In 1907, Pierre-Ernest Weiss suggested the existence of “**Magnetic Domains**” in ferromagnetic materials: distinct regions where the magnetization is oriented in the same direction. Since then, our knowledge of domains has grown significantly: we now know that they arise spontaneously because energy lowers with elimination of “**stray-fields**”, that is, magnetic fields flowing out of objects. The formation of magnetic domains is one frequent way by which nature cancels those stray-fields. However, the magnetization cannot change direction abruptly between two near points that belong to distinct but neighboring domains. For this reason, there usually is a narrow strip of space between domains where the magnetization reorients smoothly: this region is called a “**Domain Wall**”.

The presence of a domain wall increases the energy mainly in two ways: first, the “**Exchange Energy**” measures the cost of bending the magnetization across the wall; second, as it reorients within the wall, the magnetization will necessary point in unfavorable directions that have a large “**Anisotropy Energy**”. As a consequence, inside any magnetic object the size and number of domains are determined by the competition between these two effects: energy reduces by domain creation and increases by domain wall presence.

Magnetic domains are also found in another class of materials called **ferrimagnets (FI)**. Microscopically, ferrimagnets consist of two sublattices with opposite orientations of magnetic moments (see Fig. 1). Because the moments of the two sublattices counteract but not exactly cancel each other, ferrimagnets typically exhibit spontaneous magnetization in the same direction of the lattice that “dominates”. Scientists preparing ferrimagnets can set the “domination” (i.e. which sublattice dominates) by tuning the concentartion of atoms from different sublattices.

This project focuses in one class of **FI**: **Transition-Metal and Rare-Earth (RE-TM) layered systems.** Our team can tune the *global* concentration of films made of these materials and select the domination. In other words, we can make either TM dominated films (TM+) or RE dominated films (RE+). Our latest efforts are oriented to *locally* achieve this same level of control. Our very recent results are an important step in that direction: using ion bombardment on RE+ thin films, we can create two-dimensional patterns that are TM+.

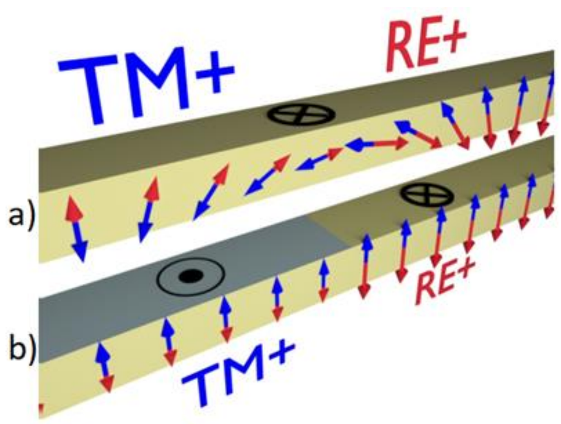

Figure 1: Magnetic configuration on the border between TM+ and RE+ areas: a) the effective magnetization points down in both areas (symbol ⊗) and there is a domain wall on the border between areas, b) The magnetization of the TM+ area points up (symbol ⊙) and there is no domain wall on the border between TM+ and RE+ areas. Red and blue arrows indicate RE and TM sublattices, respectively.

The most striking result was that, precisely at the boundary between the bombardment-made pattern and the matrix, a unique state breaks the conventional concurrence of domain-formation and domain-wall existence. More precisely, we created a situation where setting a mono-domain state requires the presence of a domain wall (Fig. 1a); and conversely, the *creation* of a new domain where the magnetization in the TM+ pattern is opposite to that of the RE+ matrix requires the *annihilation* of a domain wall (Fig. 1b).

These previous studies were performed in $(Tb/Co)_6$ multilayers bombarded with 10 keV He^+ ions through a mask made with optical lithography. In this project we intend to fabricate artificial FI for use in different applications, e.g. controlled propagation of spin waves, magnetophoresis devices, and information technologies that rely on controlled propagation of magnetic domain walls. It is important to identify the optimal patterning method for the FI layer using various figures of merit, such as: minimum resolution attainable and durability of magnetic properties. This requires an appropiate choice of layered system and the optimization of the ion modification process towards higher resolutions. For this purpose, masks will be manufactured by various methods and types of ion beams. As an alternative method to ion bombardment, we will deposit ferrimagnetic materials on ferromagnetic islands using the state-of-the-art fabrication equipment available in our laboratory.

Successful results from this project may prompt a paradigm shift in the current understanding of the relationship between domain and domain walls. They also have profound technological consequences because in our situation there is no competition between the aforementioned contributions to the energy. Thanks to this, the state of multiple domains without domain walls is very stable and it might be possible to reduce domain sizes well below the limits reachable with ferromagnets. This is the core objective of this project: to defy the current miniaturization limits by taking advantage of these newly found structures. It is hard to overestimate the tremendous impact on high-density magnetic memories if our efforts beat present records.