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May 12, 1969

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# THE ROLLING TEXTURE OF SOME PLUTONIUM-GALLIUM ALLOYS


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U.S. ATOMIC ENERGY COMMISSION
CONTRACT AT(29-1)-1106

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Available from
Clearinghouse for Federal Scientific and Technical Information
National Bureau of Standards, U. S. Department of Commerce
Springfield, Virginia 22151
Price: Printed Copy $3.00; Microfiche $0.65

May 12, 1969

RFP-1315
UC-25 METALS, CERAMICS, AND MATERIALS
TID-4500

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ACKNOWLEDGEMENTS

The author wishes to thank R. L. Moment for guidance on this work and J. E. Parker who assisted with many of the experiments.

# THE ROLLING TEXTURE OF SOME PLUTONIUM-GALLIUM ALLOYS

*J. E. Schindler*

**Abstract.** The rolling textures of Pu-0.75 wt % Ga and Pu-1.0 wt % Ga alloys were studied as a function of rolling reduction through the use of pole figures. The samples were cold-rolled to 70%, 80%, 90%, or 95% reduction. The texture of the alloys was found to be very close to that of cold-rolled copper at high reductions.

## INTRODUCTION

Deformation textures in cold-rolled sheet are normally described through the use of pole figures which show crystallographic pole density as a function of orientation in the sheet for selected crystal planes. Because textures result from particular orientations of crystallographic planes, x-ray diffraction techniques are generally used to study them. The description of a texture from a pole figure is not unique. It varies to some extent with the individual interpreter.

Preferential orientation of crystals results in a metal which is anisotropic. Anisotrophy greatly affects physical properties such as the elastic modulus. Thus, rolling textures may also be studied through changes in elastic constants such as Young's modulus (Liu and Alers, 1966). Neither pole figures nor elastic constants are adequate to fully characterize a texture. Together, studies of elastic constants and pole figures can be used to gain a more detailed understanding of preferred orientation, and perhaps a way of controlling the degree of anisotropy in rolled sheet.

This study of low-percentage plutonium-gallium alloys was begun to gather data on texture development as a function of rolling reduction and alloy composition. Of particular interest was the determination of the alloy composition for which the texture might change from the metal-type to the alloy-type: e.g., copper-type to brass-type. Such a texture transition has been observed often in copper-based alloys (Richman and Liu, 1961).

## THEORY

The plastic deformation of a polycrystalline metal produces a preferred orientation or texture. This preferred orientation comes from the alignment of certain lattice directions or sets of crystallographic planes with the rolling direction and rolling plane. Face-centered cubic (fcc) metals and alloys exhibit two distinct textures – the metal or copper-type, and the alloy or brass-type (Barrett, 1952). The fcc metal texture is normally expressed in the literature as a combination of {112} <111> and other higher index combinations, where {112} refers to a plane parallel to the rolling plane; and <111> refers to a direction parallel to the rolling direction. Several theoretical models of texture development have been presented in the literature, but none have been completely successful in describing a mechanism of texture development (Leffers and Grum-Jensen, 1968).

One of the more interesting correlations is that of stacking-fault energy with texture. Metals and alloys which have a low stacking-fault energy give an alloy-type texture upon plastic deformation which is caused by conjugate {111} <110> slip. A higher stacking-fault energy is associated with the metal-type texture which results from more complicated {111} <110> slip of the fcc system on multiple slip systems (Leffers and Grum-Jensen, 1968).

## PROCEDURE

The materials used in this study were doubly electrorefined plutonium-gallium alloys of nominally 0.75 wt % and 1.0 at. % gallium. Each alloy was melted in a tantalum crucible and cast into rectangular bars in a coated graphite mold. Small samples of each casting were analyzed by mass spectrography with the results shown in Table I.

The 0.75 wt % Ga alloy was homogenized for 300 hours at 460°C and the 1 wt % alloy for 240 hours at 500°C under a vacuum of about $10^{-6}$ torr. After homogenization the metal was stored in a freezer at about –18°C until needed. The cold-storage of the metal was to preclude any recrystallization. Recrystallization textures are very common for fcc metals and alloys. A study by Hanson and Pavlick (1965) on delta-plutonium showed that no recovery was present in Pu-1 wt % Ga samples annealed 170 hours at room temperature. Because of this work it

Table I. Results by Mass Spectrography

| | ANALYSIS | |
|---|---|---|
| Ga | 0.75 wt % | 1.0 wt % |
| Al | 1 ppm | 1 ppm |
| C | 20 | 12 |
| Ca | 1 | |
| Cl | 4 | |
| Cr | 0.5 | |
| Fe | 7 | 12 |
| Mg | 6 | 10 |
| Mn | 2 | 6 |
| Ni | 1 | |
| S | 4 | 7 |
| Si | 3 | 7 |
| Ta | 10 | 13 |
| U | 20 | 20 |
| W | 30 | 30 |
| Zn | 3 | 25 |
| All others | 15 | 23 |
| Total ppm by weight | 125 | 166 |

is fairly certain that only deformation texture due to cold work is present in the samples.

Rolling was done on a two-high rolling mill, with oil as a lubricant to minimize friction on the rolls. The draft per pass was 0.030 in. except for the final sizing passes. The metal was rolled in one direction to a reduction of 30%, rotated 90°, and rolled in this new direction only until reductions of 70%, 80%, 90%, and 95% were achieved.
Disks about 0.9 in. in diameter were cut from the rolled sheet with a saw. Exceptions were the random samples which were machined from the ends of the homogenized ingots. The samples were then mounted on plastic holders, mechanically ground and polished. Mechanical grinding and polishing transformed some of the delta-phase plutonium into alpha-phase plutonium. This problem was found by x-ray diffractometer scans which were then incorporated into the procedure to check the samples. The diffractometer scan indicated a composition of about ⅓ alpha-plutonium and ⅔ delta-plutonium, however, the problem was confined to a very thin layer (about 0.002 in.) of the surface. Electropolishing the sample surface before a texture run appeared to remove any detectable trace of alpha-plutonium. The electropolish was done with a solution, 8 parts $H_3PO_4$, 4 parts 2-ethoxyethanol, and 4 parts ethylene glycol, using 20 volts and 2 amps. The first 4 samples were repeatedly ground, polished and run until the texture diffraction pattern showed little or no change. The sample thickness at this point was about ½ the original thickness. Thus later samples were ground initially to within 5 mils of the center of the rolled sheet before electropolishing.

A Siemens texture goniometer and Picker x-ray equipment were used in the analyses. The line focus of the x-ray tube was used because of the equipment design. Nickel-filtered copper K$\alpha$ radiation was used exclusively for all measurements. Detection was by a scintillation counter whose output was connected to a pulse height analyzer set to remove any gamma radiation from the sample. Records of the runs were made on a Brush strip chart recorder. Plotting of the pole figures was done by hand.

Background intensity was found to be very small, thus no background corrections were introduced on the records. The intensity data from the texture samples were expressed as a multiple of a random intensity. The random intensity was determined by running a cast, homogenized sample.

To maintain a complete containment of the metal and its oxide, the samples were backed with a plastic tape and covered with a Mylar film. Tests showed no correction needed to be made for the Mylar film in the x-ray path.

Only the central portion of the pole figure was plotted, 0°-75° (where 0° is the center of the pole figure) because the high absorption of x-rays by plutonium precluded using transmission to obtain the outer 15°.

## RESULTS AND CONCLUSIONS

The rolling textures of plutonium 0.75 wt % and 1.0 wt % gallium alloys with thickness reductions of 70%, 80%, 90%, and 95% were studied using (200) and (111) pole figures. These alloys exhibit a typical face-centered cubic (fcc) texture of the copper-type. For comparison, the (111) pole figure for copper rolled 99% is shown in Figure 1 (Goodman and Hu, 1968). Figure 2 for Pu-0.75 wt % Ga and Figure 3 for Pu-1 wt % Ga, show the (111) pole figures for reductions in thickness from 70% through 95%.

A very rapid development of the metal-type texture is found in the pole figures in the 70%-80% range; the 70% figure shows little in the way of definite texture while the 80% figure shows a more developed

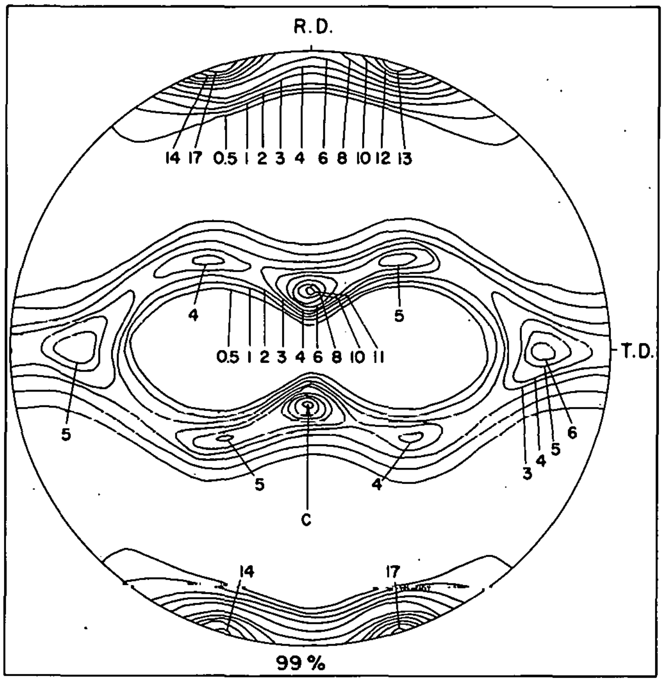


**Figure 1. Texture of polycrystalline copper rolled 99% reduction, determined from the (111) reflection (Goodman and Hu, 1968).**

characteristic texture. Pole figures of the 90% and 95% reductions show continuing advancement of the texture.

The (200) pole figures, Figures 4 and 5, present essentially identical observations. The figures show only the pure-metal-type texture.

Preferred orientations for fcc metals and alloys having the copper-type texture have been expressed in the literature as basically {358} <523> (Liu and Alers, 1966). Orientations in the plutonium-gallium alloys studied appear to be no different from other fcc alloys with a copper-type texture.

Since these two gallium-stabilized delta-plutonium alloys have a similar rolling texture to that of copper, it might be concluded that the slip mechanism in these alloys is similar to that of copper.

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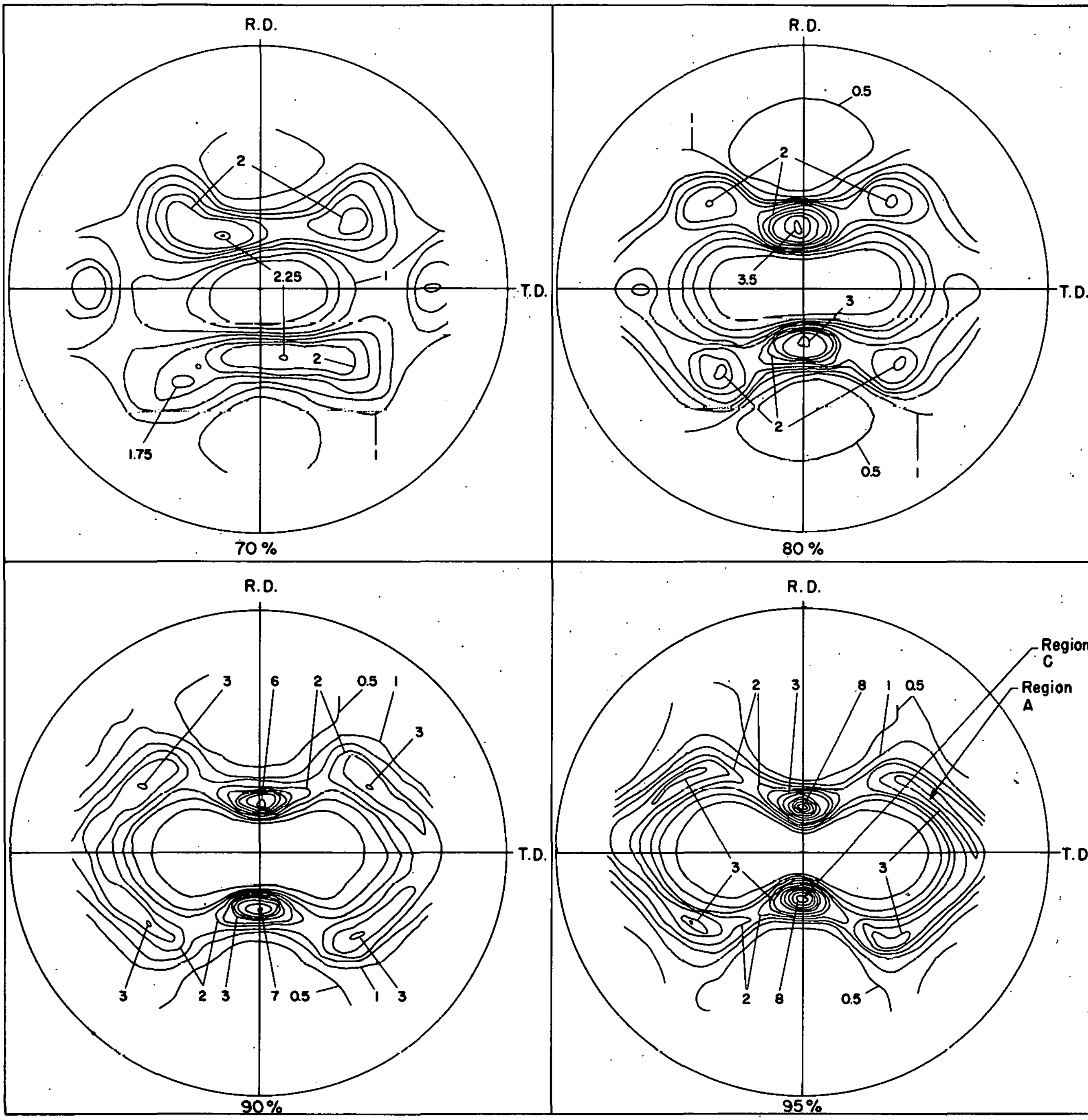


Figure 2. Texture of polycrystalline plutonium-0.75 wt % gallium alloy rolled 70%, 80%, 90%, and 95% reduction, determined from the (111) reflection.

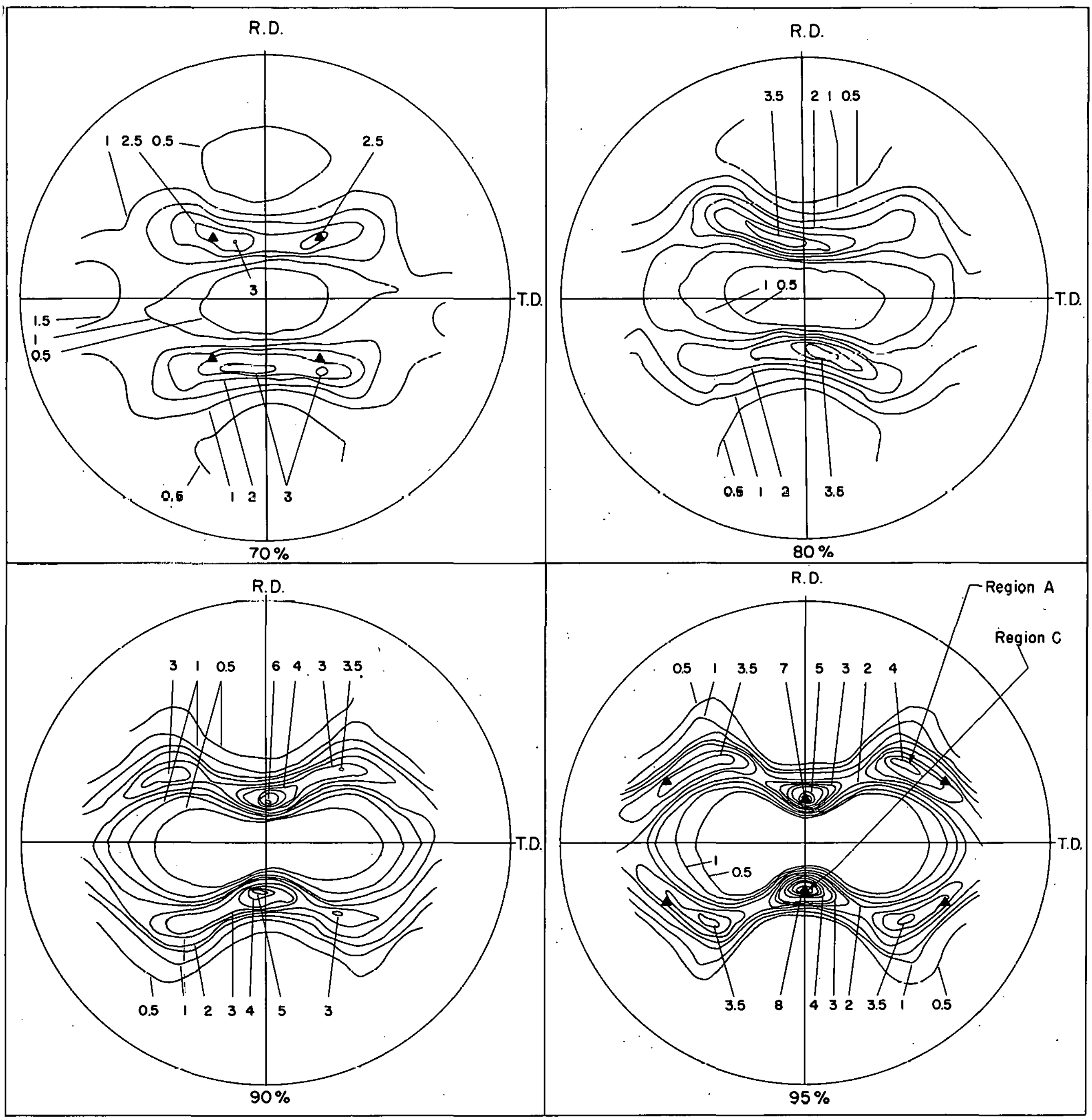


**Figure 3. Texture of polycrystalline plutonium-1.0 wt % gallium alloy rolled to 70%, 80%, 90%, and 95% reduction, determined from the (111) reflection. The triangles in 70% rolled correspond to (110) <112>, and in 95% rolled to correspond to (112) <111>.**

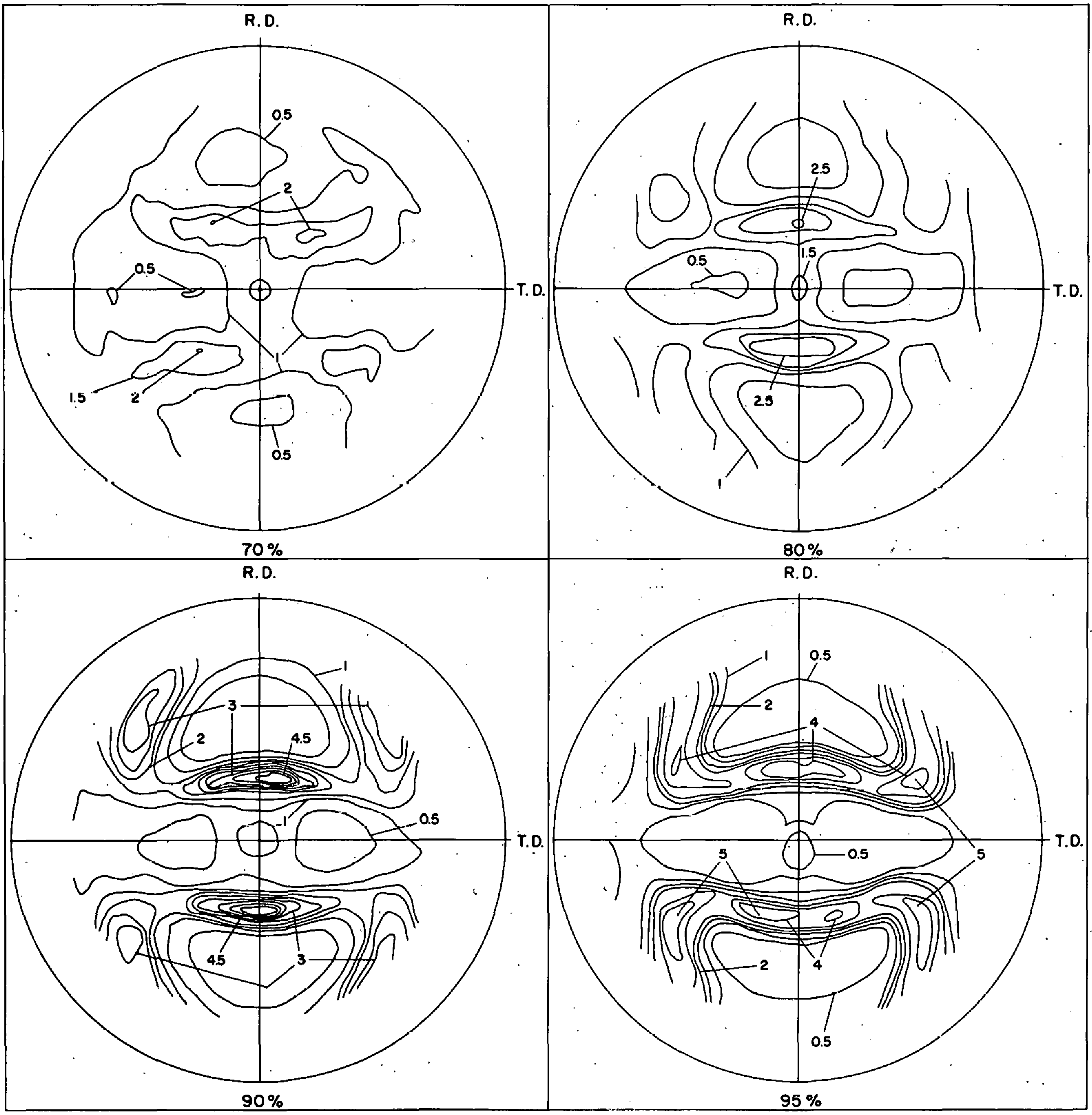


Figure 4. Texture of polycrystalline plutonium-0.75 wt % gallium alloy rolled to 70%, 80%, 90%, and 95% reduction, determined from the (200) reflection.

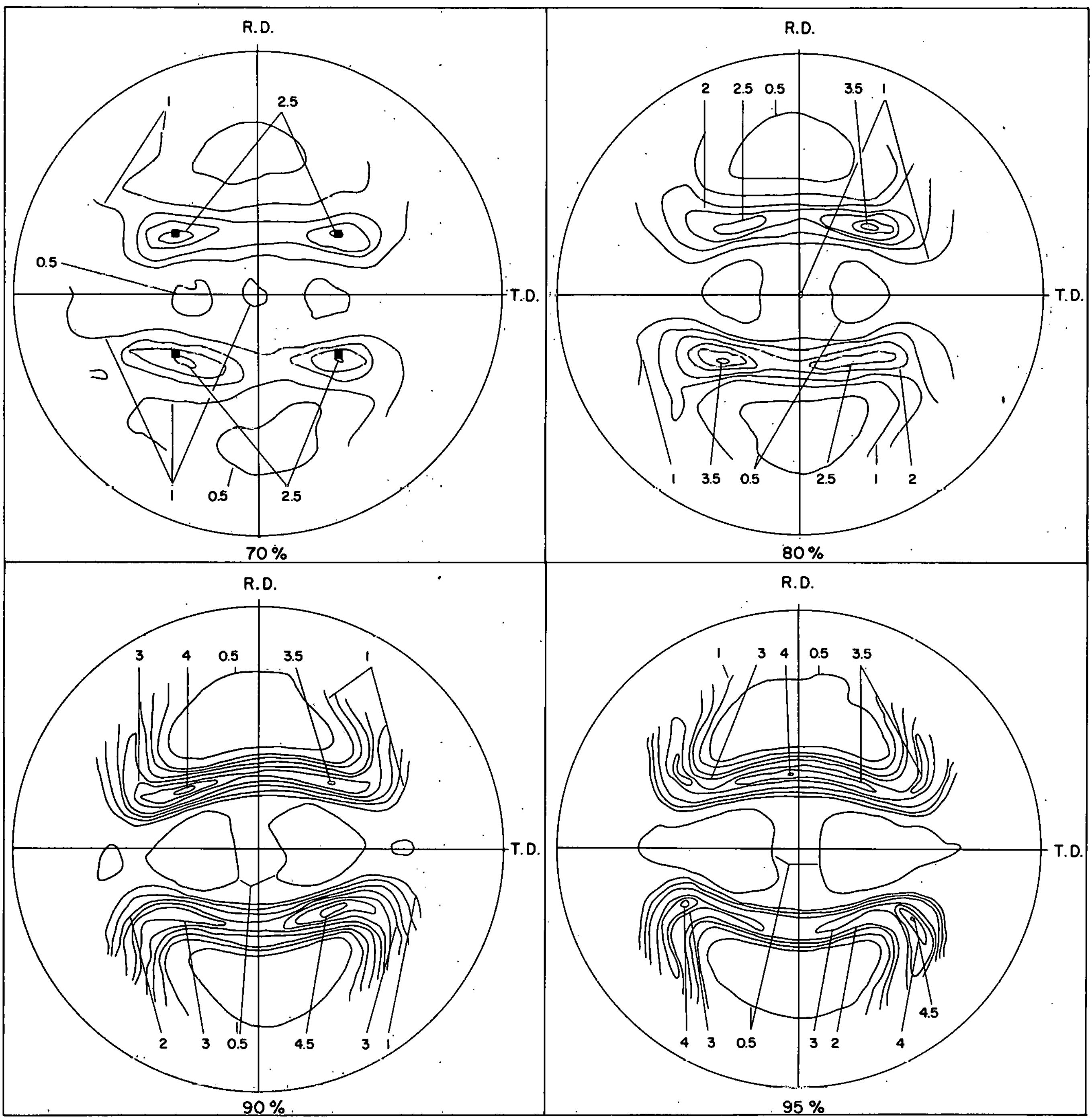


**Figure 5. Texture of polycrystalline plutonium-1.0 wt % gallium alloy rolled to 70%, 80%, 90%, and 95% reduction, determined from the (200) reflection. The squares in 70% rolled correspond to (110) <112>.**