be produced either by a primary soft particle or by the cascade process for the following reasons:

(1) Any highly energetic soft particle capable of producing so many (more than 200) particles would have surely multiplied long before in the thickness of lead of 13 cm that it had to cross before it reached the third lead plate inside the chamber.

(2) This high multiplication in such a short range (less than two radiation units) is almost impossible by the cascade process.

(3) A cone of a shower produced in a direction opposite to the direction of the incident particle is not possible in a cascade process.

The shower is therefore due to some explosive process which has taken place just inside the upper surface of the third lead plate. The production of particles in almost all directions and particularly a copious number in the upward direction indicates a time lag between the incidence of the initiating particle and the occurrence of the explosion.

The nature of the particles constituting the shower is difficult to determine. The occurrence of one or two heavy nuclei inside the downward cone cannot be detected. It is, however, clear that most of the particles emitted in the upward direction are soft and of low energies as they could not penetrate the second lead plate (thickness 2 cm). Among the particles emanated in the downward direction, there are some very straight and thin tracks which appear to be highly energetic and penetrating.

We believe this picture to be unmistakable evidence of the production of soft and penetrating particles in one act by the nuclear interaction of an incident particle with a lead nucleon. There are three particles entering the chamber from above; but none of these seem to be the originator of the shower and nothing can be said with certainty about the initiating particle except that it is definitely not electronic in nature.

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* Now at the Massachusetts Institute of Technology, Cambridge, Massachusetts.

[1] B. Rossi, Rev. Mod. Phys. **21**, 104 (1949).

[2] M. S. Sinha, Phys. Rev. **64**, 248 (1943).

Study of High Polymers by Nuclear Magnetism*
I. Line Widths at Room Temperature

L. V. Holroyd, B. A. Mrowca, and E. Guth
University of Notre Dame, Notre Dame, Indiana
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QUALITATIVE observations on nuclear magnetism in rubber-like high polymers have been reported by Alpert.[1] Recently, we have obtained quantitative data on the magnetic resonance line widths of various polymers. We have also followed the line width as a function of temperature through the transition range which separates the soft, rubbery state from the hard, glassy state. (See following Letter to the Editor.)

The line widths, in gauss, at room temperature, obtained in a field of approximately 7000 gauss at about 30 Mc, are shown in Table I.

The width of 0.19 gauss represents the line width due to magnetic field inhomogeneity, determined by obtaining the line width for a water sample. Both unvulcanized natural rubber and GR-S may have, therefore, a width narrower than 0.19 gauss. The GR-S signal is perhaps slightly broader than that for natural rubber.

TABLE I. Line widths.

Sample	Unvulcanized	Vulcanized	Carbon black loaded 30%	50%
Natural rubber	≤ 0.19	≤ 0.19	≤ 0.19	
GR-S	≤ 0.19	0.27	0.57	0.67
Hycar OS-10	0.38	0.51	0.57	
Butyl rubber	0.38	0.42	0.91	
Polyethylene	0.57			
Plexiglas (at 103°C)	1.2			
S-polymer 30	1.5			
S-polymer 50	1.9			
S-polymer 75	5.8			

GR-S and Hycar OS-10 are approximately 70/30 and 50/50 butadiene styrene co-polymers respectively. The *S*-polymers 30, 50, GR-S and Hycar OS-10 are approximately 70/30 and 50/50 butadiene styrene co-polymers respectively. The *S*-polymers 30, 50, and 75 are isobutylene-styrene co-polymers, the number giving the approximate styrene content. Plexiglas is polymethylmetacrylate.

The narrowness of the line width for unvulcanized natural rubber and GR-S shows that the "free" rotation of molecules containing proton groups is about as fast in these rubbery materials as that of the protons in water. This "free" rotation must take place with a frequency much higher than that of the r-f field (30 Mc), so that the magnetic interaction of the "freely" rotating protons averages out. One expects that vulcanizing (cross linking of flexible long chains) and loading with carbon black will impede the "free" rotation, thus broadening the line as observed. One also expects increasing amounts of styrene to impede "free" rotation more and more, again broadening the line as observed in going from GR-S to Hycar OS-10 and from *S*-polymer 30 to 50 and 75. The large line widths for the *S*-polymers indicate that the "free" rotation is slowed down to a frequency comparable to that of the r-f field of 30 Mc. It seems that the method of nuclear magnetism is the first one to prove *directly* the existence of "free" rotation in polymers, a concept which was previously inferred *indirectly* from other phenomena and which forms the basis of the statistical network theory of rubber elasticity.

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[1] N. L. Alpert, Phys. Rev. **75**, 398 (1949).

Study of High Polymers by Nuclear Magnetism*
II. Line Widths through Transition Temperatures

B. A. Mrowca, L. V. Holroyd, and E. Guth
University of Notre Dame, Notre Dame, Indiana
July 10, 1950

THE polymers investigated (see preceding Letter to the Editor) exhibit in a certain temperature region a transition from the soft rubbery state to a hard, glassy state. The line width was found to increase with decreasing temperature through this transition region. For natural rubber this increase in line width was not large. However, the signal weakens so much as one approaches the transition region (−70°C) that accurate measurements of line width or shape are precluded. Since natural rubber is known to crystallize, it seems reasonable to attribute these results to crystallization or a related process which suppresses the rotation of molecular groups in a major fraction of the material. This would drastically broaden the contribution of these groups to the resonance line and correspondingly weaken it; the observed sharp resonance line would then be due to a relatively

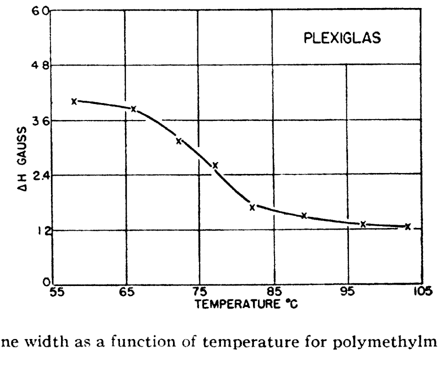

FIG. 1. Line width as a function of temperature for polymethylmetacrylate.