy that transform in to photons in light emission process and are created in light absorption process) – is still in its early stages. Scientists don't even agree on basic properties like how strongly these excitons are bound, or how they interact with the material's magnetism. Crucially, we lack strategies to actively control these properties using light or magnetic fields. This project aims to change that.

Our overarching goal is to fundamentally understand and master the unique coupling between magnetic and excitonic states in CrSBr and its chemically modified versions (alloys with Chlorine, forming CrSBr(Cl)). By doing so, we aim to gain unprecedented control over these properties in this novel 2D magnetic semiconductor.

To achieve this, we will undertake cutting-edge experiments, including studies in extremely powerful magnetic fields, up to 90 Tesla – far stronger than typical laboratory magnets. Through this ambitious research, we will:

1. **Develop new optical "probes"**: We will find ways to use light to precisely map out the material's magnetic states.
2. **Establish new methods for manipulating excitons**: We will devise techniques to control how excitons behave by leveraging the material's magnetic order.
3. **Demonstrate active control**: We will show how to actively tune CrSBr's magnetic and light-emitting properties using three key approaches: chemical modification (alloying with Chlorine), applying electric fields, and cleverly designing the substrate the material sits on.

The success of this project will unlock CrSBr's vast potential for both fundamental scientific discovery and a wide range of technological applications, paving the way for integrating magnetic functionalities into the world of 2D devices, such as revolutionary spintronics