Current-induced Bistability and Dynamic Range of Microwave Generation in Magnetic Nano-structures

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We give a simple picture of magnetization dynamics in magnetic multi-layers under the action of spin-polarized current. Based on the idea that the main effect of the current I is the creation of negative damping $GI_{-} = {}_{-} - sI$, we explained both the current-induced bistability and microwave generation in a finite range of currents. In the absence of current the magnetization vector in a "free" layer of a magnetic layered structure has at least two equilibrium orientations: one stable ("bottom" state), corresponding to the minimum of the magnetic energy and one unstable ("top" state), corresponding to the maximum of the energy. Since the effective damping created by spin-polarized current is negative, at a certain critical current $I_{c-} = {}_{-}G/s$ the total effective damping $Gtot_{-} = {}_{-}G_{-} + {}_{-}GI$, where G is the natural positive damping, could become negative not only for the "bottom" state of magnetization orientation, but also for the "top" state. When that happens the "bottom" (initially stable) state loses itsstability, while the "top" (initially unstable) state, in contrast, becomes stable. The change of stability for each state happens, in general, at the different values of current. The "bottom" state becomes unstable at $I_{c-} = {}_{-}Imin$, thus allowing precession of magnetization with microwave frequency, while the "top" state becomes stable at $I_{c-} = {}_{-}Imax$, thus stopping any magnetization precession. If $I_{min-} < {}_{-}I_{max}$ there exists a finite range $I_{min-} < {}_{-}I_{-} < {}_{-}I_{max}$ of currents in which the system demonstrates microwave oscillations of magnetization. In the opposite case $Imin_{-} > {}_{-}Imax$ the precessional dynamics could not exist at all, and with the current variation in the interval $I_{min-} < {}_{-}I_{-} < {}_{-}I_{max}$ the system becomes bistable, i. e., it switches between two stable states corresponding to the minimum and maximum of the magnetic energy. We derived simple analytical expressions for both threshold currents $Imin$ and $Imax$ and compared our results with available experimental data.