Domain-acoustic echo in Ni-Cu ferrite

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It has been shown experimentally that a domain-acoustic echo is produced at a frequency of 30 MHz in a polycrystalline ferrite of composition $Ni_{0.97}Cu_{0.03}Fe_2O_3$. The mechanism of this echo, which is characterized by an anomalously long relaxation time, is related to the displacement of domain walls.

We detected an echo in a toroidal-shaped polycrystalline ferrite sample $Ni_{0.97}Cu_{0.03}Fe_2O_3$ (with dimensions $20\times8\times8$ mm). The echo in this sample was detected by exciting in it by means of a coil 1 (Fig. 1) two 30-MHz magnetic-field pulses 0.3–15 μs in length and $\tau = 1$–$20\ \mu$s time interval between the pulses. The signal from a two-pulse echo (an auxiliary winding 2 was used to pick up the signal) was detected at a time τ after the application of the second pulse. A third ("readout") pulse of the same frequency was applied to coil 1 after an arbitrary time interval T (ranging from a few microseconds to several days or longer). At a time τ after its application, we detected a three-pulse-echo (stimulated-echo) signal. The signals from a two-pulse echo and stimulated echo are identical in amplitude and shape.

The stimulated echo signal was detected after a multiple application of the readout field pulse: We observed no change of any sort in the echo amplitude for three days after the application of the first pair of pulses to the sample.

Of the known types of rf echoes,[1] such large relaxation times are characteristic of an electroacoustic echo in powdered crystals, which can be attributed to such "storage" mechanisms as the dislocation shift, reorientation of the individual particles of

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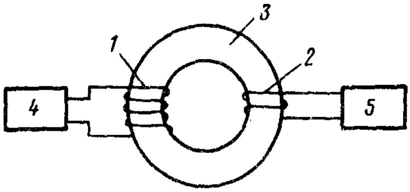

FIG. 1. Experimental arrangement. 1—Field coil; 2—pickup coil; 3—ferrite sample; 4—rf generator; 5—detector.

the powdered crystal, and the triboelectrification of these particles.[2–4] The relaxation times of the stimulated magnetoacoustic echo in ferromagnetic powders can be as high as several hours at liquid-nitrogen temperature.[5]

In contrast with Ref. 5, the echo which we have detected can be seen only if the sample is in the polydomain state. No echo is detected when single domains are formed in the sample by an external constant magnetic field. Figure 3 is a plot of the stimulated echo signal as a function of the static magnetic field which is applied to the sample by the auxiliary coil after a single excitation by the first pair of pulses. The magnetic structure which forms in the sample after the application of the first pair of pulses is destroyed completely by a >50-Oe field.

The echo-formation mechanism can, in our view, be described as follows. Because of the magnetostriction, the first field pulse excites acoustic waves in various inhomogeneities (sample's boundaries, domain walls, boundaries of the crystallites, etc.) of the sample. The nonlinear interaction of these oscillations with the magnetic field of the second pulse, the principal contribution to which apparently comes from the magnetostriction, leads to the formation of a stationary magnetic structure in the sample due to a shift in the domain walls. Because of the coercitivity of the sample, this structure remains after the conclusion of the interaction. The application of a third rf field pulse to this structure after an arbitrary time interval sets up acoustic waves in the sample which come into phase in a time τ. The phase coherence of the waves is accomplished, as in the case of other types of echo, because of the phase conjugation

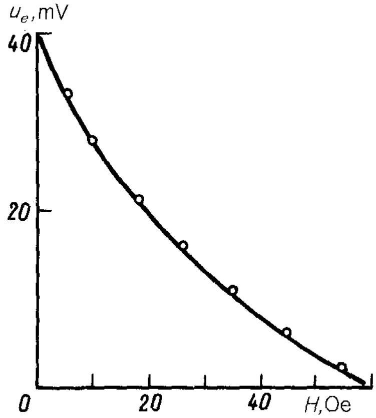

FIG. 2. Oscilloscope trace of a stimulated echo signal. 1—Stray electromagnetic pickup from the readout (third) pulse; 2—stimulated echo signal.

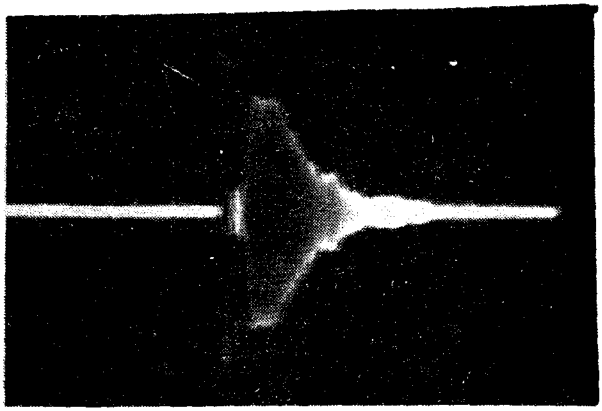

FIG. 3. Stimulated echo signal versus the "erasing" field strength.

(because of time reversal). Because of the magnetostriction, the in-phase acoustic waves induce a stimulated echo signal in the coil.

The difference between the echo formed by two pulses and the mechanism described above is that the second field pulse, which forms the stationary magnetic structure, also interacts with it and thus simultaneously generates an echo signal.

The damping of acoustic waves, which are excited in the sample by the first field pulse, reduces the amplitude of the echo signal as the time τ is increased. The damping can be observed directly by increasing the length of the first pulse (to several tens of microseconds), as illustrated by the oscilloscope trace in Fig. 2. The damping of ultrasound, calculated from the decay of the echo signal ($\sim 1\text{dB}/\mu\text{s}$), is of the same order of magnitude as that determined from direct ultrasonic measurements at the same frequency.

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