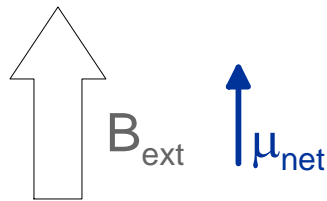
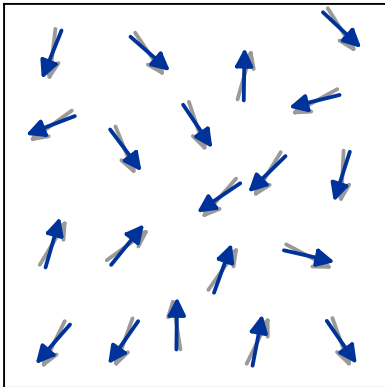
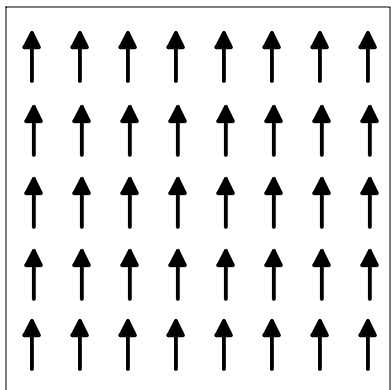


$$B_{\text{ext}} = 0, \mu_{\text{net}} = 0$$

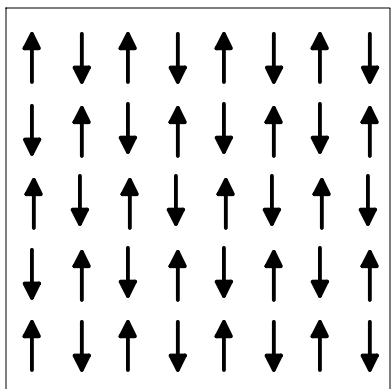
no external magnetic field:
thermal agitation randomizes
the direction of the
magnetic moments



external magnetic field :
exerts a torque on the
magnetic moments and turns t
hem slightly into a direction
parallel to the external field B_{ext}

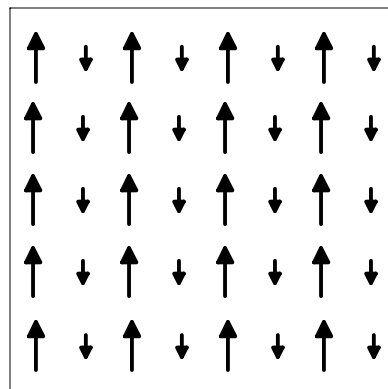


ferromagnet

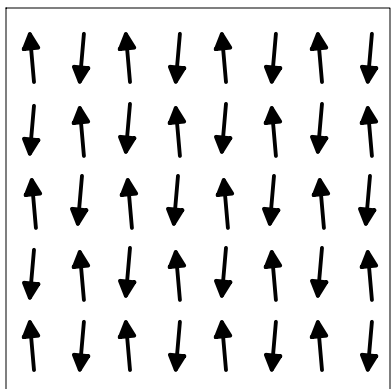


$$\mu_{net} = 0$$

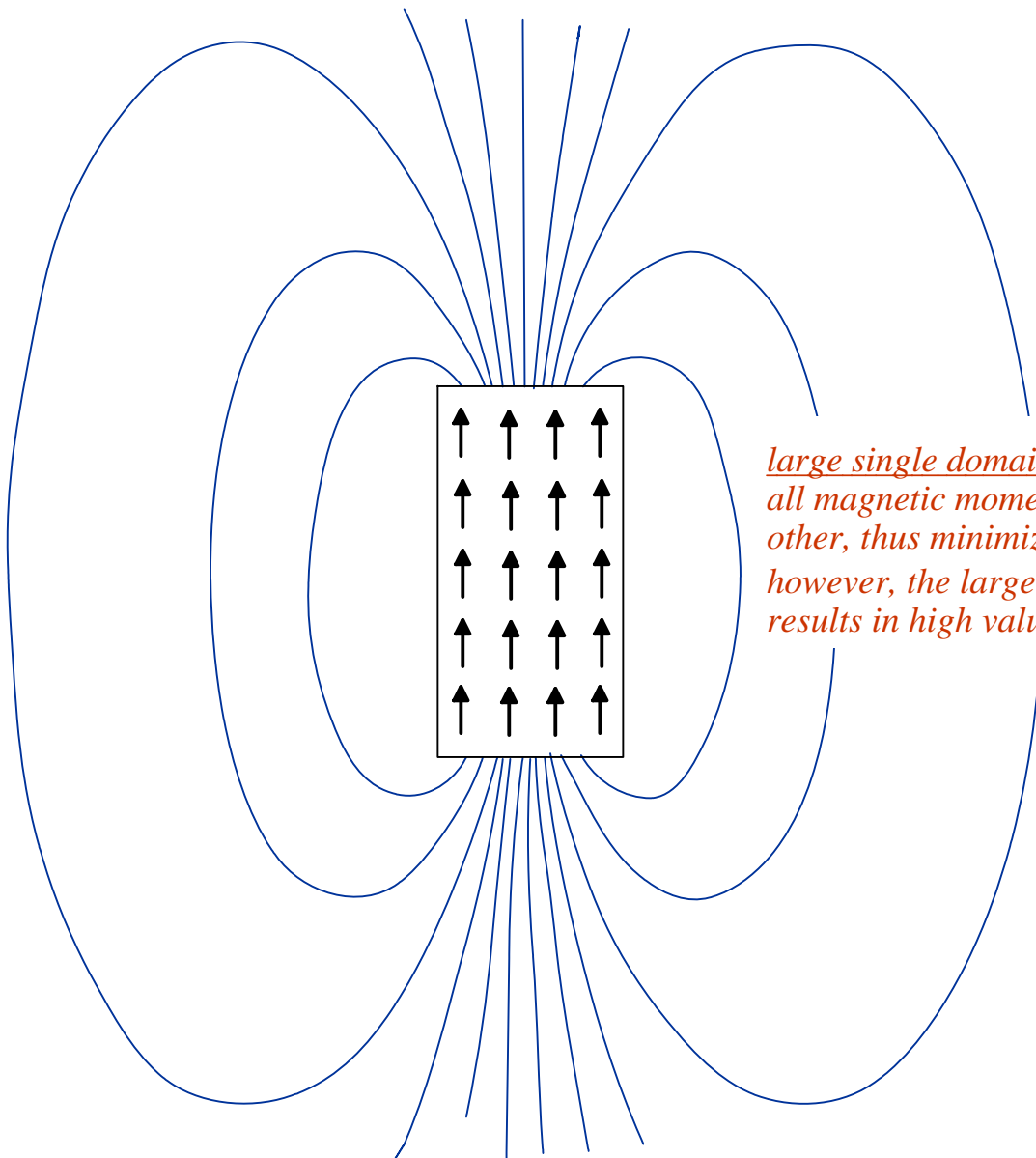
antiferromagnet



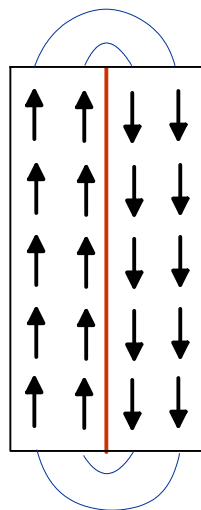
ferrimagnet



*spin canted
antiferromagnet*



large single domain grain:
 all magnetic moments are parallel to each other, thus minimizing U_{exch}
 however, the large external magnetic field results in high values for U_{field}



two-domain grain:
 dividing the same grains into two magnetic domains results in a slight increase in U_{exch} as some magnetic moments at the domain wall are not parallel to their neighbors, but also decreases the potential energy U_{field} associated with the grain's external magnetic field

superparamagnetic (SP)

single-domain (SD)

pseudo-single-domain (PSD)

multi-domain (MD)

approx.
grain diameters:

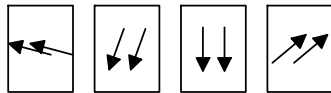
0.025 μm

0.25 μm

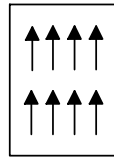
10 μm



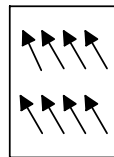
magnetic moments parallel to each other but thermal fluctuations prevent stable remanence



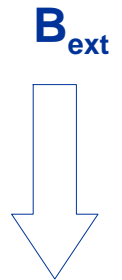
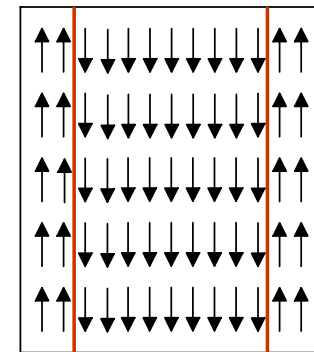
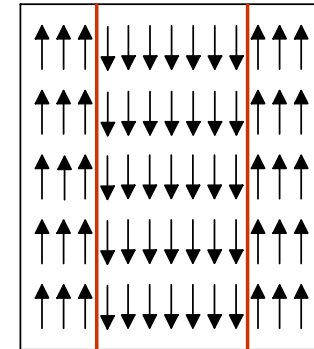
when exposed to an external magnetic field, the magnetization of SP grains will tend to line up parallel to the external field, but thermal noise is still preventing a stable magnetization direction



grain homogenously magnetized along an easy axis of magnetization grain volume large enough that $U_{aniso} > U_{thermal}$

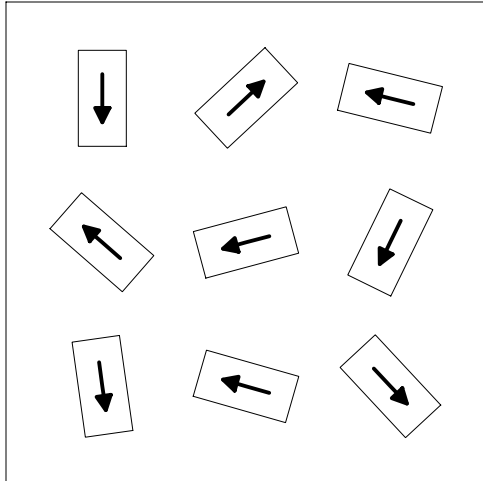


to remagnetize a SD grain requires the roatation of all magnetic moments



particles have magnetic properties characteristic of both SD and MD grains

MD grains respond to an external magnetic field through domain wall movements



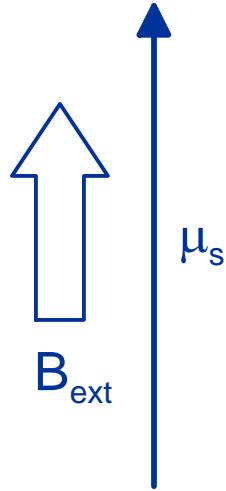
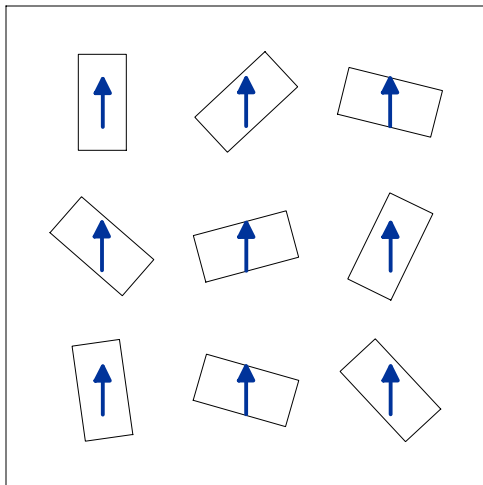
$$\mu_{\text{net}} = 0$$

*"easy axis"
of magnetization
parallel to long grain axis*

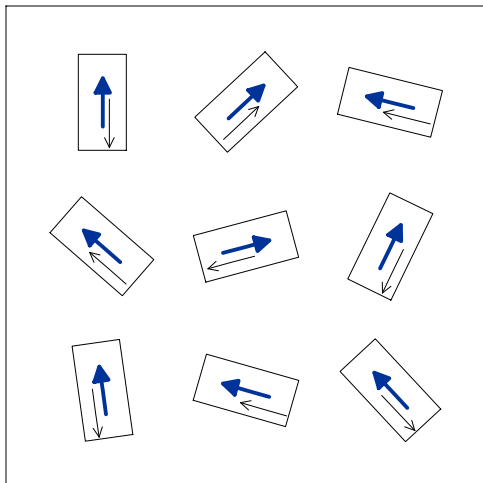


*"hard axis"
of magnetization*

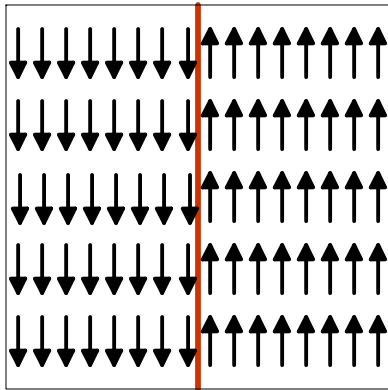
*assemblage of small SD grains
with shape anisotropy
all grains magnetized along their
preferred axis of magnetization
("easy axis")*



*external magnetic field
rotates magnetic moments out of
their preferred directions and
parallel to the external field*

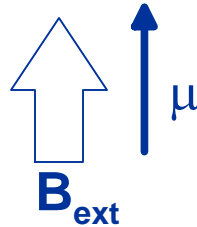
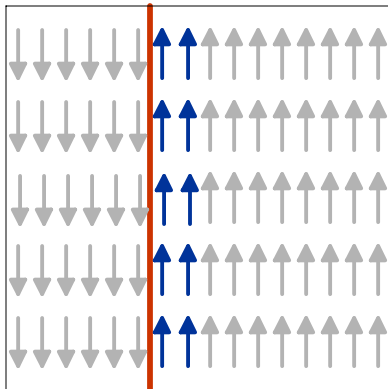


*once the sample is in zero field
the magnetic moments relax
into a direction parallel to
the closest easy axis*

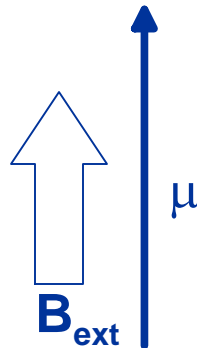
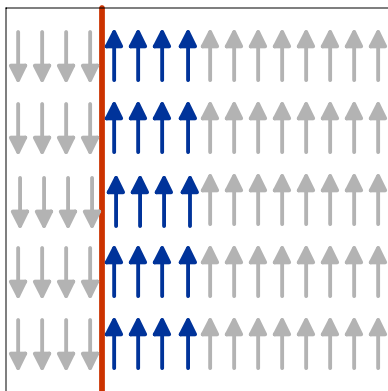


$$\mu_{\text{net}} = 0$$

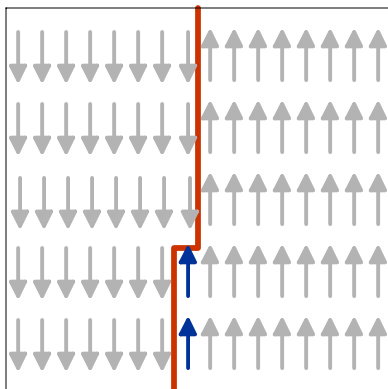
demagnetized state:
both domains have the same size,
net magnetic moment is zero



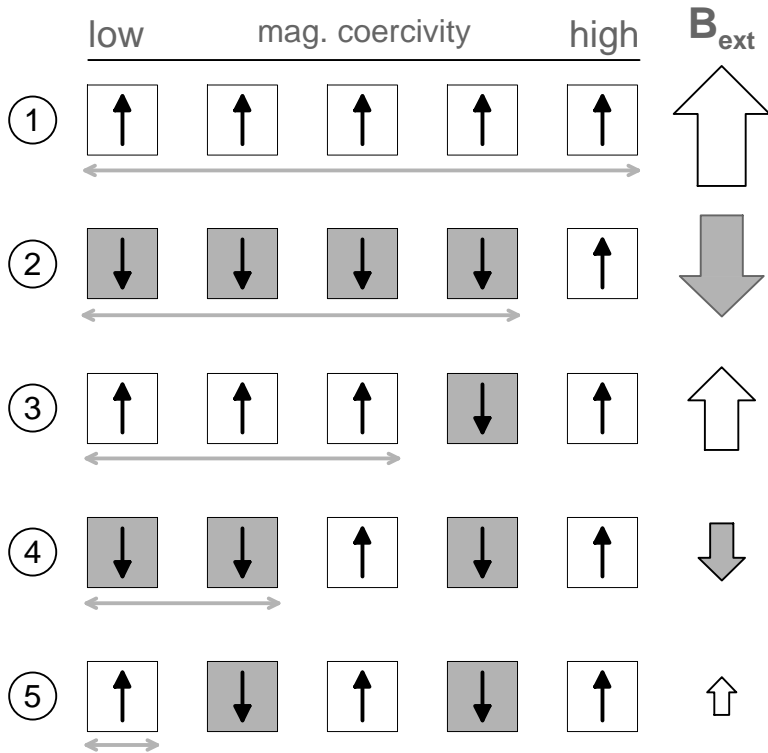
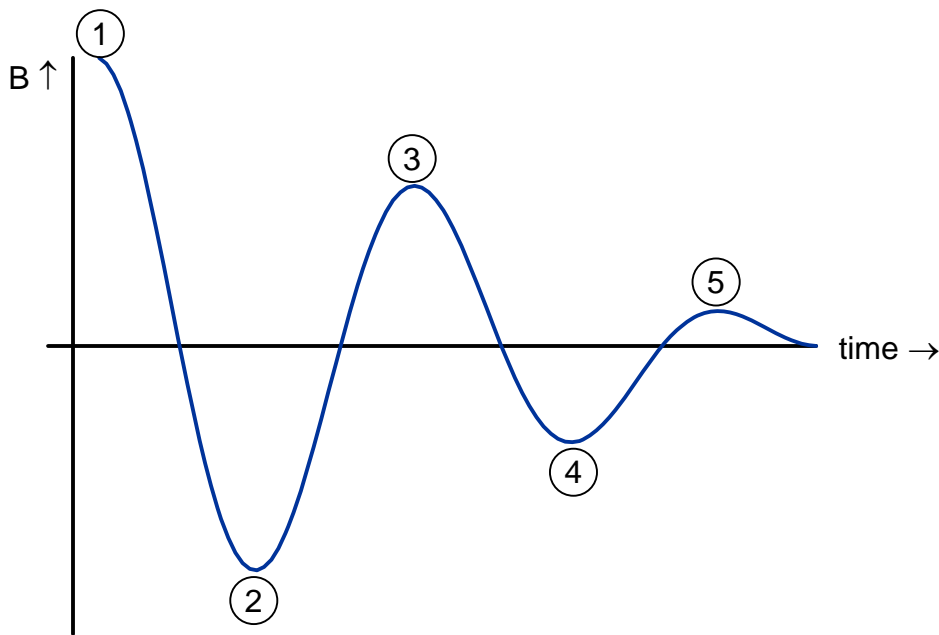
weak external field:
exposure to a weak external
magnetic field drives the domain wall
to the left as the "up" magnetized domain
grows
the two domains are now of unequal size,
and the grain displays a net magnetic moment μ
parallel to the external field



with increasing field the
domain wall moves farther to the left
and the net magnetic moment μ of
the grain grows further



remanence state:
once the external field is zero again
the domain wall moves back towards
its initial position.
however, some magnetic moments fail
to remagnetize and remain magnetized in
the "up" position, the grain carries a
small magnetic remanence μ_r



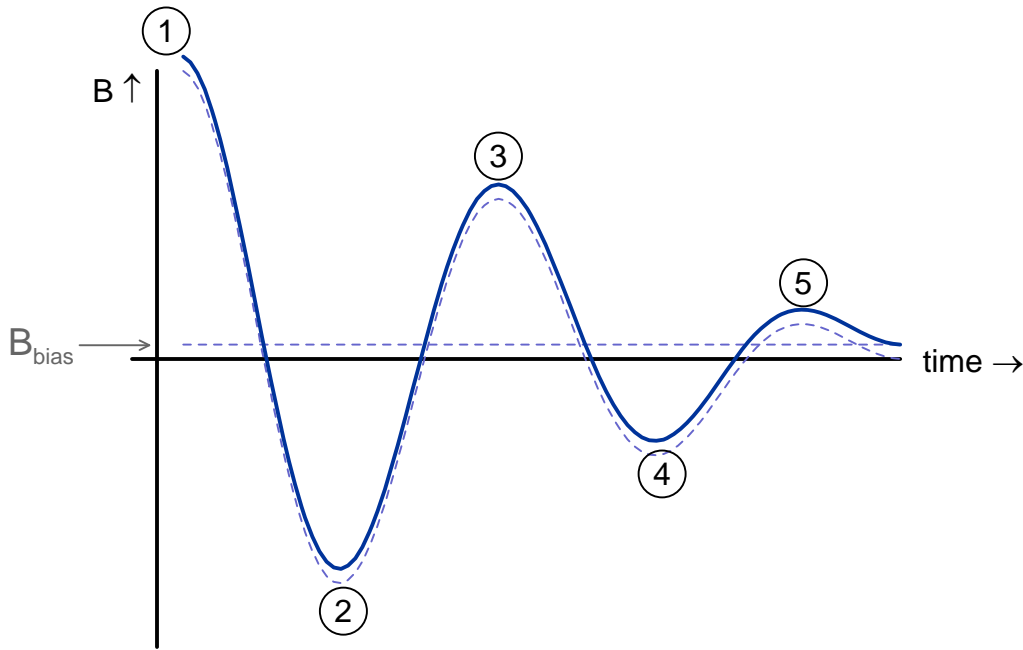
demagnetization of five idealized grains:

B strong enough to remagnetize all grains

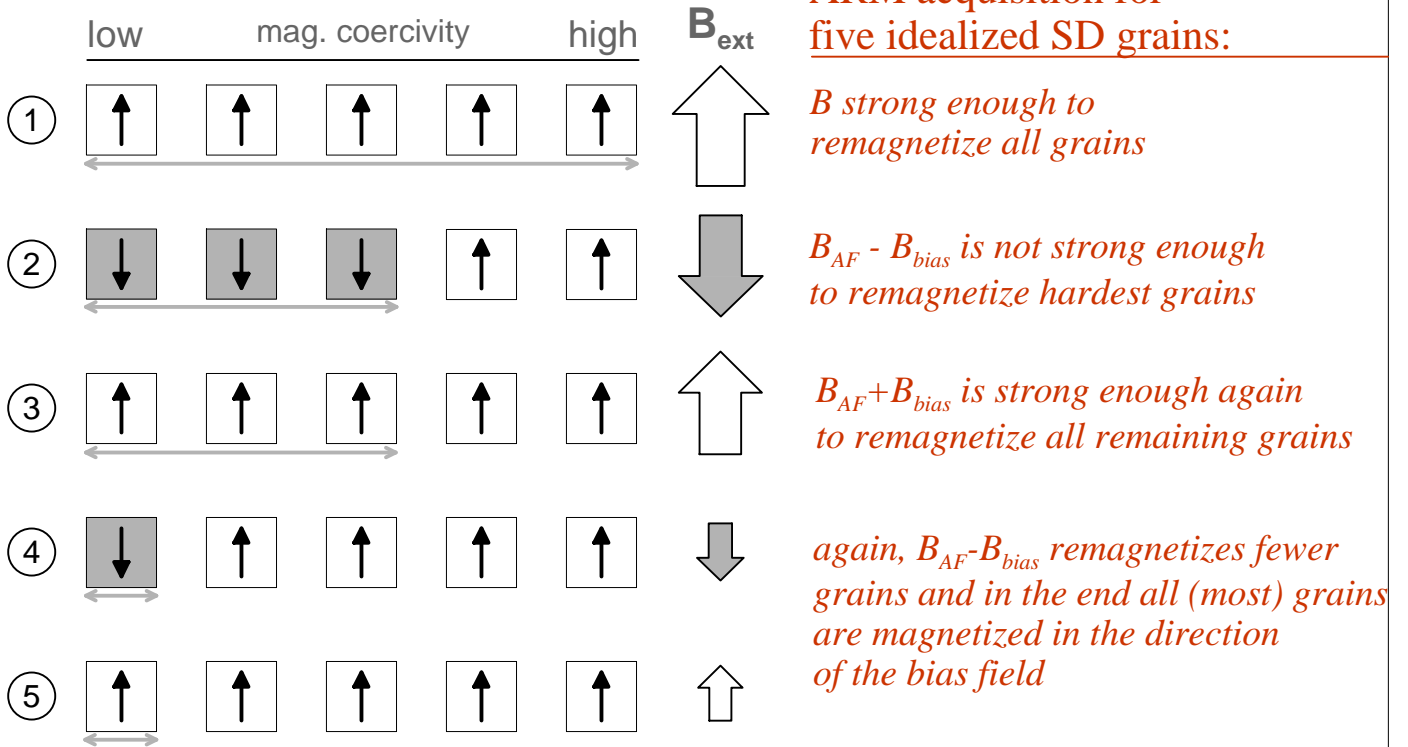
reversed field too weak to remagnetize high-coercivity grains

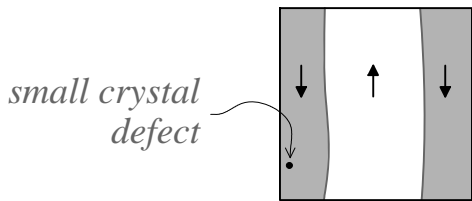
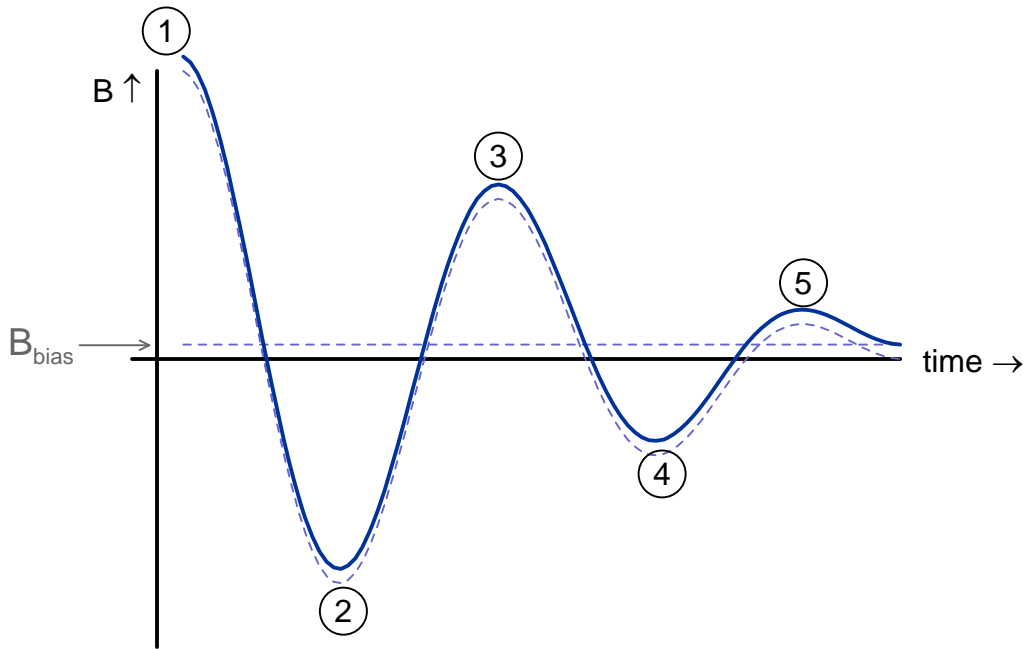
with decreasing field amplitude fewer and fewer grains are affected by alternating field

at the end of demagnetization process approximately half the grains are magnetized "up", the other half is magnetized "down" and the net magnetization is zero



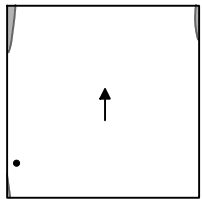
ARM acquisition for five idealized SD grains:





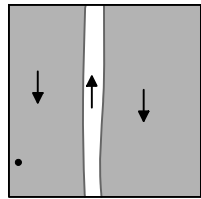
*demagnetized state:
"up" and "down" domains
cancel*

*nearly saturated state
domain wall driven
past defect*



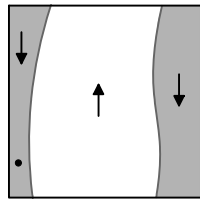
①

*reversed field strong
enough to move wall
across defect*



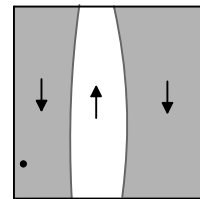
②

*with decreasing field strength
domain wall does not cross
defect any longer*

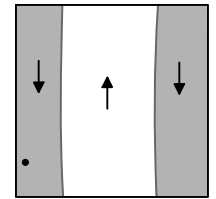


③

*as field amplitude decreases
further grain settles into a
(nearly) demagnetized state*

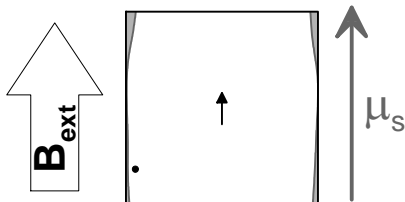


④

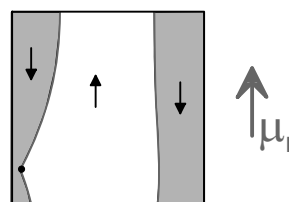


⑤

for comparison: IRM acquisition



*saturated state:
downward magnetized domains
are driven to the edge of the grain,
grain displays large magnetic
moment*



*remanence state:
upward magnetized domains expand
towards the center of the grain,
but one domain wall is pinned,
and grains retains a small magnetic remanence*