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LOS ALAMOS SCIENTIFIC LABORATORY
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Fabrication of a Coaxial Shock-Sensitive Switch

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R. S. Kirby

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ABSTRACT

A technique was developed for fabricating a coaxial switch using metal inner and outer conductors separated by a CdS insulation which becomes an electrical conductor on exposure to an explosive shock wave. Coaxial assemblies of 0.040 and 0.025 in. o.d. were fabricated using a copper outer conductor and an 1100 Al inner conductor.

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1. INTRODUCTION

This program was initiated by a request for fabrication of a coaxial switch based on information that CdS, an electrical insulator, becomes an electrical conductor on exposure to a high velocity pressure wave. The proposed use of the device was to study explosive shock wave behavior by placing the coaxial switches around an explosive change and, through the use of high speed recording equipment, obtaining time-distance profiles of the shock wave.

This report describes the development of a fabrication procedure for the coaxial switch.

2. MATERIALS AND EQUIPMENT

Materials

Cadmium Sulfide

The CdS powder used in this program was a chemically pure grade powder of approximately -150 mesh. The material is a standard LASL chemistry-stock item.

Conductor Materials

The metals used as conductor materials were standard commercial grades of copper electrical wire, copper refrigerator tubing, 3003 and 1100 Al alloys, 304 stainless steel, and 70-30 brass. The silver wire used as an internal conductor for some of the work was commercial silver of 99.9% purity.

Binders and Lubricants

Binder-lubricants were mixed with the CdS powder to reduce friction between the powder and the inner and outer conductors. Materials used for this purpose were stearic acid, TFE (Teflon) powder, and methylcellulose.

A wax-base commercial lubricant (Johnsons wax No. 151) was used as a drawing lubricant for all of the work.

Equipment

Tamping Device

The CdS powder was tamped into the starting tube (outer conductor) using a simple plunger with a hole up the center (Fig. 1) which centered the inner conductor in relation to the inside diameter of the outer conductor.

Drawing Bench

The coaxial assembly was drawn using a small 12-ft-long, chain driven draw bench of approximately 4000-lb capacity. The draw bench is shown in Fig. 2.

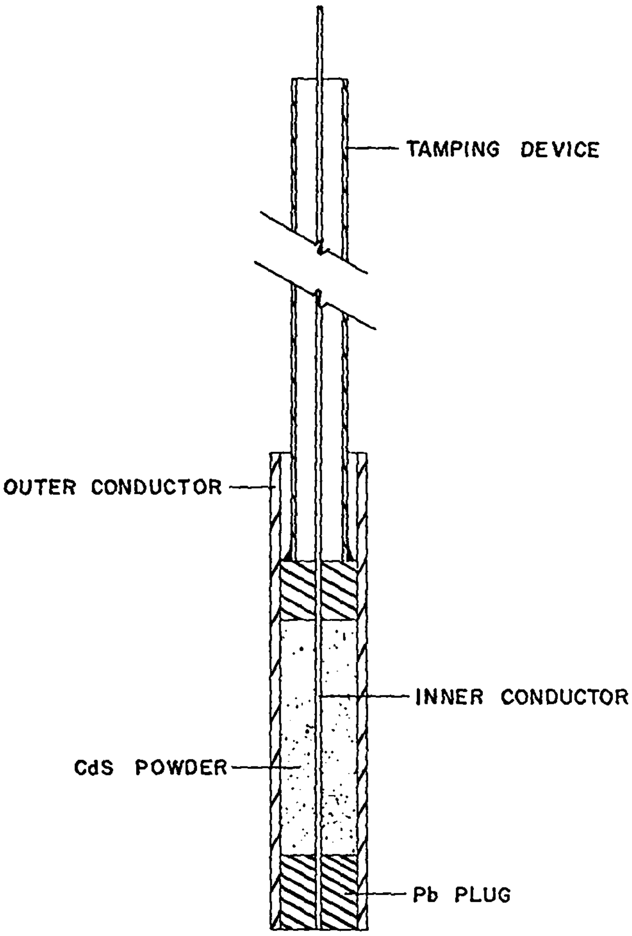


Fig. 1. Tamping device used for compacting CdS powder and centering the inner conductor.

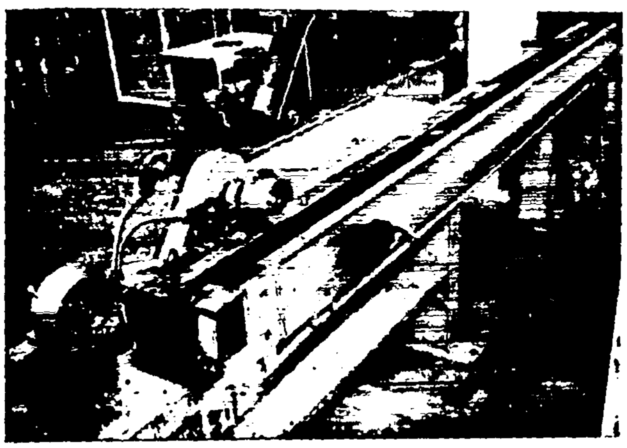


Fig. 2. Draw bench used for fabricating the coaxial switch.

3. PROCEDURE

Very little information was available concerning the nonconductive-to-conductive transformation behavior of CdS. It was not known if the change in electrical conductivity induced by a high velocity pressure wave was accompanied by a phase transformation or if the condition might be induced in some other manner such as heating. The information which was available on CdS indicated that it was a toxic orange powder with the following physical properties:

Crystal structure	- hexagonal
Density	- 4.82 g/cc
Melting point	- 1750°C (pressure of 100 atm)
Boiling point	- sublimes at 980°C (N_2 at pressure of 1 atm)
mohs hardness	- 3 to 3-1/2

In view of the lack of knowledge about the effect of heat on CdS properties, a maximum annealing temperature of 300°C was arbitrarily chosen. The choice of this maximum annealing temperature automatically limited the materials available for the inner and outer conductors.

Two approaches for fabricating the coaxial switch were considered.

1. Use of a soft metal (i.e., copper) for the outer conductor and a high tensile strength, highly polished material for the inner conductor. In this method, the inner conductor is not reduced during reduction of the composite. The theory is that, on drawing, the CdS material is compacted as the outer conductor is reduced in diameter with the outer conductor-CdS composite being drawn over the high strength inner conductor core. A graphic representation of this setup is shown in Fig. 3.

2. Use of a reasonably soft material (i.e., copper) for the outer conductor and an equally soft or softer material for the inner conductor. In this method the composite is assembled using a desirable size ratio between the diameters of the inner and outer conductors and packing CdS into the annulus between the two conductors. The composite diameter is then reduced by drawing, reducing the diameters of both the inner and outer conductors simultaneously. The setup used for this method is similar to that shown in Fig. 3, the only differences being a slightly larger starting diameter for

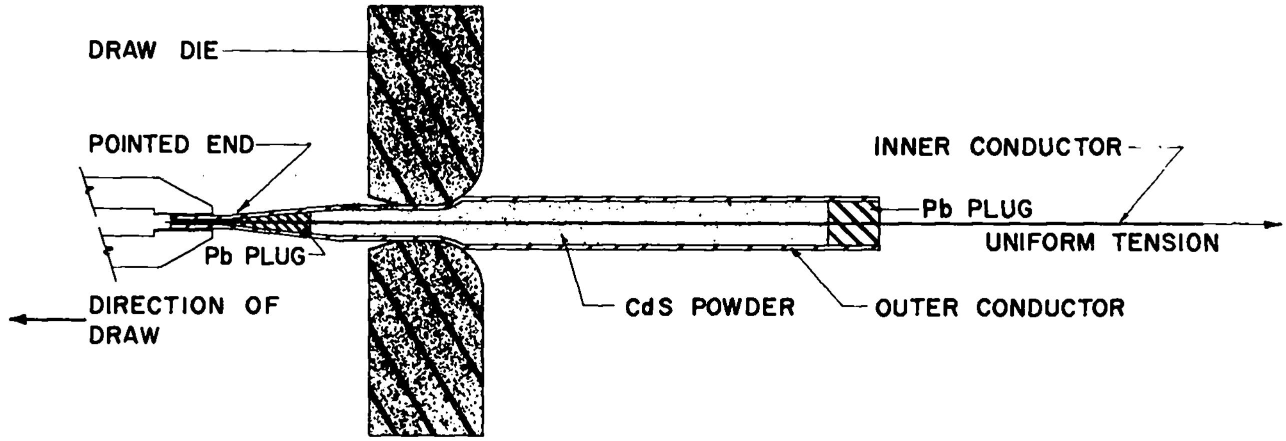


Fig. 3. The coaxial switch fabrication setup using a high strength inner conductor.

the inner conductor and the elimination of the tensile forces applied to the inner conductor.

The initial work was done using a copper outer conductor and a music steel spring wire (ASTM A228) inner conductor of approximately 375,000-psi tensile strength. As the CdS powder became compacted around the inner conductor, resistance to movement of the copper-CdS over the music wire increased until the wire finally failed in tension. The addition of TFE and stearic acid lubricants to the CdS powder did not improve the situation. After a rather extensive investigation this approach was dropped.

The feasibility of the second approach was investigated by first using a copper outer conductor and lead inner conductor. The composite was drawn down to 0.040-in. diameter with no problems, indicating that the use of an inner conductor of much less tensile strength than the outer conductor was a satisfactory solution.

The disadvantage of using a lead inner conductor was one of insufficient strength which resulted in breaking of the leads during handling of the product and making electrical connections. In an attempt to modify the process by using a higher strength inner conductor, the following metal combinations were used.

Copper Inner Conductor and 70-30 Brass Outer Conductor

This combination appeared satisfactory when an annealing temperature greater than 400°C was used between drawing stages. However, when an annealing temperature below the arbitrarily chosen 300°C was used, the brass outer conductor split during drawing.

Copper Inner Conductor and 3003 Al Outer Conductor

This particular combination was not at all satisfactory. At all annealing temperatures attempted up to 200°C, the aluminum outer conductor failed in tension during drawing. The strength ratio of the inner to outer conductor was apparently too high.

Copper Inner Conductor and 304 Stainless Steel Outer Conductor

This combination proved unworkable because of the work hardening rate of the outer conductor. The 304 stainless steel hardened very rapidly and would have required an annealing temperature of about 900°C which was well above the 300°C maximum.

Silver Inner Conductor and Copper Outer Conductor

These metals were used because both are good electrical conductors annealable at less than 300°C. To prevent tensile failure of the silver wire, the composite required an annealing temperature of 275 to 300°C, which so weakened the copper that it failed in tension during drawing. The silver was used as an inner conductor because both silver wire and copper tubing were readily available. If a copper inner conductor and silver outer conductor had been used the results might have been more satisfactory.

OFHC Copper Inner Conductor and Copper Outer Conductor

Fabrication using copper for both conductors showed the benefit of having an inner conductor which was slightly weaker or might be annealed at a lower temperature than the outer conductor. When the assemblies were annealed at 200°C, the inner conductor failed in tension; when an annealing temperature of 250°C was used, the outer conductor failed in tension. It is possible that an assembly of this type might be fabricated by swaging after initially drawing to an outside diameter of about 0.100 in.

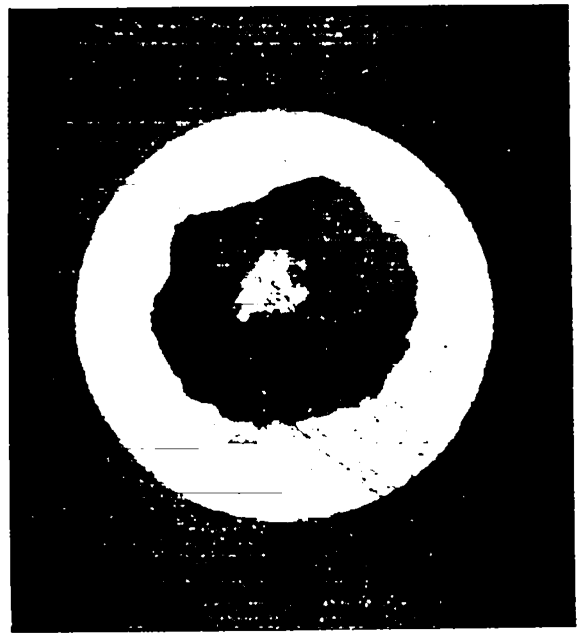
1100 Al Inner Conductor; Copper Outer Conductor

Approximately 50 ft of 0.040-in.-o.d. and 30 ft of 0.025-in.-o.d. coax was drawn using this combination of materials. The outside diameter was first reduced from 0.250-in.-o.d. to 0.090-in.-o.d. in 0.010-in. increments with a 200°C anneal after each drawing stage. The coax was then drawn in 0.005-in. increments to 0.070-in.-o.d. with a 200°C anneal after the 0.080-in.-o.d. and 0.070-in.-o.d. stages. The coaxial assembly was subsequently swaged from 0.070-in.-o.d. to 0.045-in.-o.d. in two 0.010-in. and one 0.005-in. reduction with a 200°C anneal after each reduction. The 0.040-in.-o.d. coax was made by making one additional drawing reduction of 0.005-in. The 0.025-in.-o.d. assembly was made by continuing the drawing in steps of 0.002 to 0.003-in. with a 200°C anneal after each 0.005- to 0.006-in. reduction in diameter.

4. DISCUSSION

From the results described under Procedure, it appears that the most feasible approach to the problem is to use an outer conductor material of slightly higher tensile strength than the inner conductor material and to draw or swage the composite assembly to the desired diameter. Because of the 300°C maximum annealing temperature which was arbitrarily selected, the only successful assemblies made were composed of a copper outer conductor and 1100 Al inner conductor. It is entirely possible that annealing temperatures in excess of 300°C would have had no detrimental effect on the properties of the CdS insulator. However, no information was available on this, and no tests have been run at LASL on assemblies heated over 250°C. If a higher annealing temperature could be used, the choice of inner and outer conductor materials would be much greater and a higher strength inner conductor might be used.

The 1100 Al inner conductor was not completely satisfactory because it was so soft that the CdS particles were imbedded in the aluminum during drawing thereby causing an irregular cross section and weakening the inner conductor. Figure 4 presents cross sections of 0.040-in.-o.d. and 0.025-in.-o.d. assemblies showing the particles imbedded in the inner conductor and the irregular outside



(A) 0.025-in.-o.d. assembly at 100X

(B) 0.040-in.-o.d. assembly at 100X

Fig. 4. Cross sections showing the irregular shape of the inner conductors and the irregularities in the inside wall of the outer conductor.

diameter of the inner conductor and inside diameter of the outer conductor. The 0.040-in.-o.d. assembly had a nominal 0.009-in. wall with a nominal 0.007-in. inner conductor diameter. The 0.025-in.-o.d. assembly had a nominal 0.005-in. wall and a nominal 0.004-in. inner conductor diameter. The starting material in both cases was 0.250-in.-o.d. copper tubing with a 0.035-in. wall and a 0.031-in.-diam inner conductor.

Figure 5 shows the relationship of the assembly outside diameter to the nominal wall thickness and the nominal inner conductor diameter during drawing. After the assembly outside diameter was reduced from 0.250 to 0.160 in., the CdS insulator material apparently reached a state of compaction which enabled the assembly components to be reduced as a true composite. Measurement of the outer conductor outside diameter and wall thickness and inner conductor diameter during drawing indicated that the components were reduced more or less uniformly after sufficient compaction of the CdS was achieved.

A comparison of the handbook properties of 1100 Al and commercially pure copper is shown in Table I. The table shows that the ratio of the yield strength of annealed copper to that of annealed 1100 Al is approximately 2:1. The data also indicate that the annealing temperature of both materials is in the 250 to 300°C range. Apparently, the 200°C annealing temperature used for the coaxial assemblies did not fully anneal either component but constituted more of a stress relieving treatment.

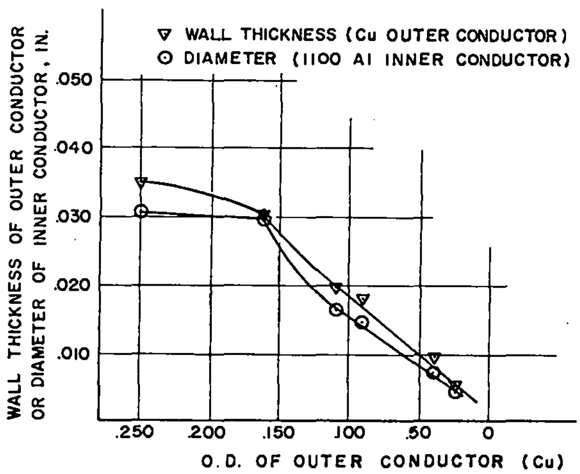


Fig. 5. The relationship between outer conductor wall thickness and inner conductor diameter as a function of the outer conductor diameter.

TABLE I

PROPERTIES OF COPPER AND 1100 Al

	Copper	1100 Al
Tensile strength (annealed), psi	30,000	13,000
Yield strength (annealed 2% offset), psi	10,000	5,000
Recrystallization temp (~ 70% red), °C	225-250	250-290
Elongation annealed (2-in. gage length), %	50	45

The data have shown that to fully anneal the copper outer conductor results in tensile failure of the point during drawing. This particular problem might be avoided by swaging; however, no investigation was done along these lines.

5. CONCLUSIONS

1. A pressure-sensitive coaxial switch may be fabricated using an 1100 Al inner conductor, a copper outer conductor, and a CdS insulator material by assembling a large diameter composite and reducing the diameter by drawing and swaging.

2. The inner conductor should be made of a lower yield strength material than the outer conductor.

3. The recrystallization temperature of the inner conductor should be approximately the same or lower than that of the outer conductor.

6. ACKNOWLEDGMENTS

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