New type of magnetic domains in multisublattice antiferromagnets

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With UO_2 as an example, a new type of domain walls is indicated, separating phases in which the spin orientations cannot be made congruent by continuous rotation. These walls always have microscopic (atomic) thickness.

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It is well known that the Bloch walls between domains are of macroscopic thickness. Inside the wall, the magnetization is continuously turned from the orientation in the interior of one domain to the orinetation in the other domain. This always takes place in ferromagnets and in two- and three-sublattice antiferromagnets, in which all the spaces that are in equilibrium can be transformed into one another by continuous rotation.

The situation changes in antiferromagnets with 4 or more sublattices, when phases that cannot be transformed into one another by rotation can in principle be in equilibrium. We consider the antiferromagnetic UO_2, the magnetic structure of which was recently finally established by Faber and Lander.[1] This structure was theoretically described in our preceding papers (see[2], and in particular[3]).

In the paramagnetic phase, UO_2 is a cubic phase-centered crystal (group $Fm3m-O_h^5$). In the antiferromagnetic phase it has a 4-sublattice structure consisting of four cubic lattices made up respectively by ions in the site and

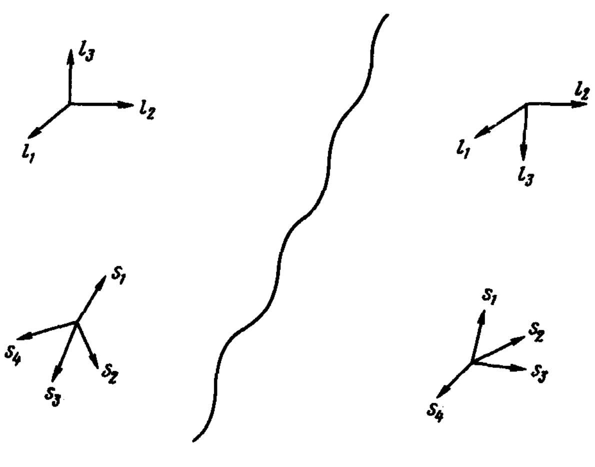

FIG. 1.

in the centers of the faces 000, $0\frac{1}{2}\frac{1}{2}$, $\frac{1}{2}0\frac{1}{2}$, and $\frac{1}{2}\frac{1}{2}0$, which have respective spins $\mathbf{s}_1$, $\mathbf{s}_2$, $\mathbf{s}_3$, and $\mathbf{s}_4$ which are of equal length but are not collinear. Mathematically this structure is described by three "antiferromagnetism vectors"

$$\mathbf{l}_1 = \mathbf{s}_1 + \mathbf{s}_2 - \mathbf{s}_3 - \mathbf{s}_4, \qquad \mathbf{l}_2 = \mathbf{s}_1 - \mathbf{s}_2 + \mathbf{s}_3 - \mathbf{s}_4,$$

$$\mathbf{l}_3 = \mathbf{s}_1 - \mathbf{s}_2 - \mathbf{s}_3 + \mathbf{s}_4$$

and by the spontaneous moment

$$\mathbf{m} = \mathbf{s}_1 + \mathbf{s}_2 + \mathbf{s}_3 + \mathbf{s}_4 .$$

In the antiferromagnetic state of UO_2 it is understood that $\mathbf{m} = 0$ and

$$l_1 = l_2 = l_3, \quad \mathbf{l}_1 \perp \mathbf{l}_2 \perp \mathbf{l}_3 .$$

The sublattice spins are then directed along four different body diagonals of the cube:

$$\mathbf{s}_1 \sim [111], \ \mathbf{s}_2 \sim [1\bar{1}\bar{1}], \ \mathbf{s}_3 \sim [\bar{1}1\bar{1}], \ \mathbf{s}_4 \sim [\bar{1}\bar{1}1].$$

Besides the structure described by the "reference frame" $\mathbf{l}_1$, $\mathbf{l}_2$, $\mathbf{l}_3$, there exists a structure having the same energy and specified by the reference frame

$$\mathbf{l}_1, \mathbf{l}_2, -\mathbf{l}_3 ,$$

where

$$\mathbf{s}_1 \sim [11\bar{1}], \ \mathbf{s}_2 \sim [1\bar{1}1], \ \mathbf{s}_3 \sim [\bar{1}11], \quad \mathbf{s}_4 \sim [\bar{1}\bar{1}\bar{1}] .$$

These two phases cannot be obtained from each other by continuous rotation. Therefore the domain wall that separates them cannot be a Bloch wall (see Fig. 1). It has microscopic thickness and a surface energy $\sigma \sim T_N/d^2$, where T_N is the Neel temperature, and d is the interatomic distance.

We note that owing to its atomic thickness, such a wall will be pinned by any defect of atomic dimension, especially by local displacements of the oxygen atoms (for details see[1,3]).

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